# Behavioural risk patterns in adolescents with excess weight participating in the PRALIMAP-INÈS trial

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# Behavioural risk patterns in adolescents with excess weight participating in the PRALIMAP-INÈS trial

Chantal Julia[1,2,3,*], Abdou Omorou[3,4], Edith Lecomte[5], Johanne Langlois[5], Mathilde Touvier[1], Serge Hercberg[1,2], Serge Briançon[3], Emmanuelle Kesse-Guyot[1], Francis Guillemin[3,4] and the PRALIMAP-INÈS Trial Group

[1]Sorbonne Paris Nord University, Inserm U1153, Inrae U1125, Cnam, Nutritional Epidemiology Research Team (EREN), Epidemiology and Statistics Research Center, University of Paris (CRESS), Bobigny, France: [2]Public Health Department, Avicenne Hospital, Bobigny, France: [3]University of Lorraine, EA 4360 APEMAC, Nancy, France: [4]CHRU-Nancy, INSERM, University of Lorraine, CIC-1433 Clinical Epidemiology, Nancy, France: [5]National Conservatory of Arts and Crafts, Nancy, France

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## Abstract

*Objective:* To investigate clustering of risk behaviours in adolescents with excess weight.

*Design:* Cross-sectional analysis of baseline data from the PRALIMAP-INÈS trial. Information on food frequency consumption (fruit, vegetables, sugary products and beverages), physical activity, sedentary behaviour (week and weekend days), smoking and alcohol consumption (current frequency and intoxication episodes) and socio-demographic data was collected using self-reported questionnaires. Behavioural risk factors were entered as categorical variables in a two-step clustering procedure: multiple correspondence analysis followed by hierarchical clustering. Associations between cluster membership and socio-demographic variables were investigated using multivariable multinomial logistic regression.

*Setting:* French PRALIMAP-INÈS trial.

*Participants:* Adolescents with excess weight.

*Results:* A total of 1391 participants (13–18 years old, 58·2 % female) were included in the analysis, which resulted in the identification of four groups of participants, including, respectively, 543 (39·0 %), 373 (26·8 %), 246 (17·7 %) and 229 (16·5 %) participants. Clusters 1 and 4 showed associations of rather healthy behaviours (high physical activity and low consumption of sugary products; high consumption of fruit and vegetables, respectively), while clusters 2 and 3 showed associations of rather unhealthy behaviours (high sedentary behaviour and low consumption of fruit and vegetables; smoking and alcohol consumption, respectively). Both social status and family structure were associated with cluster membership.

*Conclusions:* Risk behaviour patterns in adolescents with excess weight were clustered in both healthier and less healthy ways, with a complex interplay with socio-demographic factors.

**Keywords**
Dietary patterns
Addictive behaviour
Adolescents
Overweight
Obesity

Non-communicable diseases (NCD) represent a growing burden for both developed and developing countries, contributing to an estimated 73·4 % deaths worldwide in 2017[1]. In addition, the rise of obesity prevalence poses a growing threat to the balance of social and healthcare systems[2]. Younger generations are particularly at risk, as 254 million children are predicted to be obese by 2030 worldwide[3]. Around 55 % obese children remain obese in adolescence, and in turn, 80 % of obese adolescents continue to become obese adults[4]. Given the association between obesity and a host of NCD, among which cancer, CVD or diabetes, this rising prevalence challenges the long-term trend of improvement in life expectancy over the last

Philip Böhme (PB), Serge Briançon (SB), Rozenn De Lavenne (RDL), Cécile Gailliard (CG), Johanne Langlois (JL), Edith Lecomte (EL), Karine Legrand (KL), Laurent Muller (LM), Abdou Y. Omorou (AO), Céline Pourcher (CP), Marie-Hélène Quinet (MHQ), Laura Saez (LS), Elisabeth Spitz (ES), Brigitte Toussaint (BT)

*Corresponding author: Email c.julia@eren.smbh.univ-paris13.fr

decades[5]. Though with somewhat lower estimates of overweight and obesity prevalence than its European neighbours[2], France is still predicted to reach more than 1 million obese children and adolescents by 2030 (representing 13·9 % of children aged 5–9 years with obesity and 10 % of children aged 10–19 years with obesity), highlighting the challenge of obesity prevention in youth[3].

