Nutrition and Lifestyle in European Adolescents: The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study[1–3]

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ABSTRACT

Adolescence is a critical period, because major physical and psychologic changes occur during a very short period of time. Changes in dietary habits may induce different types of nutritional disorders and are likely to track into adulthood. The aim of this review is to describe the key findings related to nutritional status in European adolescents participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. We performed a cross-sectional study in 3528 (1845 females) adolescents aged 12.5–17.5 y. Birth weight was negatively associated with abdominal fat mass in adolescents and serum leptin concentrations (in female adolescents), providing additional evidence for a programming effect of birth weight on energy homeostasis control. Breakfast consumption was associated with lower body fat content and healthier cardiovascular profile. Adolescents eat half of the recommended amount of fruit and vegetables and less than two-thirds of the recommended amount of milk and milk products but consume more meat and meat products, fats, and sweets than recommended. For beverage consumption, sugar-sweetened beverages, sweetened milk, low-fat milk, and fruit juice provided the highest amount of energy. Although the intakes of saturated fatty acids (FAs) and salt were high, the intake of polyunsaturated FAs was low. Adolescents spent, on average, 9 h/d of their waking time (66–71% and 70–73% of the registered time in boys and girls, respectively) in sedentary activities. Factors associated with adolescents' sedentary behavior included the following: *1*) age; *2*) media availability in the bedroom; *3*) sleeping time; *4*) breakfast consumption; and *5*) season. Sedentary time was also associated with cardiovascular risk factors and bone mineral content. In European adolescents, deficient concentrations were identified for plasma folate (15%), vitamin D (15%), pyridoxal 5′-phosphate (5%), β-carotene (25%), and vitamin E (5%). Scientists and public health authorities should raise awareness of the importance of a healthy and sustainable lifestyle as a foundation of the health of the European population, now and in the future. *Adv. Nutr. 5: 615S–623S, 2014.*

Introduction

Adolescence is a critical period in life, because major physical and psychologic changes occur during a very short period of time. Nutritional issues in adolescence are mainly characterized by increased energy and nutrient requirements and changes in dietary habits, which could induce different types of nutrition-related disorders and are likely to track into adulthood (1).

Nutrition related noncommunicable diseases have their origin very early in life, and they develop during childhood and adolescence (2). Apart from genetics, lifestyle behaviors

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are the main determinants of these diseases, especially dietary patterns and sedentary behaviors (3,4). During adolescence, the most prevalent nutritional problems are not only obesity and its comorbidities but also some micronutrient deficiencies (5). Literature on lifestyle factors and diseases in European adolescents is scarce (6). Therefore, the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence)[10] study aimed to investigate different lifestyle factors and health outcomes among European adolescents. The aim of this review is to summarize the main findings of the HELENA study related to the nutritional programming of adolescent nutritional diseases, dietary intake, physical activity, and vitamin status in European adolescents.

Methods

The HELENA cross-sectional study was designed to assess the nutritional status of the adolescent population in Europe. Because the majority of the European adolescents are living in urban areas, we aimed to assess adolescents (aged 12.5–17.5 y) in 10 cities, with >100,000 inhabitants: *1*) Athens, Greece; *2*) Dortmund, Germany; *3*) Ghent, Belgium; *4*) Heraklion, Crete; *5*) Lille, France; *6*) Pécs, Hungary; *7*) Rome, Italy; *8*) Stockholm, Sweden; *9*) Vienna, Austria; and *10*) Zaragoza, Spain. Inclusion criteria were as follows: *1*) not to participate simultaneously in another clinical trial; *2*) be free of any acute infection lasting <1 wk before the inclusion; and *3*) have valid data for age, sex, and BMI. A total of 3528 (1845 females) adolescents participated in the study. One-third of the adolescents were also invited to have a blood sampling for additional analysis. In all the cities, the study protocol was approved by the corresponding ethics committees. The adolescents and their parents signed the written informed consent.

The HELENA cross-sectional study was conceived to obtain standardized, reliable and harmonized data on the following: *1*) dietary intake; *2*) food choices and preferences; *3*) anthropometry; *4*) serum indicators of lipid and glucose metabolism; *5*) vitamin and mineral status; *6*) immunoinflammatory markers; *7*) physical activity and fitness; and *8*) genetic polymorphisms. Detailed information on specific methods will be provided in each section.

Results

Perinatal nutrition—how does it affect adolescents?

