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Diet and physical activity profiles in French preadolescents

Carine Platat[1], Anne-Elisabeth Perrin[1], Mohamed Oujaa[1], Aline Wagner[1], Marie-Christine Haan[2], Jean-Louis Schlienger[1] and Chantal Simon[1]*

[1]*Medical Faculty, Louis Pasteur University, EA1801, Strasbourg, F-67000, France*
[2]*Academic Inspection of the Department of Bas-Rhin, Strasbourg, F-67000, France*

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Dietary patterns have been identified in adults, but less is known about children and adolescents. For the first time, we have investigated lifestyle patterns combining diet and physical activity in 12-year-old French preadolescents and examined their association with sociodemographic factors. Physical activity, sedentary activities and dietary habits were assessed by questionnaires given to 2724 students in 2001. Family income tax and parents' educational level, as indicators of socio-economic status, and the size of the residence commune were obtained from parents. After adjusting for socio-economic status, physical activity was positively associated with a consumption of fruit/vegetables/fruit juice on more than four occasions in the previous 24 h ($P<0{\cdot}001$). Sedentary activities were positively associated with the consumption of French fries or potato chips ($P<0{\cdot}001$), with sweetened drink as the most usual drink ($P<0{\cdot}001$) and with nibbling while watching television ($P<0{\cdot}001$), and inversely associated with a high consumption of fruit/vegetables/fruit juice ($P=0{\cdot}04$). Multiple correspondence analysis identified two independent axes and specific combinations of behaviour: one axis characterised by sedentary activity, sweetened drink as the most usual drink, the consumption of French fries or potato chips and nibbling while watching television; a second one associating physical activity and the consumption of fruit/vegetables/fruit juice. Both socio-economic proxies were associated with the former axis ($P<0{\cdot}001$). The size of the residence commune was associated with the latter ($P<0{\cdot}1$). Combinations of diet and physical activity habits were identified in adolescents, indicating that prevention programmes targeting both behaviours may have an enhanced outcome.

Physical activity: Sedentariness: Adolescents: Diet: Multiple correspondence analysis

Participating in regular physical activity and eating a balanced diet are recognised to be beneficial for health. Physical activity may protect from obesity and several components of metabolic syndrome, such as insulin resistance (Brage *et al.* 2004), which can already be observed in adolescents (Weiss *et al.* 2004). Relationships between cardiovascular risk factors such as obesity and sedentariness are well established for both adults and adolescents (Gortmaker *et al.* 1996; Martinez-Gonzalez *et al.* 1999; Eisenmann *et al.* 2002). Similarly, the protective effects against metabolic risk of certain single nutrients or foods, such as fruits and vegetables, have been suggested (Albert *et al.* 1998; Liu *et al.* 2000).

Current thinking is, however, that diet has to be considered overall so that interactions between nutrients, foods and food groups can be taken into account (Jacobs & Murtaugh, 2000; Jacques & Tucker, 2001). Studies conducted over the past few years have shown the relevance of such approaches for investigating the relationships between diet and chronic diseases (Kant, 2004). These analyses have made it possible to confirm the protective effect of a 'prudent diet' (combining a high intake of fruits, vegetables, fish and whole grains) and the unhealthy impact of the Western diet on the risk of diabetes (Montonen *et al.* 2005) and cardiovascular diseases (Fung *et al.* 2001; Millen *et al.* 2001). More recently, this approach has been extended to other behaviours that may interact with diet, such as physical activity and smoking (Johnson *et al.* 1995; Mensink *et al.* 1997; Fung *et al.* 2001; Gillman *et al.* 2001).

In children and adolescents, recent studies have also succeeded in identifying dietary patterns. These patterns have been conceptually similar to those described in adults, with one pattern characterised by 'traditional' foods and the other associated with more 'health-conscious' food choices (Aranceta *et al.* 2003; Mikkila *et al.* 2005; Northstone & Emmett, 2005), although a third pattern more specifically related to 'junk' foods has recently been described in young children (Northstone & Emmett, 2005).

On the other hand, different studies have been concerned with the relationships between several dietary behaviours and physical activity in children and adolescents (Broyles *et al.* 1999; Pate *et al.* 2000), but none has used both physical activity and diet to investigate lifestyle patterns. Such studies are all the more important because a better understanding of the relationships between healthy behaviours is necessary for the efficient prevention of cardiovascular risk. Moreover, owing to the interindividual similarities in the groups that have been identified, this approach could provide useful information to develop targeted prevention programmes.

