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Summary Report ILSI Europe Workshop: Nutrition in children and adolescents in Europe: what is the scientific basis?

E. Krause and J. F. Desjeux

Objectives of the workshop

The objective of the ILSI Europe Workshop held on 14–16 May 2003 in Rome was to look at the scientific information and knowledge related to nutrition in healthy children and adolescents in Europe. Its main purpose was to highlight and understand the discrepancies in dietary recommendations and intake between European countries. The workshop focused on children between 2 years of age and the end of the growth period (18 years).

Two expert groups critically reviewed the available data and methodological approaches relating to the current dietary recommendations, dietary intake and nutritional status in children and adolescents in Europe. Based on presentations of the data collected by the expert groups, reasons for discrepancies in dietary recommendations and intakes were analysed by individual expert researchers and working groups. The following issues were discussed: methodological limitations, identification of conflicting or lacking data, diversity of scientific background for consensus, and significance of dietary intake in terms of metabolism and, more importantly, physiological functions.

Summary of the presentations

Logically, the first question proposed was child specificity: 'Why is it necessary to make specific dietary recommendations for children?' Professor Yvan Vandenplas (Free University of Brussels, Belgium) clearly identified the following factors: gender differences, metabolic needs involving turnover, growth development and differentiation, physical activity and eating patterns, and finally changing body composition with age including a special dynamic period at puberty. He highlighted that 'a child is not a small adult, but a future adult' and that this needs to be considered when making dietary recommendations for children.

The concept of recommended nutrient intakes was then critically analysed by Dr Francesco Branca (National Food Research Institute, Italy). Several different concepts are used throughout the world and harmonisation is required for common definition of nutrition policies (Prentice *et al.* 2004).

Dr Barbara Livingstone (University of Ulster, UK) critically reviewed studies of food habits and dietary intakes. She stressed a number of unique respondent and observer considerations at different stages of a child's life. In studies there is a need for critical data examination on dietary intake in children and a need to improve the method to take under-reporting and bias towards a selective reporting of foods into account (Livingstone *et al.* 2004).

Dr Ann Prentice (Elsie Widdowson Laboratory, UK) reported on behalf of Expert Group 1 on energy and nutrient dietary reference values for children in Europe. The data compiled by this group are a comprehensive computation of all the available data in Europe. They reveal the diverse methodological approaches used to establish nutritional needs: dietary reference values are derived from several sources including extrapolation from adult data, extrapolation from intakes of breast-fed infants, a factorial approach with allowance for growth and balance studies in children, and functional outcome specific to children and interpolation between infant and adult.

There is significant disparity between reference values and comparison is made difficult by the definition difference of age bands and the onset of puberty and a lack of gender differences. Thus, the results of the expert group will contribute to the ongoing discussion about the harmonisation of dietary reference values in Europe. In addition, they raise the question of whether harmonisation is a desirable or achievable goal. The rationale proposed to improve reference values highlights the need for improvements, e.g. in the assessment of food intake, adequacy of dietary intake, food labelling, need for upper limits, food for specific groups of children, and food development for specific conditions (Prentice *et al.* 2004).

Dr Janet Lambert (Masterfoods, UK) reported on behalf of Expert Group 2 on dietary intake and nutritional status. The data compiled by this group are a comprehensive collection and evaluation of dietary intake and status data for children and adolescents. The data show that an accurate assessment is difficult to obtain because of flaws and discrepancies in the available data and methodologies. However, trends on dietary intakes with increasing age were clearly identified. The main conclusions of the report were the necessity for improved and harmonised methodologies for dietary intake assessments and the establishment of a European nutrient database to be able to compare food intake directly (Lambert *et al.* 2004).

Abbreviations: DRV, dietary reference value; ILSI, International Life Sciences Institute.

* **Corresponding author:** ILSI Europe, 83 Avenue E. Mounier, Box 6, B-1200 Brussels, fax +32 2 762 00 44, email publications@ilsieurope.be

Summary of working groups

Four specific topics were then discussed in working groups by participants to evaluate how these parameters influence nutrient intake and status of children in Europe:

1. Food habits and cultural traditions.
2. Specific food components with potentially new physiological roles.
3. Fluids – water as the most essential nutrient.
4. Nutrient handling/bioavailability.