Nutritional factors in early life may have long-term physiologic effects in humans. There is evidence that low birth weight is associated with cardiovascular disease risk and with unhealthy body composition later in life (2). It was also suggested that breastfeeding may protect against the development of type 2 diabetes, cardiovascular diseases, and obesity (7).

Assessment of perinatal and early life factors. We developed a questionnaire for parents to collect information on the adolescents' birth weight, gestational age, and breastfeeding duration. Parents were specifically asked to recall this information from health booklets, in which perinatal information is recorded by health professionals. The duration of any breastfeeding and of exclusive breastfeeding was coded (**Table 1**). First, we assessed associations between birth weight or breastfeeding and health outcomes of interest and then the influence of gene and/or environment on these associations.

TABLE 1 Duration of breastfeeding according to the study centers in adolescents from the HELENA study[1]

Study center	Never	<3 mo	3 to <6 mo	≥6 mo
			%	
Athens, Greece	12.1	27.5	30.2	30.2
Dortmund, Germany	25.6	26.3	19.5	28.5
Ghent, Belgium	27.2	31.3	24.9	16.6
Heraklion, Crete	28.0	43.6	22.7	5.7
Lille, France	42.8	33.3	14.0	10.0
Pécs, Hungary	6.2	29.6	30.8	33.4
Rome, Italy	16.0	26.6	24.5	32.8
Stockholm, Sweden	4.5	21.8	23.1	50.6
Vienna, Austria	7.8	32.7	23.0	36.5
Zaragoza, Spain	14.3	25.8	32.7	27.2

[1] HELENA, healthy lifestyle in Europe by nutrition in adolescence.

Nutritional programming in European adolescents. We showed that birth weight was negatively associated with abdominal fat mass independently of total fat mass (8). One of the main genetic susceptibility factors for obesity is the so-called fat mass and obesity (*FTO*) associated gene. We observed that the minor A allele of the *FTO* rs9939609 polymorphism was significantly associated with higher BMI, body fat percentage, and fat mass index (9).

Birth weight was negatively associated with serum leptin concentrations only in female adolescents, providing additional evidence for a sex-specific programming effect of birth weight on the energy homeostasis control (10). We also showed that physical activity attenuates the negative effect of low birth weight on leptin concentrations in female adolescents (11). Ponderal index at birth interacted with the leptin rs10244329 and rs3828942 polymorphisms and the leptin receptor rs8179183 polymorphism. These results are consistent with a higher susceptibility to the deleterious effect of risk alleles on total adiposity in those adolescents born with a low ponderal index (12). We also observed that physical activity attenuated the effect of low birth weight on insulin resistance in adolescents (13).

We showed that birth weight was significantly associated with serum EPA and DHA in adolescents (14). Insufficient fetal nutrition and growth may partially program the activity and/or expression of the enzymes required for the metabolic endogenous synthesis of these FAs.

Participating to a vast genome-wide association meta-analysis with birth weight available and follow-up study, 7 new loci, some of them linked to type 2 diabetes, adult height, and blood pressure, were also found to be associated with birth weight (15).

Breastfeeding modulates the influence of the PPARγ Pro12Ala polymorphism on BMI of adolescents. *PPARγ* variants influence the BMI of adolescents who were never breastfed, although it has no influence on adiposity if the individuals were breast-fed, regardless of its duration (16).

[10] Abbreviations used: DIAT, dietary assessment tool; *FTO*, fat mass and obesity; HELENA, healthy lifestyle in Europe by nutrition in adolescence; PLP, pyridoxal 5′-phosphate.

Breastfeeding was not associated with the inflammatory status in healthy adolescents (17). We also showed that longer breastfeeding was associated with a higher performance in the standing long-jump test in adolescents (18).

Dietary intake in European adolescents: issues and controversies

Methods used to assess dietary intake. Dietary intake was assessed via 2 nonconsecutive self-reported 24-h recalls using the HELENA-Dietary Assessment Tool (DIAT) program (19) and an FFQ. The self-administration took place in a computer classroom where the pupils completed the HELENA-DIAT autonomously while field workers were present to give assistance. Consumed foods were translated to nutrients by use of the German Food Code and Nutrient Data Base (Bundeslebensmittelschlüssel, version II.3.1) (20). The multiple source method was used to estimate the habitual dietary intake of nutrients, total energy, and foods, corrected for age, sex, and study center (21,22). Supplement use was not considered.