Abbreviations: MCA, multiple correspondence analysis; SED, sedentary activity; SES, socio-economic status.

* **Corresponding author:** Professor C. Simon, fax +33 (0)3 90 24 31 71, email chantal.simon@medecine.u-strasbg.fr

The purpose of the present cross-sectional study was to identify combined diet and physical activity profiles in a representative sample of 12-year-old preadolescents from the eastern part of France and to see how these profiles were associated with sociodemographic factors.

Subjects and methods

Subjects

This study was conducted on a representative sample of middle-school first-level students (corresponding to US sixth-graders) living in the Department of the Bas-Rhin (eastern France). Briefly, one third of all classrooms were selected using a random procedure stratified by school location in towns with fewer or more than 50 000 inhabitants (i.e. Greater Strasbourg) and in low-socio-economic status (SES) neighbourhoods. The randomised sampling procedure was carried out so that about one third of the first-level classes of each of the eighty-eight public and private schools of the Department was selected. Finally, 176 classes, one to five classes per school, were selected.

Participation was voluntary, and 77·7 % of the 4421 eligible students agreed to take part in the study. For these, questionnaires were completed by 90 % of the fathers and 96 % of the mothers. Signed informed consent was obtained from the parents for all the participating students. The study was approved by the French National Committee for Informatics and Liberties. Participation rates for children and parents did not differ by geographical location or gender, and the study sample was found to broadly match the family educational background (1999 population census) of the targeted population. Lifestyle questionnaires were administered to the students from February to June 2001. Self-administered questionnaires relating to demographic and SES factors were completed by the parents. Because of a lack of data, 713 subjects were excluded from the analysis. The resulting sample size was 2724 preadolescents aged 12·0 (SED 0·5) years. This remaining population did not differ significantly from the entire sample regarding SES and prevalence of overweight.

Behavioural and sociodemographic data

Physical activity was assessed with the Modifiable Activity Questionnaire for Adolescents (Pereira *et al.* 1997). Participation in organised physical activity outside school during the previous year was reported by the students, who gave information on the weekly frequency and usual duration of each session. The number of months in which each activity was performed over the previous year was recorded and the average weekly time devoted to organised physical activity calculated. Time spent in organised physical activity was categorised into three classes: no organised physical activity; more than zero but less than 2·3 h/week in organised physical activity; over 2·3 h/week in organised physical activity (2·3 h corresponding to the median time devoted to the organised physical activity of students participating in at least one organised activity). The time spent in sedentary activities (SED), for example watching television, playing computer/video games and reading, was recorded for each day of a typical week and divided into three categories (≤ 8·5, 8·5–14·0 and over 14·0 h/week).

The validity of the Modifiable Activity Questionnaire for Adolescents has been tested against the average of four 7-d recalls of activity and different measures of physical fitness in a study (Aaron *et al.* 1995) conducted on 100 randomly selected 15–18-year-old adolescents. The results of this study provided evidence that the questionnaire yields a reasonable estimate of past-year physical activity, at least for high-school adolescents, with Spearman correlations between the questionnaire and the average of the three 7-d recalls ranging from 0·55 to 0·83 for different measures of physical activity, and a good 1-month test–retest reproducibility (intraclass correlation of 0·66). In our population, the reproducibility of the questionnaire, assessed on a sample of seventy-nine 12-year-old pupils with a 1-month test–retest interval, was also reasonably good, with intraclass correlations of 0·83 and 0·71, respectively, for time spent in organised physical activity and SED.

Pupils were asked about different dietary habits, for example, breakfast, snacks and fast-food consumption. In addition, a food-frequency and dietary checklist with the following nine items was administered: fruit; 100 % pure fruit juice; raw vegetables; cooked vegetables; cookies/candies/ice cream; sweetened drink excluding 100 % pure fruit juice; French fries and potato chips; nibbling while watching television during the previous 24 h; the most usual drink in general (water or sweetened drink). Fruit, 100 % pure fruit juice, and cooked and raw vegetables were considered as a single item, divided into two groups (four or fewer times, or more than four times in the past 24 h). French fries and potato chip consumption and nibbling while watching television were used as dichotomous variables (yes or no). In order to avoid redundancy, only the most usual drink in general and not the consumption of sweetened drinks in the past 24 h was considered (in two classes: sweetened drink or water).

