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Links Between Eating Habits, Cognitive Skills Associated with Learning to Read, and Academic Achievement in Moroccan School-Age Children

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Abstract

The links between learning disabilities and food consumption modes are not yet sufficiently explained. The objectives of this study were to describe the dietary behavior of school children, to examine the association between certain dietary patterns and cognitive skills related to learning to read, and to identify, afterward, dietary profiles that are beneficial or harmful to reading acquisition and academic performance. 611 children, aged 10 years, who participated in this study, were assessed for cognitive functions that predominate in learning to read. The children were selected from schools belonging to areas with the same socio economic level. Absenteeism and neuro developmental disorders were two exclusion criteria. The study was conducted from December 2019 to the end of February 2020. A food frequency questionnaire was used to collect dietary information from the respondents. Descriptive and explanatory analyses were applied to the collected data. The study population's diet was varied, with a low consumption of fruits and vegetables. The number of meals/ snacks eaten per day and the regularity of main meals was significantly and positively associated with the underlying reading skills. High consumption of fruits, vegetables, bread/starches, olive oil, vegetables, poultry, and water with low consumption of meats are behaviors consistently associated with better reading performance and academic achievement. Educating children to practice healthy eating habits can help them minimize academic difficulties and improve their learning abilities.

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Introduction

Dietary habits and nutrition are a priority in public health. Almost all dietary surveys aim at estimating average food and/or nutrient consumption in a population of people.[1] Such estimates should look for the links between food consumption and the development of certain non-communicable diseases (cancer, diabetes, cardiovascular diseases...). Many other studies focused on the identification of foods that positively influence intellectual potential, particularly among children. Inaddition to their impact on physical health, diets have immediate repercussions on the brain's function of the individual. Thus, the child's physical growth and mental development are affected by faulty feeding practices.[2] An appropriate diet seems to optimize children's ability to learn at school. Many researchers suggest that eating breakfast contributes to good brain health and improves learning. In the United States, improvements in scores in reading, maths, and spelling have been found among children in low-income areas, aged 8 to 10 years, by eating breakfast at school.[3] Similarly, through a pilot "food program," elementary school students in Minnesota couldimprove their reading and math scores.[4] The importance of certain foods and nutrients is obvious in terms of good brain activity. For example, a shortage of iron, which is an essential element ofoxygen transport, results in concentration and memory problems. Although the relationship between learning difficulties and food consumption patterns is not yet sufficiently clear. Usinga healthy and balanced diet may represent a protective factor against the decline of children's mental and intellectual abilities during school tasks. In the absence of a priori profile determined by a balanced diet, a posteriori profiles represent an innovative and exploratory approach applicable in different populations since they are based on data collected from the study sample.[5] To our knowledge, in the international literature, no study hasused this method of creating posterior profiles to evaluate the relationship between dietary profiles and cognitive performance associated with learning to read. The choice to study this academic learning is justified by the place it occupies not only in the acquisition of all other learning but also in the activities of daily life. Indeed, previous studies have provided significant evidence of a strong association between reading difficulties and academic failure, suicide attempts, and psycho-emotional disorders in youth.[6-8] Other researchers have noted that reading difficulties may be potential factors in social and professional integration difficulties.[9] In this study, we define academic achievement (or academic performance), which would be affected by the level of reading mastery, as the grade obtained by the student at the end of the school year (or the end of each semester). The importance of the mastery of reading, as anessential school acquisition, makes it necessary to explore it in different aspects. It is in this perspective, we conducted this study to analyze the links between nutrition and success at school, focusing on reading. The objectives were, on the one hand, to describe the dietary behavior of the population studied, and on the other hand, to relate the modes/profiles of food consumption and the cognitive functions known to be determinant in reading acquisition, namely phonological short-term memory, phonological awareness and rapid automatized naming.[10-12] The results can be used to sensitize children to move toward dietary profiles that may be significantly correlated with better reading skills. The major gap in our research lies in the difficulty of controlling for all the factors that may influence the cognitive skills that underlie reading. However, our present study will contribute to identifying Mediterranean dietary profiles that are beneficial to school learning in children.