Adolescents reported in a questionnaire to what extent they agree (1 for strongly disagree to 7 for strongly agree) to the following statement: "I often skip breakfast." Adolescents were categorized into 3 groups: *1*) "consumers" (1 or 2); *2*) "occasional consumers" (3, 4, or 5); and *3*) "skippers" (6 or 7).

An overall diet quality index for adolescents was calculated based on the dietary intake information obtained via the 2 24-h dietary recalls. It was based on an existing diet quality index for preschoolers (23). Two dietary indices were calculated, with the only difference between them being the inclusion or not of physical activity (24).

Dietary intake and associated factors. Only half of the adolescents were breakfast consumers (51% of males vs. 45% of females), and 25% of males were breakfast skippers vs. 33% of females (25). Adolescents who regularly consume breakfast have lower body fat content, higher cardiorespiratory fitness, and a healthier cardiovascular profile, especially in males (26).

Food intake among European adolescents was not optimal compared with food-based dietary guidelines. Adolescents eat half of the recommended amount of fruit and vegetables and less than two-thirds of the recommended amount of milk products but consume much more meat products, fats, and sweets than recommended (27).

When investigating beverage consumption, results showed that water was consumed by the largest percentage of adolescents, followed by sugar-sweetened beverages, fruit juice, and sweetened milk. Sugar-sweetened beverages, sweetened milk, low-fat milk, and fruit juice provided the highest amount of energy. Patterns of energy intake from each beverage varied between countries (28). Multiple linear regression analysis showed that the frequency of sugar-sweetened beverage consumption was significantly associated with the HOMA-IR after controlling for potential confounders (29).

In both sexes, waist circumference and sum of skin folds were inversely associated with consumption of milk and yogurt, and milk- and yogurt-based beverages, whereas a positive association was observed with cardiorespiratory fitness. Moreover, dairy consumption was inversely associated with cardiovascular disease risk score ($\beta = -0.230$, $P = 0.001$) in adolescent girls (30).

The dietary index including physical activity was inversely associated with the HOMA-IR and directly with the quantitative insulin sensitivity check index in females, but not in males, after adjusting for pubertal status, study center, BMI, and cardiorespiratory fitness. Therefore, considering physical activity as part of the dietary index is of relevance because the resulted index is inversely related to insulin resistance independently of potential confounders (31).

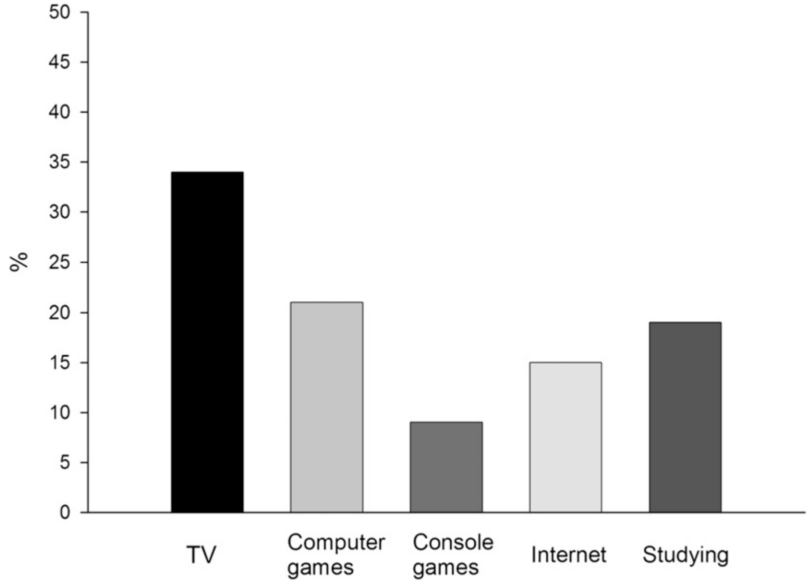

FIGURE 1 Percentage of daily time spent on different sedentary activities in a typical weekday in adolescents from the HELENA study (based on results from reference 34). $N =$ 3278 adolescents (1537 males and 1741 females). HELENA, healthy lifestyle in Europe by nutrition in adolescence; TV, television.

The intakes of most nutrients were, in general, in line with the German/Austrian/Swiss Nutrition Societies recommendations. Although the intakes of SFAs and salt were too high, the intake of PUFAs was too low. Furthermore, the intakes of vitamin D, folate, iodine, and fluoride were less than ~55% of the recommendations (32).