Annual family income tax (a measure of income) and parents' educational level as reported by the parents were used as proxies of SES. Family income tax was classified into three categories (no family income tax, 2000€ or less, more than 2000€). Level of family education was taken as the highest level attained by either parent and was divided into three classes: low (no formal education, primary school, first years of secondary school), medium (secondary school or technical training) and high (university). The size of the residence commune (fewer than 2000, 2000–50 000, more than 50 000 inhabitants, i.e. Greater Strasbourg) was also considered.

Statistical analysis

All analyses were carried out using SAS software (version 8, SAS Institute Inc., Cary, NC, USA). Because no relevant differences were observed between genders, the analyses presented here are those performed on the complete sample. All statistical inferences were drawn at a significance level of 5 % with two-sided tests.

We used χ^2 tests to compare qualitative variables according to gender, physical activity or SED. Logistic regression models were used to determine the relationships between dietary habits and physical activity or SED after adjustment for gender and for both SES proxies. Four dichotomous food

items or dietary habits for the previous 24 h were considered for these analyses: consumption of fruit/vegetables/fruit juice four or fewer times, or more than four times; sweetened drink or not sweetened drink as the most usual drink; consumption or no consumption of French fries or potato chips; nibbling or not nibbling while watching television. The associations identified were further tested by taking into account the cluster sampling procedure using mixed models (the procedure MIXED and GLIMMIX macro in SAS).

To identify lifestyle patterns combining diet and physical activity, a multiple correspondence analysis (MCA) was used (Greenacre, 1984). This descriptive technique enables the analysis of qualitative variables. It is based on a disjunctive table whose columns correspond to modalities of the variables and whose rows correspond to individuals. Its purpose is to determine the axes or planes that provide the most informative graphical representation of the relationships. The ability of an axis to describe the layout is quantified by the percentage of information represented by this axis and by its eigenvalue. MCA enables identification of the modalities of the variables introduced into the model that contribute most to the construction of the successively determined axes. A contribution (percentage) to the construction of each axis is associated with each modality. Variables not taken into account in the initial analysis can be projected as supplementary variables in the models.

In this study, the four dietary habits studied in the logistic regression analyses (each in two classes), physical activity (in three classes) and SED (in three classes) have been introduced into the MCA. Family income tax, parents' educational level and the size of the residence commune (all in three classes) were considered as supplementary variables. Their associations with the two main axes were tested using general linear models with adjustment for gender. The relationships between the supplementary variables and the axes identified by MCA were further tested by taking into account the cluster sampling procedure, as described for the logistic regression analyses.

Results

Characteristics of the subjects

Complete data were obtained for 2724 students from the Department of the Bas-Rhin selected as described earlier. The characteristics of the study population are presented in Table 1. The distribution of subjects by family income tax, parents' educational level and size of the residence commune were similar for both genders. More than one third of the pupils did not undertake any physical activity, with boys being more active than girls ($P<0{\cdot}001$). In contrast, a third of the pupils spent more than 14·0 h/week in SED, more boys doing so than girls ($P=0{\cdot}03$). Scarcely a third of the pupils had consumed fruit/vegetables/fruit juice more than four times in the past 24 h. A similar proportion had consumed French fries or potato chips or had nibbled while watching television in the past 24 h. Sweetened drink (not water) was the most usual drink for almost half the pupils, particularly for boys ($P<0{\cdot}1$).

Relationships between diet and physical activity

Dietary habits are presented according to physical activity and SED in Table 2. Physical activity was positively associated

Table 1. Characteristics (%) of the study population by gender*

	Girls (*n* 1367)	Boys (*n* 1357)	*P*
Family income tax			
Low	38·6	36·6	0·22
Medium	44·4	43·9	
High	17·0	19·5	
Parents' educational level			
Low	34·1	34·5	0·60
Medium	33·9	32·1	
High	32·0	33·4	
Size of the residence commune			
< 2000 inhabitants	28·8	31·6	0·14
2000–50 000 inhabitants	31·1	31·7	
> 50 000 inhabitants (Greater Strasbourg)	40·1	36·7	
Physical activity (h/week)			
0	41·7	25·4	< 0·001
≤ 2·3 h	35·0	31·8	
> 2·3 h	23·3	42·8	
Sedentary activities (h/week)			
≤ 8·5 h	35·7	32·4	0·03
8·5–14·0 h	34·1	32·7	
> 14·0 h	30·2	34·9	
Fruit/vegetables/fruit juice in the previous 24 h			
More than four times	31·8	30·5	0·46
Most usual drink			
Sweetened drink	39·7	45·8	< 0·1
French fries or potato chips in the previous 24 h			
Yes	31·1	32·5	0·43
Nibbling while watching television in the previous 24 h			
Yes	27·3	30·1	0·11

* Comparisons were performed with χ^2 tests.