Beyond obesity, behavioural risk factors are the main modifiable drivers for NCD, accounting for 36·5 % (34·7–38·4) of attributable disability-adjusted life years (DALY) globally in 2017[6]. In France, the three leading risk factors for DALY in 2017 were smoking (accounting for 2979 (2702; 3253) DALY per 100 000 inhabitants), dietary risks (accounting for 1834 (1635; 2044) DALY per 100 000 inhabitants) and alcohol use (accounting for 1818 (1359; 2368) DALY per 100 000 inhabitants)[7]. The proportion of DALY attributable to dietary risks in France was estimated at 7 % (6·3; 7·7) in 2017[8].

Acting upon modifiable risk factors is paramount to tackle their consequences, and understanding their distribution and determinants is a major step to devise efficient strategies to this effect. Behavioural risk factors have been shown to cluster in specific populations, with for example associations between less healthy diets, smoking and alcohol consumption in adults[9]. In adolescents, a recent review identified complex clusters of behavioural risk factors including both healthy and unhealthy clustering of dietary, physical activity and sedentary behaviours[10].

While each individual risk behaviour is independently associated with health outcomes, their combinations have been suggested to have additive or interactive effects in adults[11,12]. Adolescence is a key transition period in which attitudes and behaviours are initiated that may be carried out throughout life, with potential long-term health consequences[13]. Finally, determinants of risk behaviour include socio-demographic condition, with lower socio-demographic groups more likely to engage in unhealthier behaviours, thus participating in social inequalities in health[14].

While clustering of risk factors in adolescents has been explored[10], their association with socio-demographic determinants has been less documented[15–17]. To the best of our knowledge, such an investigation has never been conducted in France, or specifically in adolescents with excess weight, who are already more at risk of developing chronic diseases in adulthood.

Our objective was to describe the clustering of five behavioural risk factors (diet, smoking, alcohol, sedentary behaviour and physical activity) in French adolescents with excess weight and their socio-demographic correlates using data from the PRALIMAP-INÈS trial.

## Methods

### *Study population*

Participants were selected from the PRALIMAP-INÈS trial participants. Briefly, the PRALIMAP-INÈS trial was a school-based multicentre trial including thirty-five state-run schools in Eastern France (Vosges department) between 2012 and 2015. The study included adolescents with excess weight defined using the International Obesity Task Force (IOTF) reduced by 1 kg/m$^2$ for BMI[18] and/or the McCarthy[19] standards for waist circumference, respectively. Given the inclusion criteria, some adolescents that would be classified as 'normal weight' considering only BMI thresholds were included in the study. However, the study population was homogeneous with regard to overweight risk[20].

Adolescents were then allocated into standard or strengthened care management according to their socio-demographic background to evaluate the impact of interventions based on proportionate universalism to tackle social inequalities in health and nutrition (diet and physical activity). The PRALIMAP-INÈS study inclusion criteria and data have been described in depth elsewhere[20]. The present cross-sectional study is based on baseline data from participants.

### *Data collection*

*Non-communicable disease-related risk behaviour*

At baseline, participants were invited to complete a set of self-administered questionnaires covering various lifestyle dimensions, including diet, physical activity, sedentary behaviour, smoking and alcohol consumption. Diet was investigated using a nine-item FFQ[21]. The questionnaires included information on the frequency of consumption of nine food groups, including in particular: fruits, vegetables, sugary products and sugar-sweetened beverages (SSB). For each food group, the frequency of consumption was provided as daily and weekly, and participants were able to report the number of occurrences (as an integer number). For each food, reported frequencies were later converted into six frequency alternatives. The questionnaire did not include information on the quantity consumed. Sedentary behaviour was investigated through self-reported time spent sitting in various settings ('school', 'TV, computer and video games', 'transportation' and 'other leisure activities') during the week and during the weekend (using average number of hours and minutes). Physical activity was investigated using the French short version of the validated International Physical Activity Questionnaire (IPAQ)[22], reporting frequency and time spent in high and moderate physical activity and walking. Time spent in each type of activity is then translated into total energy expenditure expressed in metabolic equivalent task minutes per week. Participants were then classified according to the IPAQ guidelines for physical activity in children and adolescents as low, moderate and high physical activity. High physical activity corresponds to the WHO guidelines of at least 60 min of moderate to vigorous physical activity daily with at least 3 d of vigorous physical activity[23]. Smoking status was assessed using self-reported smoking behaviour and