Energy intake was inversely associated with fat mass and positively associated with vigorous physical activity (33). Active youths develop lean bodies while ingesting relatively large amounts of energy and accompanying nutrients needed for healthy growth.

Sedentary behavior in European adolescents

The amount of daily sedentary time in adolescents across Europe is rather unknown. The accelerometer data from the HELENA study provides a great opportunity to determine the sedentary levels of European adolescents and to identify associated factors with excess sedentary time.

Sedentary time assessment. Sedentary time was assessed using a reliable self-reported sedentary behavior questionnaire (34) and accelerometry (GT1M accelerometer; Actigraph) (35,36).

Sedentary time of European adolescents participating in the HELENA study. The percentage of self-reported time spent on different sedentary activities in a typical day in adolescents from the HELENA study is presented in **Figure 1** (34). Adolescents spent, on average, 9 h/d of their waking time (66–71% and 70–73% of the registered time in boys and girls, respectively) in sedentary activities (35). Based on self-reported measures, we observed that one-third of adolescents spent >2 h/d watching television during weekdays (34).

The following are factors associated with excess sedentary time.

1) Age: Sedentary time was higher in older adolescents and in those with higher pubertal stage (35). When assessed by questionnaire, we observed that adolescents younger than 15 y were 22% less likely to watch television >2 h/d (34).

2) Media availability in the bedroom: Almost two-thirds of European males and half of females had a television in their bedroom, and 62% of males and 49% of females had a computer in their bedroom (34). Adolescents with a television in the bedroom were 2.7 times more likely to exceed the >2 h/d television recommendations.

3) Sleeping: Adolescents sleeping <8 h/d were more sedentary (~15 min/d) as assessed by accelerometry and were more likely to exceed the >2 h/d recommendations for television (36). Short sleepers tend to wake up more tired (37) and to reduce their participation in organized sports (38), which may explain the association between short sleep duration and increased sedentary time.

4) Breakfast consumption: Breakfast consumption was associated with sedentary time in both males and females yet with some inconsistencies (39). Male skippers spent, on average, ~45 min/d more on objectively measured sedentary time compared with regular consumers (39).

5) Season: Physical activity engagement is influenced by many individual, social, and environmental factors, such as the built environment (40). European females were more sedentary during winter compared with spring (**Fig. 2**), and females from the central–north region of Europe were more sedentary during winter compared with spring. No association between season and sedentary time was observed in adolescents from southern Europe (41).

The following are associations of sedentary behavior with other lifestyle behaviors and cardiovascular risk factors.

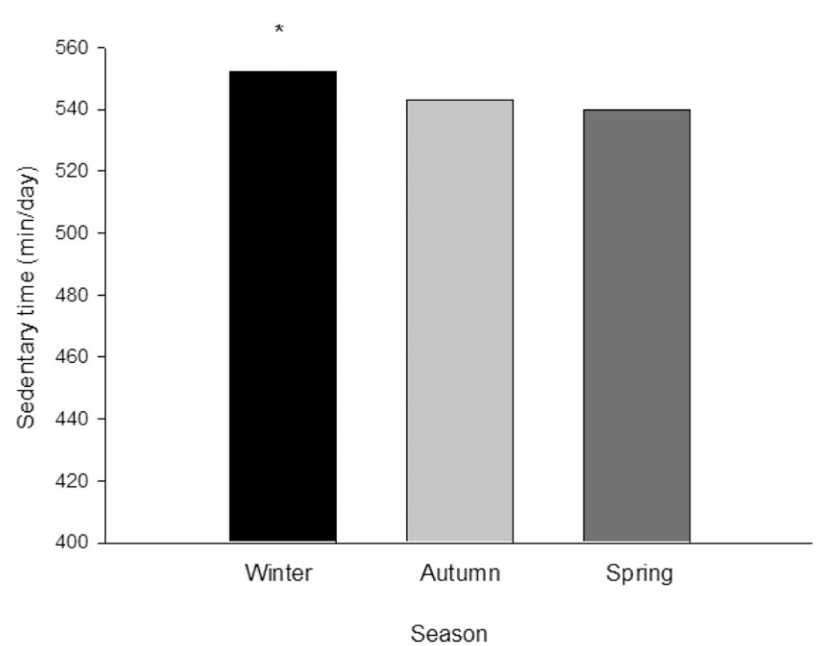

FIGURE 2 Objectively measured sedentary time in European females in winter, autumn, and spring (based on results from reference 46). Values are mean estimates. *Different from spring, $P < 0.05$.