Table 2. Diet habits according to physical and sedentary activities (%) in 12-year-old preadolescents (*n* 2724)*

	Fruit/vegetables/fruit juice more than four times in the past 24 h		Sweetened drink as the most usual drink		French fries or potato chips in the past 24 h		Nibbling while watching television in the past 24 h	
	%	*P*	%	*P*	%	*P*	%	*P*
Physical activity (h/week)								
0	28·23	<0·001	46·39	<0·1	35·12	0·02	30·53	0·30
≤2·3 h	27·44		39·08		29·31		28·10	
>2·3 h	37·93		42·71		30·92		27·36	
Sedentary activities (h/week)								
≤8·5 h	33·44	0·02	37·11	<0·001	26·21	<0·001	19·96	<0·001
8·5–14·0 h	32·20		40·77		30·00		26·15	
>14·0 h	27·70		50·62		39·46		40·36	

* Differences according to physical activity and sedentary activity levels were tested by means of χ^2 tests.

with a consumption of fruit/vegetables/fruit juice of more than four times in the previous 24 h ($P<0·001$) and inversely associated with a sweetened drink as the most usual drink ($P<0·1$) and with the consumption of French fries or potato chips in the previous 24 h ($P=0·02$). The time spent in SED was inversely associated with a high consumption of fruit/vegetables/fruit juice over the past 24 h ($P=0·02$) and positively associated with a sweetened drink as the most usual drink ($P<0·001$), with the consumption of French fries or potato chips ($P<0·001$) and with nibbling while watching television ($P<0·001$) in the previous 24 h (Table 2).

The relationships between diet habits with physical activity and SED, independent of family income tax and parents' educational level, were tested by means of logistic regression analyses and are presented in Table 3. With regard to physical activity, only the relationship with the consumption of fruit/vegetables/fruit juice remained significant when adjusted for SES ($P<0·001$). The odds ratio of consuming these foods more than four times in the previous 24 h associated with a high physical activity level (more than 2·3 h/week), compared with no physical activity, was 1·58 (95 % CI 1·28, 1·94). For SED, all the relationships remained significant, although only marginally so for the inverse association with the consumption of fruit/vegetables/fruit juice ($P=0·04$). The odds ratio associated with a high SED level compared with a low one was 1·55 (95 % CI 1·27, 1·88) for sweetened drink as the most usual drink, 1·66 (95 % CI 1·35, 2·03) for eating French fries or potato chips in the previous 24 h, and 2·59 (95 % CI 2·1, 3·21) for nibbling while watching television in the past 24 h. These results were not modified by taking into account the cluster sampling procedure through multilevel models (data not shown).

Diet and physical activity profiles

In MCA, the first two axes were identified as the major axes and accounted for 16·27 % and 12·35 % of the complete information (Fig. 1). To interpret the representation, only the modalities of the variables with the highest contributions to the axis were retained so that the sum of the contributions to the axis reached at least 80 %. Two main profiles were identified. One was characterised by SED, sweetened drink as the most usual drink, the consumption of French fries or potato chips and nibbling while watching television in the previous 24 h (Fig. 1). The other, defined by physical activity and the consumption of fruit/vegetables/fruit juice, corresponded to the second axis.

As determined by general linear models, both family income tax and parents' educational level were significantly related to the first axis ($P<0·001$ for both): a low family income tax and a low parental educational level were associated with the profile associated with a high level of SED, the consumption of French fries or potato chips, sweetened drink as the most usual drink and nibbling while watching television, whereas a high family income tax and a high parental educational level were associated with the opposite profile. The relationship of these two parameters with the first axis remains significant even when taking them into account in the same model. The size of the residence commune was associated with the second axis ($P<0·1$): living in Greater Strasbourg was associated with a high level of physical activity and a high consumption of fruit/vegetables/fruit juice, whereas living in a commune with fewer than 2000 inhabitants was associated with low physical activity and a low consumption of fruit/vegetables/fruit juice. The associations between the sociodemographic variables and the profiles identified were not modified by taking into account the cluster sampling procedure.

Discussion

The present study has, for the first time in children or adolescents, identified particular combinations of behaviour related to diet and physical activity. Two distinct profiles can be identified. One is defined by physical activity and the consumption of fruit/vegetables/fruit juice. This profile is associated with the size of the residence commune. The other profile is characterised by SED, the consumption of French fries or potato chips, sweetened drink as the most usual drink and nibbling while watching television. This is associated with two estimates of SES: family income tax and parents' educational level.