Materials and Methods

Study populations

This cross-sectional study was conducted among a sample of students from three primary schools (N= 611) in Beni Mellalcity (in the center of Morocco), where girls represent 48.6% of the population (N= 304) and boys represent 51.4% (N=307). The sample studied was constructed in a random way. The participants were aged 10 years and considered healthy by the school (medical records). Participants in the study are recruited in such a way that they have, as far as, the same socio-cultural level.

Tools and Method

A food frequency questionnaire (FFQ) was completed by participants to assess habitual food consumption. It consisted of a closed list of 47 foods and beverages with a section where consumption frequencies could be indicated. Possible response categories were: never, 1-3 times per month, 1 time per week, 2-4 times per week, 5-6 times per week, 1 time per

day. Responses obtained from the questionnaire provide information on the consumption of different foods or food categories, as well as on the consumption of beverages. In addition to the classification of subjects according to their high, medium, or low consumption of certain types of food,the FFQ gives an estimate of the consumption of these foods. Other data regarding eating habits were also collected like the number of meals eaten per day, frequency of skipping main meals, location of eating, and meal organization. The distribution of the food frequency questionnaire was done collectively with small groups of children who were separated so that each child's answers were not influenced by the others. Because of the young age of the participants, we conducted the entire questionnaire item by item while providing explanations when necessary. The second part of the tests, dealing with tests assessing phonological short-term memory (TPSTM), visual-attentional skills (evaluated by bell test "BT" and letter sequence comparison test " CLS") and Rapid automatized naming (by thetest of rapid image naming "RIN"), was inspired by the screening tool for dyslexia (Jaquier-Roux et al 2002).[13] Reading accuracy and speed were measured by the one-minute reading test of vocalized words in Arabic (RTOM, khomsi test). Other meta-phonological skills underlying reading were examined by subtests derived from the work of Badda (2008),[14] such as the deletion test of the initial phoneme in Arabic (DTPIA), a test of phoneme counting Arabic (TPCA), phonemic verbal fluency test (PVFT) and semantic and phonemic verbal fluency test (SPVFT). The students also benefited from an assessment of reading comprehension through the matching and morpho-semantic judgment (MSJ) modules of the LABEL software. In the first module, animations/ images appear on the screen, the child is asked to view them and then determine which of the animations/images corresponds to the sentence or word written at the bottom of the screen. For the morpho-semantic judgment, three written words with similar morphological structures are displayed, the child has to look for the intruder (i.e. the word that has no semantic link with the other two words). Based on the results obtained in different reading tests, the children will be classified into two groups: poor and good readers. The grade point average for the last three semesters, provided by the administration of the schools attended, constitutes the academic performance variable.

When recruiting participants, two main inclusion criteria were considered. The first targets learners who have completed four years of primary education. This condition is designed to ensure that our study sample is composed of children who have had some experience learning to read. The second requirement consists in recruiting children of 10 years of age. The choice of a single age range is justified by the fact that the cognitive functions studied in our present investigation are known to be influenced by age. Excluded from our study were all children whose school records showed absenteeism and those suspected of having neuro developmental disorders such as attention deficit disorder with or without hyper activity and dyslexia. The exclusion of the latter category of learners is explained by the fact that they may have serious reading difficulties requiring special interventions and whose influence on eating habits seems secondary.[15] Taking into account the possible impact of the socio-cultural environment on learning abilities in general, we selected, within the possible limits, schools belonging to areas with the same socio-economic level. Referring to the total number of students who have completed at least 4 years of primary education in the schools of Beni-Mellalprovincial directorate, the size of our sample meets a confidence interval of 95% associated with a margin of error of 4%.

To determine the "healthy" dietary profile related to better reading performance, as stated in the objective of the study, we performed a principal component analysis (PCA) of the food frequency data set. The reducing factors (factorial axes) resulting from this first statistical analysis (PCA) will then be projected in bilateral correlation and linear regression tests with scores from the assessment of the functions that underlie reading. The interpretation of the obtained axes will be made according to the most represented foods on the principal components of these axes.

Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences version.25. Dietary patterns were derived using Principal Component Analysis (PCA), form factor analysis. To predict phonological

skills (PS), most involved in reading score variability, from the factorial axes derived from the food data, we performed a linear regression preceded clustering of these phonological variables by a second PCA. Relationships between qualitative variables were analyzed using Pearson and Spearman correlation tests. Statistical significance was set at $p<0.05$.

Compliance with Ethical Standards

Written approval was obtained from Sultan Moulay Slimane University before the initiation of this study with the number of FST/LGB/2018/15; JAN.2018-SEPT. 2018. All procedures performed in studies involving human participants were by the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants and their parents. They were notified that they could remove themselves from the study at any time during the study without any consequence or problems. All data were confidential and protected at all stages of the study. Participation in this research was voluntary and no financial compensation was paid.

Results

Food Consumption in the Study Sample

In this first part, we will describe the frequency of consumption of certain food categories and the organization of main meals/snacks in the sample. 38% of the study population does not eat breakfast regularly (less than five times per week). 90% of the children in the study rarely skip lunch and a percentage of 10% do not eat dinner. 57% of the subjects reported eating 4 meals/snacks daily, and only 7% eat more than 4 meals/snacks per day. Consumption of milk and milk products remains low. Thus, only 25% of the sample stated that they drink milk every day, 15% consume it 3 to 5 times a week, 20% never take itand in 40% of cases, consumption varies from once a week to 3 times a month. Consumption of both fruit and vegetables remains moderate, with fruit consumption being slightly higher than that of vegetables. The percentages of children who consume fruit and vegetables regularly (every day) are 42.5% and 46.5% respectively. The frequency of meat consumption was estimated in 40% of the participants to be less than once a week. For poultry, daily intake was recorded in 47% of the subjects participating in our study. We also noted that more than a third of our sample eats cold cuts once to 5 times a week. A proportion of 25% of the children answered that eggs are part of their daily meals and almost half of the sample (50%) consumes it less than 5 times a week. When we examine the intake of fizzy drinks, we have noticed that almost half of the children drink it at least 4 times a week. A little more than half of our population rarely eats rice.

Correlations Between Selected Dietary Behavior Data and Reading Performance.

The correlations between data from the dietary habits of the subjects and their performance on different tests assessing the cognitive functions involved in learning to read are shown in Table 1.

Table 1: Correlations between certain dietary habits, reading skills, and academic achievement.

Functions and skills	Tests	Number of Meals/Snacks per Days	Frequency of breakfast intake	Frequency of lunch intake	Frequency of dinner intake
	RIN	-0,87*	__	__	__
	TPSTM	0,30 **	0,25*	__	__
	DTIPA	__	__	__	0,52**
Cognitive skills	TPCA	__	__	0,46*	__
underlying	BT	__	__	__	__
reading and	CLS	__	0,45*	__	__
academic	PVFT	__	__	__	__
performance	SPVFT	__	__	__	0,33*
	RTOM	0,27**	__	__	__

	RL	__	__	0,28**	__
	AP	__	__	0,3*	__
Reading comprehension	Matching	__	__	0,21*	__
	MSJ	0,22*	__	__	__

Test de corrélation de Pearson/ Rho Spearman : *p < 0,05 ; **p < 0,01 ; __ : Non Significatif

DTIPA: Deletion Test of the Initial Phoneme in Arabic (10 words are presented to the child, each correct answer is rated one mark. The score is out of 10); **TPCA:** Test of Phoneme Counting Arabic (the score is out of 10); RIN: Rapid Images Naming , the best scores in this test are reflected in a very reduced naming time (the time, in seconds (s), needed to name a series of images) **RTOM:** Reading Test on One-minute (the number of words read correctly in one minute represents the score in this test); BT: Bells' Test (the number of bells found on the planche for 2 minutes constitutes the score); **CLS:** Comparison of Letters Sequences (this test is composed of a series of 20 sequences of letters to compare, the score is therefore on 20); **TPSTM:** Test of Phonological Short-Term Memory (the score on 8); **PVFT:** Phonemic Verbal Fluency Test (the number of words, meeting a phonemic condition, provided in one minute); **SPVFT:** Semantic and Phonemic Verbal Fluency Test (the number of words, meeting a phonemic and semantic condition, provided in one minute); **RL:** Reading Level (good or poor reader); **AP:** Academic performance: The grade point average for the last three semesters. The frequency of the three meals intake (breakfast, lunch and dinner) is: never, 1-3 times per month, 1 time per week, 2-4 times per week, 5-6 times per week, every day.