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coded as never smoker, experimenter (having already smoked but not in the previous month), occasional smoker (as less than once a day) and daily smoker. Alcohol consumption was assessed using self-reported usual consumption and specific consumption in the previous 30 d and coded as never consumer, experimenter (usual consumption reported as 'rare' with no consumption in the last month or usual consumption reported as 'never' with one consumption in the last month), occasional consumer (usual consumption reported as 'monthly' or 'rare' but with one consumption in the last month) and regular consumer (usual consumption reported as 'monthly' or 'weekly' or more than twice in the last month). Number of alcohol intoxication episodes in the last 30 d was also recorded (self-reported episode of drunkenness in the last 30 d), as a proxy for binge-drinking behaviours.

*Socio-demographic data*

Socio-demographic data were self-reported using self-administered questionnaires including date of birth, gender, curriculum (general high school, vocational high school, middle school), educational level of the parents (number of parents having achieved high school degree), place of birth of the parents (number of parents born in France) and social status of the family using the WHO Family Affluence Scale (highly less advantaged, less advantaged, advantaged, highly advantaged)[24,25] and family situation (living with none of the parents, with one of the parents, with two parents).

*BMI*

Height and weight were measured by trained practitioners in standardised conditions, with participants in light clothing and no shoes. Height and weight were measured to the nearest 0·10 kg and 0·1 cm, respectively. BMI was computed from measured height and weight, as weight divided by the square of height (kg/m²). Participants were identified as normal weight, overweight or obese according to IOTF standards.

### *Statistical analyses*

Consumption frequencies for each food group were constructed considering the specific distribution of the variable in the population, in the absence of specific dietary guidelines, as follows: fruit (<1/d, 1/d, 2/d, 3/d, ≥4/d), vegetables (<1/d, 1/d, 2/d, ≥3/d), sugary products (≤1/week, >1/week – <1/d, 1/d, 2/d, ≥3/d) and SSB (≤1/week, >1/week – <1/d, 1/d, 2/d, ≥3/d). Sedentary behaviour was categorised as quintiles of the distribution of the time spent sitting in the week (Min-510], ]510–600], ]600–690], ]690–830], ]830-Max) and weekends (Min-180], ]180–295], ]295–420], ]420–630], ]630-Max).

Using an exploratory and descriptive approach, categorical variables of NCD-related risk behaviour (consumption of fruit, vegetables, sugary products and SSB, and sedentary behaviour, physical activity, smoking status, alcohol consumption and alcohol intoxication) were used in a multiple correspondence analysis, which yielded three main dimensions of NCD-related behavioural risks. The dimensions were selected based on their adjusted inertia and interpretation. The three first dimensions covered 15·94 % of total variance (6·2, 5·0 and 4·8 %, respectively). The first dimension was positively correlated with alcohol consumption and smoking, the second dimension was positively correlated with fruit, vegetables, sugary products and SSB consumption and the third dimension was positively associated with low sedentary behaviour, alcohol and fruit and vegetables consumption.

The three first dimensions were used as input continuous variables in a two-way clustering procedure based on hierarchical methods (SAS CLUSTER and TREE procedures). The plots of semi-partial $R^2$, the semi-partial $T^2$ and the cubic clustering criterion by the number of clusters were used to identify the optimal number of clusters.

NCD-related behaviour risks were described according to clusters using chi-square tests. Socio-demographic, lifestyle and dietary variables were mutually adjusted against clusters in a multivariable multinomial regression. Adjusted percentages for each socio-demographic, lifestyle and dietary characteristic were extracted from this procedure across clusters.