Beneficial relationships between physical activity and 'healthy' food choices have been reported in several studies conducted on adults (Johnson *et al.* 1995; Mensink *et al.* 1997; Fung *et al.* 2001; Gillman *et al.* 2001) and in one of the two main studies conducted in this field on children and adolescents (Broyles *et al.* 1999; Pate *et al.* 2000). In contrast, such a

Table 3. Adjusted odds ratio of dietary habits according to physical activity and sedentary activities levels in 12-year-old preadolescents (*n* 2724)*

(Odds ratio (OR), 95 % CI and corresponding global *P*)

	Fruit/vegetables/fruit juice more than four times in the past 24 h			Sweetened drink as the most usual drink			French fries or potato chips in the past 24 h			Nibbling while watching television in the past 24 h		
	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI	*P*	OR	95 % CI	*P*
Physical activity (h/week)												
0	1		<0·001	1		0·48	1		0·71	1		0·66
≤2·3 h	0·94	0·76, 1·16		0·89	0·73, 1·09		0·92	0·75, 1·13		0·99	0·80, 1·22	
>2·3 h	1·58	1·28, 1·94		0·89	0·73, 1·09		0·97	0·79, 1·19		0·91	0·74, 1·13	
Sedentary activities (h/week)												
≤8·5 h	1		0·04	1		<0·001	1		<0·001	1		<0·001
8·5–14·0 h	0·96	0·95, 1·17		1·10	0·90, 1·33		1·15	0·93, 1·41		1·37	1·10, 1·71	
>14·0 h	0·80	0·64, 0·95		1·55	1·27, 1·88		1·66	1·35, 2·03		2·59	2·10, 3·21	

* Logistic regression models were used with adjustment for gender, family income tax and parents' educational level.

favourable association was not identified in 4–7-year-old American children (Broyles *et al.* 1999). Although these latter results could be partly explained by the age of the children (4–7 years), and by the consideration of nutrients rather than foods, another difference concerned physical activity as only spontaneous physical activity in school and at home was considered and not leisure-time organised physical activity. In adults, the relationships between physical activity with various markers of cardiovascular risk factors and eating habits differed according to the type of physical activity (leisure physical activity or occupational physical activity; de Bourdeaudhuij & van Oost, 1999; Forrest *et al.* 2001). Similarly, television-watching has already been related to rather unhealthy food habits in adults as in adolescents (Fung *et al.* 2001; Coon & Tucker, 2002).

The concept of interrelations between healthy habits has been discussed for a long time (Blair *et al.* 1985; Fung *et al.* 2001). The two main behaviour combinations identified in our work implicate physical activity and SED separately, each linked to distinct dietary habits. These latter were conceptually quite similar to those identified in adults (Hu *et al.* 2000) and more recently in the few studies conducted in children and adolescents (Aranceta *et al.* 2003; Mikkila *et al.* 2005; Northstone & Emmett, 2005), with healthy food choices on the one hand and an aggregation of unhealthy choices on the other. The inverse association observed between physical activity and the consumption of French fries or potato chips did not remain significant when taking into account SES indicators. Although the results of MCA explained only about one third of the total variance and should be confirmed by further studies, these findings