TABLE 2 Blood vitamin concentrations in adolescents aged 12.5–17.49 y from the HELENA study and reference values used to analyze sufficiency status[1]

Vitamin biomarker	Total	*n*	Males	*n*	Females	*n*	Reference values
Plasma retinol, *μg/L*	356 ± 108	933	363 ± 104	444	351 ± 111	489	Incipient deficiency, 10–20 μg/dL (0.7 μmol/L) Deficiency, <10 μg/dL (0.35 μmol/L) (58)
Plasma β-carotene, *μg/L*	245 ± 170	942	237 ± 180	449	254 ± 159	493	Preventing effect, >0.5 μmol/L Acceptable, >0.3 μmol/L (58,59)
Plasma α-tocopherol, *μg/mL*	9.9 ± 2.1	933	9.5 ± 2.0	444	10.3 ± 2.1	489	Adequate, 12–46 μmol/L Primary prevention of cardiovascular disease, >30 μmol/L (60)
Plasma vitamin C, *mg/L*	10.3 ± 3.3	1053	10.0 ± 3.3	501	10.6 ± 3.3	552	Deficiency, <1 mg/L (10 μmol/L) Insufficiency, <5 mg/L Adequate, 5–15 mg/L (61)
Plasma vitamin D, *nmol/L*	58.8 ± 23.1	1006	57.4 ± 22.7	470	60.0 ± 23.4	536	Sufficiency, ≥75 nmol/L Insufficiency, 50–75 nmol/L Deficiency, 27.5–49.99 nmol/L Severe deficiency, <27.5 nmol/L (59,62,63)
Plasma pyridoxal 5′-phosphate, *nmol/L*	49.1 (5.75–899)	974	53.7 (9.84–483)	448	46.2 (5.75–899)	526	Sufficiency, >30 nmol/L Insufficiency, 20–30 nmol/L Deficiency, <20 nmol/L (64,65)
Plasma folate, *nmol/L*	16.0 (4.8–82.9)	1051	15.9 (4.9–82.9)	499	16.0 (4.8–79.8)	522	Sufficiency, >13.6 nmol/L (6 μg/L) Insufficiency, 13.6–10.2 nmol/L (4.5 μg/L) Deficiency, <10.2 nmol/L (4.5 μg/L) (66)
RBC folate, *nmol/L*	722 (140–3673)	1040	727 (139–3673)	495	710 (213–2609)	545	Deficiency, <566 nmol/L (250 μg/L) (66) Deficiency, <318 nmol/L (140 μg/L) (59) Optimal for lowering neural tube defect risks, >906 nmol/L (400 μg/L) (67) (only for females)
Plasma cobalamin, *pmol/L*	319 (110–1091)	1051	302 (114–961)	499	334 (110–1091)	522	Deficiency, <149 pmol/L (59)
Plasma holotranscobalamin, *pmol/L*	57.8 (16.3–331.8)	1018	58.5 (16.3–318)	467	57.5 (18.4–331.8)	551	Deficiency, <30 pmol/L (68)

[1] Data are shown as means ± SDs or medians (range). HELENA, healthy lifestyle in Europe by nutrition in adolescence.

1) Food consumption and dietary pattern: Adolescents reporting >4 h/d of television viewing, playing computer games, and using the Internet for recreation were more likely to consume sweetened beverages and less likely to consume fruit than those who spent <2 h/d (42). The time spent in these sedentary behaviors were also related with adolescents' dietary patterns, such as "snacking," "breakfast," and "health conscious" (43).

2) Cardiorespiratory fitness: Females who spent ≥69% of their waking hours in sedentary time had lower levels of cardiorespiratory fitness. Meeting the physical activity recommendations (60 min/d of moderate-to-vigorous physical activity) may attenuate the harmful effect of sedentary time on cardiorespiratory fitness (44).

3) Cardiovascular diseases risk factors: We sought to determine the association of time engaged in sedentary behaviors (television viewing and video games) with single risk factors (45) and a clustered cardiometabolic risk (46). We observed no association between television viewing and metabolic risk in adolescents, whereas playing video games >4 h/d (on weekend days) was associated with the presence of a clustered metabolic risk in males (46).

4) Bone mineral content: The sum of the time spent on reported sedentary behaviors was associated with bone mineral content (47). The use of the Internet for non-study activities was negatively associated with whole-body bone mineral content in males, whereas in females, time spent studying was negatively associated with femoral neck bone mineral content (47).