Bivariate statistical analyses showed that the number of meals/snacks eaten per day was negatively associated with scores on the rapid image naming test (best results are obtained if the child takes less time to name the images) and positively correlated with performance on the RTOM and phonological short-term memory tests. Performance on the latter test was also significantly related to the frequency of breakfast consumption. Skills in tests assessing phonological awareness (DTIPA, TPCA) are positively associated with the frequency of eating lunch and dinner. A positive association was found between reading level and frequency of lunch intake. Thus, 95% of the children in the "good reader" group ate lunch every day compared to 72% in the poor reader group. In the latter group, 5% of the children stated that they never ate lunch (*versus* 0% in the good reader group).

When analyzing the responses collected to the question about the preferred taste (sweet/salty or both), the independent samples t-test shows that the mean scores of the RTOM, TPSTM, and AP differ significantly in favor of the students' group who prefer to eat sweet foods alone compared to their peers who prefer both tastes (sweet and salty) (the differences in means are, respectively: *T = -3.08; p = .004. T = -2.08; p = 0.043 and T = -2.05; p = 0.047*).

Principal Component Analysis of Dietary Data and Determination of Eating Profiles Associated With Better Reading Skills

To identify food consumption profiles that are positively or negatively correlated with the cognitive functions involved in reading, we proceed to the principal component analysis (PCA), which is a factorial method of dimensionality reduction, through which we will try to distinguish groups or categories of foods that are associated with better or bad reading performance. The PCA of the data from the food frequency questionnaire (FFQ), allowed us to retain four factorial axes (named F1,F2,F3, and F4: principal components obtained by combining the initial variables), these axes will be interpreted about the initial variables most represented on their principal components. The four axes F1,F2,F3, and F4 correspond in reality to four different food consumption profiles (FCP) that we call FCP 1, FCP 2, FCP 3, and FCP 4. Table 2 represents the foods most strongly correlated with each of these retained "synthetic" factors (food consumption profiles). The food categories most related to factor (3) and less extent with factor (4) are vegetables (cooked and dry), raw vegetables,

olive oil, starchy foods. These two factors are associated with low consumption of meat, cheese, milk, commercial fruit juice, and tea. A high content of water, poultry, and rice associated with very low consumption of cold cuts is identified only on the factorial component (3). Factors (1) and (2) are characterized by increased consumption of sweet products (jam, commercial honey, and chocolate), cold cuts, and commercial fruit juices with low consumption of wholemeal bread, salads, and water. Factor (1) was the only one characterized by a strong correlation to milk. Factor (2) is marked by very low fruit and fresh fruit juice content. The intake of fruit, soft drinks, eggs, cakes, and fish was comparable between the four factors.

Table 2: The foods most correlated with each of the food consumption profiles selected after principal component analysis (PCA)

Food / Food category	**FCP 1 (F1)**	**FCP 2 (F 2)**	**FCP 3 (F 3)**	**FCP 4 (F 4)**
Milk	0,45**	NS	NS	NS
Yaourt	0,43**	0,34**	0,34**	0,34**
Cheese	0,51*	0,40**	NS	NS
Tea	0,31**	NS	NS	NS
Rusk, croissant	0,58**	0,21*	0,23*	NS
Eggs	0,56**	0,21*	0,38**	0,24**
Honey	0,27*	NS	NS	NS
Chocolate	0,50*	0,35*	NS	NS
Jam	0,39*	0,29**	NS	NS
olive	0,20*	- 0,20*	0,57**	0,52**
Olive oil	NS	- 0,20*	0,20*	0,20*
Wholemeal bread	NS	-0,28	0,34**	0,33**
resh fruit juice	0,52**	NS	0,32**	0,27*
Commercial fruit juice	0,52**	0,53**	NS	NS
Fruits	NS	-0,2*	0,32**	0,23*
Cold cuts	0,20*	0,39**	- 0,31**	0,43**
Raw vegetables	NS	NS	0,42**	0,34**
Salads	0,24*	NS	0,40**	0,36**
Meat	NS	0,2*	0,24*	NS
Poultry	NS	NS	0,42**	NS
Fish	0,29**	0,28*	0,21*	0,39**
Potatoes	NS	NS	0,52**	0,37**
Rice	NS	NS	0,44**	NS
Pasta	NS	0,40**	0,43**	NS
Cooked vegetables	NS	NS	0,45**	0,43**
Dried vegetables	NS	0,56**	0,53**	NS
Fizzy drinks	0,33**	0,41**	0,21**	0,28**
Water	NS	-0,38**	0,25**	NS
Soup	NS	0,31*	NS	0,20*
Total variance explained		**37%**		