All tests were two-sided, and a $P$ value <0·05 was considered significant. Statistical analyses were performed using SAS Software (version 9.3, SAS Institute Inc.).

## Results

Among the 1639 included participants with excess weight, 1391 had complete data for all NCD-related behavioural risks, including 58·2 % of girls, 57·8 % overweight and 20·8 % obese participants. The clustering procedure using three dimensions from the multiple correspondence analysis resulted in the identification of four mutually exclusive groups of participants, including, respectively, 543 (39·0 %), 373 (26·8 %), 246 (17·7 %) and 229 (16·5 %) participants.

NCD-related behavioural risks according to cluster allocation are presented in Table 1. Cluster 1 (healthy) was characterised by a low consumption frequency of SSB (61·7 % of participants consumed SSB less than once a day) and low sedentary behaviour (60 % of participants were in the first two quintiles of sedentary behaviour during the week and weekend). Participants were also mainly non-smokers (75 % never smokers) and with high levels of physical activity (31·7 % of participants). Cluster 2 (sedentary-low fruit and vegetable) was characterised mainly by low consumption of fruit and vegetables (59·5 and 69·7 % of participants consumed fruits and vegetables up to once a day, respectively) and high sedentary behaviour (74·3 and 72·7 % of participants were in the last two quintiles of sedentary behaviour during the week and weekend, respectively). Cluster 3 (smoking and alcohol) was

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**Table 1** Non-communicable diseases behavioural risks according to cluster allocation in the PRALIMAP-INÈS study (*n* 1391)