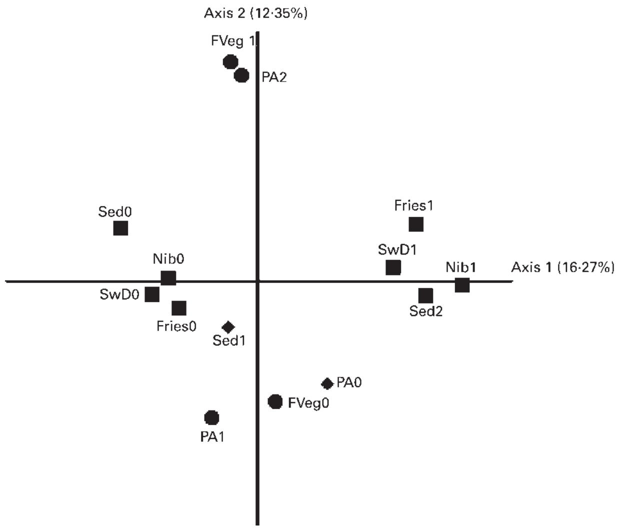

Fig. 1. Combined diet and physical activity profiles in 12-year-old preadolescents (*n* 2724). Multiple correspondence analysis identified two independent axes defined respectively by healthy (●) and unfavourable (■) behaviours. Non-significant modalities are represented by (◆). Modalities of variables included in the model: PA (0, 1, 2), physical activity (0, ≤2·3 h/week, >2·3 h/week); Sed (0, 1, 2), sedentary activities (≤8·5 h/week, 8·5–14·0 h/week, >14·0 h/week); FVeg (0, 1), consumption of fruit/vegetables/fruit juice in the previous 24 h (four or fewer times, more than four times); SwD (0, 1), sweetened drink as the most usual drink (no/yes); Fries (0, 1), French fries or potato chip consumption in the previous 24 h (no/yes); Nib (0,1), nibbling while watching television in the past 24 h (no/yes).

reinforce the hypothesis of a bidimensionality of health behaviours indicating that health behaviours tend to aggregate according to two axes.

Our results further suggest that physical activity and SED are distinct behaviours, associated with specific diet habits and also with different determinants. The profile containing physical activity was related to the size of the residence commune, whereas the profile containing SED was related to SES. This is in agreement with recent work suggesting that physical activity and SED would be determined by distinct parameters: external and family environment factors, respectively (Gordon-Larsen *et al.* 2000). Environmental factors, including the layout of the city and the density of pavements and cycle paths, as well as the accessibility of sports facilities and the proximity of food shops and fast-food outlets, have been identified as potential correlates of both physical activity and dietary habits (Popkin *et al.* 2005). In accordance with the higher level of physical activity observed in Greater Strasbourg, which is the only city of more than 50 000 inhabitants in the Department, it has been shown that urban areas are associated with a greater availability of physical activity equipment, easier transportation to places where adolescents can be physically active and better pathways to walk or cycle between home and school (Sjolie & Thuen, 2002; Loucaides *et al.* 2004; Popkin *et al.* 2005). In addition, family income tax and parents' educational level, which may influence behaviours by different social processes, have been related to both dietary habits and physical activity (Drewnowski & Specter, 2004; Popkin *et al.* 2005). The sociodemographic determinants of physical activity and dietary habits may thus have contributed to their clustering. On the other hand, some activity patterns may favour specific dietary habits. This is the case for television-viewing and nibbling food (Coon & Tucker, 2002), but one can imagine that regular exercise would also influence food choices.

Our work indicates that diet, physical activity and SED should be considered simultaneously in the prevention of major health problems, such as identifying risk factors for cardiovascular disease. Actions targeting physical activity, SED and diet simultaneously could offer a greater health benefit than the sum of the individual interventions because of their synergetic effects. Synergetic or antagonistic effects of these behaviours are indeed conceivable. Some authors have put forward the hypothesis that a change in one factor will lead to changes in associated factors and have proposed a catalytic effect for physical activity (Johnson *et al.* 1995).

Certain limitations of our study should be mentioned. First, the adolescents we studied were young and probably still influenced by parental food habits. Another limitation lies in the food questionnaire used. One cannot rule out some reporting bias owing to self-reported dietary data, with in particular an underestimation of unhealthy food choices (Lafay *et al.* 2000). Moreover, only a few food items were listed, and the food checklist more specifically registers the food consumed during the previous day, which may not represent a typical day. Some of the questions, however, related to food habits in general. On the other hand the consumption of some foods and drinks and some behaviours, such as nibbling while watching television, are a daily phenomenon, which should have reduced the impact of the procedure used on our results. In addition, care has been taken to represent both weekdays and weekends in the overall sample. Because of sample size, we can assume that the mean frequency in each subgroup of adolescents' physical activity behaviours represents a fairly good estimate of the average consumption of this subgroup.

Another concern is the type of food nibbled while watching television. This information was not available, and we cannot totally rule out the fact that the adolescents were nibbling healthy food. Nevertheless, different studies indicate that nibbling while watching television is usually associated with the consumption of snacks, junk foods and soft drinks (Matheson *et al.* 2004; Van den Bulck & Van Mierlo, 2004). Consequently, one can reasonably consider that nibbling while watching television in children and adolescents is a rather unhealthy behaviour.

A last point concerns MCA. One should mention that the statistical method used in the present study to identify diet and physical activity profiles is somewhat subjective because decisions on the number of modalities participating in the construction of the axes are based on empirical guidelines.

In conclusion, we have identified two main health behaviour profiles in preadolescents that have not yet been described. These results indicate that cardiovascular and obesity prevention programmes that target both diet and physical activity, as well as their associated determinants, may attain enhanced outcomes.

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