FCP: Food Consumption Profiles;** Strong association; * Weak association; NS: Not significant.

Analysis of the correlations between the factorial axes resulting from the PCA and the different performances that determine reading skills shows that the food groups, which are most related to factor (3) and less extent with factor (4), represent the dietary profiles most associated with better reading skills. Thus, a very clear positive association was found between the third factor (3) and reading level, scores of rapid image naming (RIN), reading fluency test (RTOM) scores and academic performance (Correlation coefficients are respectively: *r = 0.33; p<0.001. r = -0.34; p<0.0001. r = 0.38; p<0.001. r = 0.28; p<0.001).* The principal component of axis (4) was significantly correlated with RIN, phonological short-term memory (TPSTM) and the academic performance *(r = -0.21; p<0.05. r = 0.24; p<0.05. r = 0.29; p <0.05).* Factor (1) was negatively associated with RTOM and academic performance *(r = -0.20; p<0.05 and r = -0.29; p<0.01).* To predict the phonological abilities (PA) most involved in the variability of reading scores (DTIPA,TPSTM, RIN) from the selected factorial axes, we have proceeded to a linear regression preceded by a grouping of these phonological variables by a second PCA. The regression was significant (*F= 3.20; p= 0.016*), The estimated importance of each of the four factors is explained in Table (3). The data clustered in the two factors (3) and (4) are the main axes that determine the diversity of PA scores. Similarly, after clustering the items reflecting reading comprehension level by a PCA, the resulting variable was positively correlated with factor (3) *(r=0.23; p=0.007)* and negatively with factor (1) *(r=-0.22; p=0.017).*

Table 3: Coefficients of the regression of the four food consumption profiles determining phonological Abilities

Model	Non-standardized coefficients		Standardized coefficients	t	Sig.
	A	Standard error	Bêta		
(Constante)3,836E-17	,089	,000		1,000	
REGR FCP score 1(F1)	-,135	-,091	,136	-1,479	,142
REGR FCP score 2(F2)	,83	,091	,083	-0,904	,363
REGR FCP score 3(F3)	,206	0,091	,207	2,254	,026
REGR FCP score 4(F4)	,199	0,091	,200	2,176	,032

a. Dependent variable: Phonological Abilities (PA); FCP: Food Consumption Profiles

Discussion

The objectives of the present study, carried out in the city of Beni Mellal in central Morocco, were to describe some dietary habits of school-aged children and to establish associations (negative or positive) between food consumption profiles (afterward determined) and the cognitive skills underlying reading (memory, attention, phonological awareness). The results obtained on food consumption are very comparable to those of a study conducted on 271 children, mean age 10.75±1.40 years, in the city of Kenitra (Morocco), which concluded that the consumption of fruits and vegetables is below the recommendations and that only a small percentage of children drink milk daily.[16] This reflects a general tendency concerning a change in the eating habits in the Moroccan population and particularly in youth with not able deviation from the traditional Moroccan diet. From the results of the correlations shown in Table 1, it appears that the number of meals/snacks taken per day is the most correlated with the cognitive functions involved during reading acquisition. Thus, a very clear negative association was observed between the number of meals/snacks and rapid image naming time (the higher the number of meals, the shorter the naming time, and therefore the test is successful). It should also be noted that the association between the number of meals eaten and short-term memory as well as reading fluency is positively significant. Thus, it appears that an adequate number of meals/snacks per day is beneficial for acquiring foundational reading skills. In addition to the three main meals, two to three snacks per day