Food habits and cultural traditions. The working group on food habits and cultural traditions considered the availability of data on the effect of eating habits and traditions on the nutrient intakes of children across Europe. Although some studies addressing the question have been published for a few European countries, both the aims and the methods of these studies are variable to such an extent that renders any overview difficult. The working group concluded that a systematic review on the basis of the available evidence might represent an effective first step in clarifying the discrepancies.

The working group felt that eating habits and meal patterns are changing rapidly and to a great extent in Europe, and that the changes appear to result in diminishing differences in food habits among European countries. This 'globalisation' of European nutritional habits may be both beneficial and disadvantageous at the same time. On one hand, the ready availability of exotic fruits and vegetables as well as fish and seafood offers a substantially wider choice of important nutrients (vitamins, dietary fibres, essential fatty acids, etc.) to children whose preference of locally produced fruits and vegetables might be limited. On the other hand, the more uniform palette and continuous availability of foods might lead to increasing popularity of food items with less desirable nutritional profile. For instance, the rapidly increasing prevalence of childhood overweight and obesity in some Mediterranean countries suggests that, among other life-style factors, changing nutritional habits may exert untoward influence on the health status of the community. However, the very limited amount of scientific data on the changes in eating patterns renders it practically impossible to conclude on the net effect of changes over time on the quality of nutrition among children and adolescents in Europe.

The working group further pointed out that changing eating habits in combination with economic status, price, image and availability of certain foods might result in unfavourable outcomes. For that reason, local food guides (food pyramids) should take the available and affordable food into account while trying to approach the dietary reference intakes (based on biological requirements) as closely as possible. Future research on the effect of nutritional habits and traditions on the health status of children and adolescents in Europe should not only include traditional approaches to collect data on nutrient intakes, but also utilise the methodology of qualitative research and social sciences as well. Combined efforts of paediatricians, nutritionists, epidemiologists and sociologists are clearly needed for a better understanding of the influence of changes in the style of nutrition within society on the nutritional status of children and adolescents.

Specific food components with potentially new physiological roles. The second working group identified and critically reviewed food components that have the potential to positively affect the health and well-being of children and adolescents. The aim was to make recommendations to include specific beneficial food components in dietary guidelines. The group succeeded in producing a list of food components grouped according to their effect for an identified target function or health benefit, such as bone health, cardiovascular function, gut function, immune function, weight management, cancer, mental development and cognition. This was based on information available to participants at the time of the workshop. The group also provided perspective on the evidence of such a health benefit, ranking it from 1 to 5 (1, valid hypothesis based on animal or *in vitro* studies; 2, epidemiological observational study in adults; 3, epidemiological observational study in children; 4, randomised controlled study in adults; 5, randomised controlled study in children), and identified safety considerations concerning the use of some of the listed food components (Table 1).

For the food components to be included into dietary guidelines for children, the working group formulated two prerequisites: a demonstrated beneficial effect and a dose–response relationship. The working group concluded that a general recommendation is at present impossible for antioxidant compounds, as these substances need a case-by-case evaluation. Non-digestible carbohydrates should be an integral part of the diet; these are already included in most dietary guidelines, but recommendations for specific compounds are not possible currently. Recommendations for the specific inclusion of soya phyto-oestrogens or plant stanols and sterols into the diet of young children need to be substantiated with risk assessments. For folic acid, the recommendation for dietary intake should be followed. For all other food components no specific dietary guidelines can be given due to the lack of scientific data.

Overall, the working group concluded that several substances can be identified that may have particular benefits for the health of children between 2 and 18 years of age. However, at the time of the workshop, the participants knew of only a few controlled studies in children proving a beneficial effect for functional food components. Safety aspects need further consideration, particularly for young children.

Fluids – water as the most essential nutrient. The third group discussed 'water as the most essential nutrient'. As there are a number of definitions of 'fluids' in the research literature, the working group defined the term 'total water intake', comprising 'water in beverages + water in food (intrinsic water) + metabolic water', as the working definition.

The working group highlighted the functional role of water in the human body such as the transport medium for blood components and metabolic products, and its importance for the regulation of metabolism in general. For healthy children and adolescents water is needed to maintain hydration status, and may come from a variety of sources.