Vitamin status in adolescents: is there a need for intervention?

New physiologic functions beyond the classical ones (48,49) and the roles vitamins play in the prevention of chronic diseases are under debate (50). In Europe, there is a lack of comparable data on vitamin intake and blood concentrations (51,52). Reference ranges specifically developed for children and adolescents are missing, because most of the cutoffs used were those defined for adults (51,53).

Vitamin status measurement. A subsample (n = 1089) of the HELENA study was randomly selected for blood sampling. A specific handling, transport, and traceability system for biologic samples was developed (54). Concentrations of plasma folate, RBC folate, vitamin B-6 [pyridoxal 5′-phosphate (PLP)], vitamin B-12 (cobalamin and holotranscobalamin), vitamin D (25-hydroxyvitamin D), retinol, β-carotene, α-tocopherol, and vitamin C were measured (55–57).

Vitamin status of European adolescents. Descriptive values are presented in **Table 2** together with currently accepted reference values (49–68). Insufficient concentrations were identified for vitamin D (75%), PLP (20%), plasma folate (35%), and RBC folate (30%). Deficient concentrations were identified for plasma folate (15%), vitamin D (15%), PLP (5%), β-carotene (25%), and vitamin E (5%). A total of 71% of the females had RBC folate concentrations <906 nmol/L. Concentrations above this cutoff are considered maximally protective against folate-dependent neural tube defects. This high percentage of young females identified with low RBC folate concentrations should be considered and requires additional study. As expected, vitamin B-12 status is not a prevalent problem in adolescents (56).

Vitamin D and folate were identified as the vitamins most at risk in the analyzed adolescents. Median intakes of vitamin D and folate were <50% of reference values, followed by vitamin E (median intakes at 75% of reference values) and vitamins A and C (median intakes at 90% of reference values) (32). All associations between nutrient intake and concentration of biomarkers were significantly positive, and for all nutrients, biomarker status significantly increased with increasing tertiles of nutrient intake (69).

According to our own percentile values, blood concentrations of some vitamins are influenced by age and sex. Sex differences should be considered when analyzing vitamin C, α-tocopherol, vitamin B-12, and vitamin B-6. Age should be considered when analyzing plasma folate, holotranscobalamin, and RBC folate in males and β-carotene, plasma folate, and cobalamin in females. For the analysis of retinol concentrations, age should be considered in both sexes.

Regarding cardiorespiratory fitness, associations were observed with retinol and vitamin C in males and β-carotene and vitamin D in females. Muscular fitness was associated with β-carotene, retinol, and α-tocopherol in males and β-carotene and vitamin D in females (70). A significant relation between vitamin D concentrations and bone mineral content was only observed in physically active adolescents (71).

Conclusions

The HELENA study observations are obtained from a healthy population of urban European adolescents, and the interpretation is mainly descriptive given the cross-sectional design. Nevertheless, a number of important public health reflections can be made.

Lifestyle habits established during childhood and adolescence are likely to track into adulthood. Building further on this premise, the reported observations on health behavior and health status in European adolescents lead to rather pessimistic projections for lifestyle-related mortality and morbidity in the upcoming generations. Sedentary patterns and unbalanced diets seem to be widely present in the European society at the beginning of the 21st century and cast a public health shadow into the future for which, as yet, no clear answer is available. It will make a huge challenge to tackle these problems in a sustainable way, because their drivers are at the heart of the modern economic and societal life.

Our adolescents' diets clearly suffer from critical imbalances at the level of nutrient intakes and at the level of foods, especially fruit and vegetables, sugar-sweetened beverages, sweet foods, and meat. In addition, there seems to be a major concern regarding adolescents' breakfast consumption. Food manufacturers, retailers, and public health workers should collaborate and, in concert with a societal debate on this topic, find ways to make appealing changes in the everyday dietary experience of our adolescents as part of a stimulating and easily adoptable lifestyle.

For the first time, data on vitamin status are presented using the same methodology in European adolescents, showing the need for public health authorities to find ways of enhancing particularly vitamin D and folic acid status in identified risk groups.

At the level of physical activity and sedentary patterns, scientists and public health authorities should work together to find creative solutions for a reversing of the generalized "slowing down" of the general population, indeed most critically demonstrated here in European adolescents.

The current recovering from the deep economic and political crisis in Europe should be done in parallel with efforts for integrating a healthy and sustainable lifestyle as a foundation of the health of the European population, now and in the future.

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