are recommended.[17] Due to the increased energy needs during childhood and adolescence (periods of significant growth), and the brain's inability to build up its energy reserves, healthy snacks may represent an adequate compensatory recourse to ensure proper mental and intellectual functioning by covering the increased nutritional needs of this period. The results of our study also show that the high frequency of breakfast consumption is closely related to good short-term memory performance, whereas low frequencies of lunch and dinner consumption are mostly associated with poor phonological awareness (DTIPA, TPCA). Thus, the frequency of skipping lunch is negatively correlated with academic performance. Along with the negative influence of irregular meal consumption on physical health: cardio vascular disease[18] and diabetes in children and adolescents,[19] the results of our study indicate that regular meal consumption improves memory, attention, and learning abilities in general. In examining the relationship between lunch intake and academic performance, Rampersaud's (2005) review, suggests that eating lunch improves cognitive function and promotes academic performance.[20] This association was less certain in the findings from another review linking diet with academic performance.[21] We believe that the degree of the impact of lunch on academic performance is determined by whether the student is nutritionally deficient and/or malnourished. Thus, the two factors that can explain academic performance are under nourishment and food insecurity, not poor nutrition.[22-24]

Concerning breakfast, poorer quality diets have been linked to skipping this meal.[18] The importance of breakfast consumption is explained by the length of time, which is relatively long, that separates this meal from the dinner that precedes it (often 8 to 12 hours) and by the energy requirements necessary to ensure optimal intellectual production throughout the morning. Focusing on the importance of the nutritional composition of breakfast, a study assessing attention, working memory, and secondary memory before and after consuming different breakfasts (cereal, sweetened beverage, or nothing at all) for four days, found that a breakfast rich in slow sugars contributes to the maintenance of the efficiency of mental skills during the morning.[25]

The principal component analysis method used in our study allowed us to identify two dietary profiles: a relatively "healthy" profile, clearly associated with better reading performance, and a profile negatively related to this performance. Although the two profiles were found to be opposite in terms of food composition, some similarities were recorded. Thus, the consumption of fruit, soda, eggs, cakes, and fish was comparable between the two diets. The "unhealthy" profile is mainly marked by an increased intake of milk, dairy products, sweet products (jam, commercial honey, and chocolate), and cold cuts. While the "healthy" profile is characterized by a variety of food represented by an important consumption of vegetables (cooked and dry), raw vegetables, olive oil, starchy foods, water, and poultry combined with a light consumption of meat. It seems that the latter type of diet provides nutrients, such as vitamin B, antioxidants (vitamins E and C, carotenoids, polyphenols), and polyunsaturated fatty acids (n-3 PUFAs), which could protect and increase the quality of cognitive and mental functions involved in school tasks. In the same context, a study of dyspraxic children aged 5 to 12 years concluded that a nutritional supplementation program containing omega-3 and omega-6 significantly improved reading and spelling scores after 3 months (without effects on motor skills).[26] Both nutrients (omega-3 and omega-6) have a pivotal role in brain physiology by regulating fundamental neurobiological processes associated with cognition and mood.[27,28]

Conclusion

The usual eating habits of the students who participated in our study remain somewhat varied. Irregularity and skipping one or more of the main meals seem to hurt the learning abilities of these school-aged children. By synthesizing the information obtained by the food profiles afterward identified, it appears clear that a food intake rich in fruits, vegetables, starch, poultry, water, and to a lesser extent meat is beneficial for good mental and intellectual functioning. On the other hand, the predominance of consumption of fast sugars and cold cuts is linked to poor cognitive performance studied. Although our study did not focus on the quantitative aspect of food intake, we believe that the distribution of fortified snacks of high energy

density and rich in micronutrients could reduce nutritional deficits and cover their recommended daily allowances (RDA) in energy. Such a strategy, supported by the integration of pedagogical programs targeting good nutritional practices, in the teaching contents of the primary cycle, could be an effective aid among others to face the difficulties resulting from an alteration of the cognitive functions involved in school learning.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions

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Conflict of interest

The authors declare that they have no ties of interest.

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