Table 1. Food components that have the potential to positively affect the health and well-being of children and adolescents

Food component	Function or health benefit	Evidence*	Comments	Gaps	Safety
Bone health					
Prebiotics	Calcium absorption	2 (5)		More controlled intervention studies in children on long-term effects	Diarrhoea dose-dependent
Phyto-oestrogens	Bone health	1			Suggestions for adverse effects; proper risk assessment needed
Bioactive peptides	Calcium absorption	1	Some evidence – mixed	Intervention studies needed	
Cardiovascular function					
Soya protein	Cholesterol reduction	4	Not 2–5 years; only four studies in children		Allergy risk
Plant sterols	Cholesterol reduction	4	at what age is active cholesterol reduction desirable? – not 2–5 years	Additional longer-term studies in children needed	Need dose–response data; safety review for children
Anti-oxidative food components (carotenoids, Se, tocopherols)	Atherogenesis	4			Consumption as part of food: no adverse effects expected Consumption of isolated substances: adverse effects possible for high doses (vitamin E, Se)
Folic acid	CVD via homo cysteine reduction	4	Need to establish the link to CVD	Intervention studies needed in children	Upper limit
Phyto-oestrogens	Cholesterol reduction	4			Risk assessment needed
Psyllium	Cholesterol reduction	4			
Bioactive peptides	Blood pressure	1			
Gut function					
Probiotics	Gastroenteritis (treatment)	5	Strain-specific/dose-dependent		Bacterial translocation
Probiotics	Gastroenteritis (prevention)	5	strain-specific		Bacterial translocation
Non-digestible carbohydrates	Gastroenteritis	2		More controlled intervention studies in children	Diarrhoea, constipation
Prebiotics	Constipation	2 (age 2–10 years) 5 (age >10 years)			Diarrhoea
Prebiotics	Gastroenteritis				Diarrhoea
Immune function – infection and allergy					
Probiotics	Allergy prophylaxis	5	One study	More data needed	Bacterial translocation
Probiotics	Other infections	2			Bacterial translocation
Weight management					
Non-digestible carbohydrates	Energy balance/appetite	4	Not for age 2–5 years	More controlled intervention studies in children	Diarrhoea, constipation
Ca as a signalling substance	Obesity	4	Promising area; merits further work in children	intervention studies needed in children	Upper limit

Table 1. *Continued*

Food component	Function or health benefit	Evidence*	Comments	Gaps	Safety
Conjugated linoleic acid	Obesity	2	Good animal data; some human studies		Need safety data in children, insulin resistance
Low-glycaemic-index carbohydrates	Obesity	3	Studies in diabetic and obese children	Intervention studies needed in children	
Thermogenic compounds	Weight control	2	Some evidence in adults of thermogenesis	Intervention studies needed in children	Need safety data in children
Structured triacylglycerides	Weight control/ energy intake	4	Interesting area; needs further study		
Non-digestible carbohydrates	Glucose kinetics	2/4 in adolescents		Evidence on long-term protection	Diarrhoea, constipation
Cancer					
Anti-oxidative food components	Cancer	4		Evidence on long-term protection	
Extracts from tea, cocoa, berries and wine	Cancer	2		Evidence on long-term protection	Diarrhoea, constipation
Non-digestible carbohydrates	Colon cancer	1		Evidence on long-term protection	
Phyto-oestrogens	Cancer	2			Risk assessment needed
Mental development					
Long-chain PUFA	Attention deficit disorder	1	Special patient groups	Controlled studies in healthy children	Pro-oxidative; balance $n-6$:$n-3$

* Evidence ranked as follows: 1, valid hypothesis based on animal or *in vitro* studies; 2, epidemiological observational study in adults; 3, epidemiological observational study in children; 4, randomised controlled study in adults; 5, randomised controlled study in children.

Regular fluid intake replaces losses that take place via the kidneys, the skin and the lungs. Losses vary considerably, depending on climatic conditions (temperature, humidity, wind and altitude) and on the surface area to volume ratio of an individual, the clothes worn and physical activity level. Food and fluid intake can restore glycogen and the glycogen-bound water pool, as well as the sodium pool and sodium-bound extracellular water volume, without changing hydration status characterised by a constant functional water volume. Food ingredients may alter intestinal water absorption, functional water volume, renal solute excretion, metabolic water production, diuresis and natriuresis.