| | Cluster 1 | | Cluster 2 | | Cluster 3 | | Cluster 4 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 543 | 39·0 | 373 | 26·8 | 246 | 17·7 | 229 | 16·5 | 1391 |
| | *n* | % | *n* | % | *n* | % | *n* | % | *P* |
| Fruit consumption frequency | | | | | | | | | |
| <1/d | 39 | 7·2 | 91 | 24·4 | 20 | 8·1 | 32 | 14·0 | $<10^{-3}$ |
| 1/d | 189 | 34·8 | 131 | 35·1 | 83 | 33·7 | 13 | 5·7 | |
| 2/d | 221 | 40·7 | 108 | 29·0 | 84 | 34·1 | 26 | 11·4 | |
| 3/d | 89 | 16·4 | 36 | 9·7 | 40 | 16·3 | 48 | 21·0 | |
| ≥ 4/d | 5 | 0·9 | 7 | 1·9 | 19 | 7·7 | 110 | 48·0 | |
| Vegetable consumption frequency | | | | | | | | | |
| <1/d | 64 | 11·8 | 120 | 32·2 | 43 | 17·5 | 24 | 10·5 | $<10^{-3}$ |
| 1/d | 224 | 41·3 | 140 | 37·5 | 97 | 39·4 | 24 | 10·5 | |
| 2/d | 245 | 45·1 | 106 | 28·4 | 84 | 34·1 | 67 | 29·3 | |
| ≥ 3/d | 10 | 1·8 | 7 | 1·9 | 22 | 8·9 | 114 | 49·8 | |
| Sugary products consumption frequency | | | | | | | | | |
| ≤1/week | 94 | 17·3 | 47 | 12·6 | 25 | 10·2 | 44 | 19·2 | $<10^{-3}$ |
| 1/week – 1/d | 85 | 15·7 | 48 | 12·9 | 16 | 6·5 | 11 | 4·8 | |
| 1/d | 261 | 48·1 | 122 | 32·7 | 96 | 39·0 | 46 | 20·1 | |
| 2/d | 96 | 17·7 | 114 | 30·6 | 59 | 24·0 | 45 | 19·7 | |
| ≥ 3/d | 7 | 1·3 | 42 | 11·3 | 50 | 20·3 | 83 | 36·2 | |
| SSB consumption frequency | | | | | | | | | |
| ≤1/week | 224 | 41·3 | 81 | 21·7 | 42 | 17·1 | 74 | 32·3 | $<10^{-3}$ |
| 1/week – 1/d | 111 | 20·4 | 79 | 21·2 | 46 | 18·7 | 33 | 14·4 | |
| 1/d | 157 | 28·9 | 86 | 23·1 | 82 | 33·3 | 30 | 13·1 | |
| 2/d | 49 | 9·0 | 83 | 22·3 | 44 | 17·9 | 18 | 7·9 | |
| ≥ 3/d | 2 | 0·4 | 44 | 11·8 | 32 | 13·0 | 74 | 32·3 | |
| Sedentary behaviour during the week | | | | | | | | | |
| Min-510 | 156 | 28·7 | 17 | 4·6 | 66 | 26·8 | 50 | 21·8 | $<10^{-3}$ |
| 510–600 | 167 | 30·8 | 25 | 6·7 | 55 | 22·4 | 28 | 12·2 | |
| 600–690 | 148 | 27·3 | 54 | 14·5 | 36 | 14·6 | 31 | 13·5 | |
| 690–830 | 44 | 8·1 | 116 | 31·1 | 41 | 16·7 | 68 | 29·7 | |
| 830-Max | 28 | 5·2 | 161 | 43·2 | 48 | 19·5 | 52 | 22·7 | |
| Sedentary behaviour during the weekend | | | | | | | | | |
| Min-180 | 184 | 33·9 | 9 | 2·4 | 62 | 25·2 | 52 | 22·7 | $<10^{-3}$ |
| 180–295 | 140 | 25·8 | 23 | 6·2 | 32 | 13·0 | 22 | 9·6 | |
| 295–420 | 158 | 29·1 | 70 | 18·8 | 54 | 22·0 | 61 | 26·6 | |
| 420–630 | 41 | 7·6 | 113 | 30·3 | 45 | 18·3 | 43 | 18·8 | |
| 630-Max | 20 | 3·7 | 158 | 42·4 | 53 | 21·5 | 51 | 22·3 | |
| Physical activity level | | | | | | | | | |
| Low | 140 | 25·8 | 112 | 30·0 | 85 | 34·6 | 83 | 36·2 | 0·0001 |
| Moderate | 231 | 42·5 | 181 | 48·5 | 86 | 35·0 | 77 | 33·6 | |
| High | 172 | 31·7 | 80 | 21·4 | 75 | 30·5 | 69 | 30·1 | |
| Alcohol consumption frequency | | | | | | | | | |
| Non-consumer | 271 | 49·9 | 180 | 48·3 | 10 | 4·1 | 142 | 62·0 | $<10^{-3}$ |
| Experimenter | 108 | 19·9 | 84 | 22·5 | 11 | 4·5 | 37 | 16·2 | |
| Occasional consumer | 146 | 26·9 | 92 | 24·7 | 68 | 27·6 | 29 | 12·7 | |
| Regular consumer | 18 | 3·3 | 17 | 4·6 | 157 | 63·8 | 21 | 9·2 | |
| Alcohol intoxication frequency | | | | | | | | | |
| Never | 543 | 100·0 | 372 | 99·7 | 136 | 55·3 | 229 | 100·0 | $<10^{-3}$ |
| ≥1/month | 0 | 0·0 | 1 | 0·3 | 110 | 44·7 | 0 | 0·0 | |
| Smoking status | | | | | | | | | |
| Non-smoker | 407 | 75·0 | 241 | 64·6 | 41 | 16·7 | 158 | 69·0 | $<10^{-3}$ |
| Experimenter | 74 | 13·6 | 79 | 21·2 | 37 | 15·0 | 34 | 14·8 | |
| Occasional smoker | 31 | 5·7 | 10 | 2·7 | 30 | 12·2 | 8 | 3·5 | |
| Daily smoker | 31 | 5·7 | 43 | 11·5 | 138 | 56·1 | 29 | 12·7 | |

characterised by high levels of alcohol and tobacco consumption (63·8 and 56·1 % of participants were regular consumers of alcohol and tobacco, respectively). All but one of the participants who had reported at least one alcohol intoxication in the previous month were allocated to this cluster. Cluster 4 (high fruit and vegetables and SSB) was characterised by high frequency of consumption of fruit and vegetables (69·0 and 79 % of participants consuming fruits at least three times a day and vegetables at least twice a day, respectively), low consumption of alcohol and tobacco (62·0 and 69·0 % of non-consumers, respectively) and higher consumption of SSB (32·3 % consumed SSB more than three times a day).