If conditions are extreme, such as in prolonged intense physical activity during high environmental temperatures, severe dehydration can lead to overheating and even death. Mild dehydration in adults is or may be associated with an increased risk of development of kidney stones, constipation, cardiovascular disease and stroke. It has been suggested that in children mild dehydration is related to reduced alertness and ability to concentrate, as well as tiredness and headaches.

Total water requirement varies depending on climate, physical activity and renal solute load. Therefore it is difficult to set reference intakes for total water intake. If in a particular life-style and gender group the mean minus two standard deviations of actual maximum urine osmolality is accepted as a physiological criterion of water requirement, a theoretically adequate 24 h total water intake value can be calculated and should ensure euhydration in 97 % of subjects.

The methods to assess water intake and hydration status in children were critically reviewed. (Table 2). Actual hydration status may be characterised by functional water volume; and 24 h hydration status, by free water reserve (Manz *et al.* 2002; Kampmann *et al.* 2003). Total water intake, serum parameters, urine volume, urine osmolality, change in body mass and water turnover rates are indirect indices of hydration status.

In most EU countries there are no recommended dietary allowance or adequate intake values for water. Exceptions are Austria, Germany, Switzerland, Belgium and The Netherlands. For Austria, Germany and Switzerland, a range of total water intake between 1300 ml/d for 2- to 3-year-olds and 2800 ml/d for 15- to 18-year-olds is recommended. In Belgium, daily intake ranges of 75–100 ml/kg for 2- to 6-year-olds and 45–60 ml/kg for 15- to 18-year-olds are recommended. The Netherlands makes a recommendation for 5-year-olds of 83 ml/kg per d.

Total water consumed has been defined as beverages + intrinsic water (from food) or beverages + intrinsic water + water from oxidation. There are very few data on total water intake and markers of hydration status in European children. In addition, differences in the methodology of dietary assessment (e.g. weighed, household measures (calibrated), standard volumes) and difference in ‘beverages/drink’ definition make an interpretation and comparisons of the available data difficult.

From the data that are available it is clear that there are great differences in drinking habits between populations (Table 3). Germany appears to get around 10 % more of its fluid intake from intrinsic sources compared with The Netherlands, which obtains more of its total water intake from beverages (Table 4).

The working group pointed out the following areas for future research.

Table 2. Methods used to assess water intake and hydration status

Parameter	Marker	Comment
Water balance	Change in body mass	Acceptable for acute losses as during short-term exercise
Water input (water in beverages, food metabolic water)	Total water intake	Difficult to measure with any degree of precision Not necessarily related to hydration status
Water losses (respiration, perspiration, urine, faeces)	Urine volume	Urine volume is easily measured, but other losses are not Not necessarily related to hydration status, but low urine volumes indicate hypohydration
Water turnover	Labelled water	Not related to hydration status
Hydration status	Serum parameters	Relatively invasive and require laboratory measurements
	Urine osmolality	Urine colour, volume and frequency may be easily assessed using surrogate measures; urine osmolality is a concentration and not a measure of water deficit/surplus volume
	Functional water volume	
	Free water reserve	
Adequate total water intake	Total water intake in the subject with the 3rd percentile of free water reserve and urine osmolality corresponding to −2SD value of maximum urine osmolality	If in a particular age and gender group 97 % of the subjects show a total water intake above adequate total water intake value, euhydration is ensured

Table 3. Total daily consumption of beverages (ml) in some European countries

Age (years)	UK	The Netherlands	Germany	France
1–3		843		
1·5–4·5	1055			
2–3			614	
2–4	1018			
3–5				937
4–8			693	
5–7	941			
6–8				1012
7–9		943		

- To establish population reference intakes for adequate total water intake, more data are needed on health outcomes (e.g. physical and mental performance as well as disease states) given different hydration states and water intakes.
- Urine volume and osmolality in validated 24 h urine samples should be determined in groups of healthy children to determine free water reserve. This parameter may be a useful marker in epidemiology to investigate health effects of different states of euhydration and mild states of dehydration, and to calculate population- and life stage-specific adequate total water intake values.
- The physiological and clinical consequences of the intake of fluids with a similar increase of total water intake but different effects on functional water volume or thirst and free water reserve should be established.
- Scientists analysing the aetiology of urolithiasis, urinary tract infection, dental diseases, broncho-pulmonary disorders, constipation, cardiovascular disease, stroke, diabetic ketoacidosis, salt-sensitive hypertension, chronic renal failure, headache and inability to concentrate in children and adolescents should investigate hydration status of the subjects as a possible further aetiological factor.
- In populations in which 24 h urine samples show more than 3 % of subjects in the range of risk of hypohydration, preventive measures to increase the level of water intake should be considered.

Nutrient handling/bioavailability. The fourth working group considered nutrient handling and bioavailability, which is the fraction of the ingested nutrient that is absorbed and utilised physiologically. In the establishment of recommendations, it is essential to consider the functional utility of each nutrient and its effect on specific organs. Thus, for each nutrient several factors need to be considered, these include end-points and (bio)markers, adaptation to varying nutrient supplies, nutrient interactions, and identification of the rate-limiting step(s) in the bioavailability.

The working group agreed that the term ‘absorption’ was too narrow and established the working definition of bioavailability as the ‘fraction of the ingested nutrient that is absorbed and utilised physiologically’. The functional utility of each nutrient, and its effects on specific target organs, are paramount considerations.

End-points, i.e. criteria of adequacy, need to be judged in terms of adequate or appropriate physiological function for each nutrient individually. The ultimate criterion is a reduction of risk of disease. Nutrient concentration indices may be useful as intermediate markers. Appropriate end-points and reference ranges need to be defined for future studies and surveys of children.

In addition to genetically determined (i.e. gene polymorphisms) primary metabolic variations in nutrient requirements, there are also key phenotypic or environmental factors affecting nutrient availability, which include age, gender, and adaptations to varying food patterns and nutrient supplies. Also, the time frame is part of the adaptation equation. In general, adaptation of nutrient handling processes in response to environmental variations needs further research, especially in children.

Nutrients frequently interact with each other, especially within the gut lumen, but also within the tissues and body fluids. For instance, within the gut, haem Fe in food is more readily available for absorption than non-haem Fe. The availability of non-haem Fe is enhanced by protein and vitamin C, but is inhibited by phytate, polyphenols and certain other metal ions.

A framework for dissection of the integrated processes of nutrient handling is needed, to identify the rate-limiting step(s) in the bioavailability of each individual nutrient.

Confusion in terminology has often arisen because the rate-limiting steps in the processes of nutrient handling differ between different nutrients. Therefore, a single descriptive term such as ‘nutrient handling’ needs to encompass many different steps. For instance, the main rate-limiting step for Fe occurs early in the sequence, at the level of intestinal mucosal transfer, whereas the most important rate-limiting steps for vitamins A and C occur later, in the subsequent processes of nutrient handling. The working group suggested that, for future committees on dietary reference values (DRV), a framework for the different elements of nutrient handling could usefully be developed by subdivision into the following steps:

Table 4. Contribution (%) of beverage types to average daily beverage consumption

	The Netherlands (1–3 years)	UK (1·5–4·5 years)	Germany (2–3 years)	France (3–5 years)
Milk	49	28	31	36
Water	25	29	28	43
Fruit juice	10	3	19	19 (fruit juice + soft drinks)
Soft drinks	11	35	9	
Coffee, tea	5	5	13	2

- Dietary intake (of foods or nutrient mixtures); impact of processing and preparation.
- Milieu within the gastrointestinal tract (matrix effects, intraluminal nutrient interactions, gut transit time).
- Mucosal binding.
- Mucosal cell uptake.
- Mucosal export (portal circulation or mesenteric lymphatic transport).
- Hepatic uptake.
- Organ (including liver) clearance.
- Biliary clearance and excretion.
- Systemic circulation and peripheral distribution.
- Renal clearance and excretion.
- Peripheral tissue utilisation (e.g. metabolic/catabolic use, structural roles) and deposition.

Each nutrient can then be individually assigned one or more of these key steps as being rate-limiting for its utilisation.

The working group did not address the harmonisation of existing DRVs or of existing dietary intake data sets. However, the outcome of the discussion is relevant to future DRV committees and to the future interpretation of survey data sets. Consideration of nutrient handling and nutrient interactions, as well as total nutrient intakes, is essential. The working group therefore recommends:

- Clarification of the key steps in the processes of handling of individual nutrients in children, especially those that are critical for DRV revision and harmonisation, and for the robust interpretation of dietary intake data.
- Development of new, more informative and predictive functional markers to reflect nutrient availability and handling, especially in children.
- New studies of key adaptive processes in children, particularly in relation to nutrient availability and handling.

Other presentations

Professor Peter Aggett (University of Central Lancashire, UK) reviewed current knowledge on the functional effects of food in children. He again stressed that the functionality of food has physiological, pharmacological and toxicological dimensions, all of which should be considered in preparing recommendations. The optimisation of the functionality of foods for children will depend very much on the identification and validation of appropriate markers. Such a topic presents strong research opportunities. One good example is how diet can affect cognition and behaviour in children and adolescents (Aggett, 2004).

Dr France Bellisle (INSERM, France) stressed that beneficial effects are primarily visible from the correction of sub-optimal nutritional status, both short-term and long-term. This is the case e.g. for breakfast omission that deteriorates mental performance, or micronutrient supplementation that can improve intelligence score. Good regular dietary habits are the best way to ensure optimal mental and behavioural performance at all times (Bellisle, 2004).

Finally, Dr Ben van Ommen (TNO – Nutrition and Food Research Institute, The Netherlands) presented nutrigenomics as a new way of exploiting biology systems in the nutrition and health area, and highlighted that it is now time to consider the health effects of food components through specific interactions at the molecular level, including DNA, RNA, protein and metabolites. The complexity of nutrition can now be considered in its different components: the diet consists of complex mixtures of many potential bioactive compounds, chronically administered in varying composition, with a multitude of biological effects. Such an approach combines the development of transcriptomics and proteomics, which allow for the simultaneous determination of thousands of genes at the mRNA and protein level, together with appropriate statistical methods allowing for a complete description of biological systems. Recent examples indicate a new way to define biomarkers or biological targets in nutrition.

Conclusions and recommendations

Considering the main objective of the workshop, which was to highlight and understand the discrepancies in dietary recommendations and intake between European countries for children between 2 years of age and the end of the growth period, it is possible to identify four main outcomes.

First, the target population requires special attention, and this has not been fully addressed until now. The first two years of life and the period of adulthood are covered by a large part of knowledge and recommendations, while the period in between still lacks a sustained and comprehensive approach. From the physiological point of view, a child requires less absolute quantity of food but more per unit of body weight. Many specificities characterise this period of life, including change in body composition, gender differences, variability in metabolic needs, physical activity and eating pattern, dependence of genetic background and environmental context, including family, school and socio-cultural context. Puberty represents the most dramatic change. Thus the main area for research for this age period is the definition of reference values.

Second, current nutritional recommendations across European countries cannot be properly grouped together at a European level. Thus the main question is whether the present recommendations can be used in their diversity in different parts of Europe, or whether it is more appropriate to harmonise them at the European level. Harmonisation is clearly favoured with the intention to use common scientific and methodological approaches to propose recommendations taking into account the many parameters, including regional specificity. Harmonised recommendations are required both for industrial and research activities; this includes proper food labelling, assessment of dietary intake, search for upper limits, evaluation of the reasons for regional differences, food selection for communities, and possibly designing new food.

Third, dietary intakes and nutritional status are both the main sources of data to build reasonable dietary recommendations and the target of the recommendations.

However, data in this age group are scarce (for example at puberty), difficult to compare in their methodology, and uncertain in relation to immediate and future quality of life.

Fourth, some limitations in the current recommendations are clearly identified:

- Paucity of information on total water intake in the nutrients considered.
- Energy and metabolism are not the sole nutrient characteristics to be considered. In addition, nutrients have functional utility that depends both on absorption and utilisation, and needs to be evaluated by proper endpoints or markers.
- Nutrients interact with each other. This interaction is in part under genetic control. It would be useful to evaluate the efficacy of methods that can take into account such interactions.
- Nutrient intake is not only influenced by food availability but also by eating habits and tradition.

To sum up, information on nutrient dietary reference values and intakes for children between 2 years of age and the end of the growth period in Europe has been gathered and evaluated. The workshop identified discrepancies and reasons for those discrepancies. The workshop furthermore highlighted specific biological and functional targets for this period of life, and new methods of investigation. It is now time to propose a European network to improve nutritional recommendations. Harmonisation of the methods may help in providing proper recommendations, taking into account the specificity of the children and adolescents in the different regions of Europe.

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