Mutually adjusted percentage of socio-demographic characteristics according to cluster allocation is presented in Table 2 and the corresponding multinomial logistic

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**Table 2** Mutually adjusted socio-demographic characteristics according to non-communicable disease-related behavioural risk clustering in the PRALIMAP-INÈS study (*n* 1391)

| | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | |
|---|---|---|---|---|---|
| | 543 | 373 | 246 | 229 | 1391 |
| Sex | | | | | |
| Boy | 35·84 | 49·75* | 48·45* | 43·28 | 0·0004 |
| Girl | *64·16* | *50·25* | *51·55* | *56·72* | |
| Age | | | | | |
| Less than 15 years | 39·46 | 35·61 | 15 | 30·58 | <0·0001 |
| 15 years or more | *60·54* | *64·39* | *85* | *69·42* | |
| Curriculum | | | | | |
| General high school | *62·29* | *58·96* | *41·03* | *48·06* | <0·0001 |
| Vocational high school | 18·32 | 24·5* | 44·49* | 32·86* | |
| Middle school | 19·39 | 16·54 | 14·48 | 19·08 | |
| Socio-demographic class | | | | | |
| Highly less advantaged (1 2) | 0·0289 | 0·055 | 0·0242 | 0·0272 | 0·0041 |
| Less advantaged (3 4 5) | 58·22 | 55·05 | 44·14* | 45·3* | |
| Advantaged (6 7 8) | *37·82* | *40·17* | *47·68* | *45·26* | |
| Highly advantaged (9) | 3·928 | 4·728 | 8·157 | 9·417* | |
| Professional status of the main breadwinner | | | | | |
| Blue collar | 22·95 | 21·74 | 24·61 | 22·45 | 0·83 |
| Other profession | *77·05* | *78·26* | *75·39* | *77·55* | |
| Number of parents having achieved high school degree | | | | | |
| None | 71·41 | 74·47 | 69·77 | 72·47 | 0·0654 |
| One parent | *21·59* | *21·45* | *26·15* | *22·25* | |
| Two parents | 7 | 4·08* | 4·08* | 5·28 | |
| Number of parents born in France | | | | | |
| None | 2·839 | 3·839 | 1·628 | 8·359 | <0·0001 |
| One parent | 28·41 | 30·23 | 31·9 | 25·65 | |
| Two parents | *68·751* | *65·931* | *66·472* | *65·991* | |
| Family situation | | | | | |
| Not living with the parents | 0·0359 | 0·0548 | 0·1043* | 0·0983* | 0·0481 |
| Living with one parent | 11·36 | 15·7 | 20·88* | 18·87* | |
| Living with both parents | *88·6* | *84·25* | *79·02* | *81·03* | |
| BMI | | | | | |
| Normal weight | 17·4 | 24·27* | 17·61 | 27·98* | 0·0146 |
| Overweight | *67·08* | *62·83* | *69·96* | *60·71* | |
| Obese | 15·52 | 12·9 | 12·43 | 11·31 | |

Percentages were obtained using multinomial logistic regression including all socio-demographic variables.
Reference categories for the multinomial logistic regression are highlighted in an italic font.
Figures with * symbol correspond to percentages significantly different compared with cluster 1 (used as reference in the multinomial logistic regression).

regression in Table 3. Cluster 1 (healthy) included more younger girls in the general high school curriculum. They were also more likely to belong to less advantaged backgrounds with parents born in mainland France and more likely to be overweight or obese. Compared with cluster 1, cluster 2 (sedentary-low fruit and vegetables) included significantly more boys and participants whose excess weight did not reach the overweight threshold (categorised as 'normal weight'). Compared with cluster 1, cluster 3 (smoking and alcohol) included significantly more older boys from a vocational curriculum. They were also more likely than participants from cluster 1 to come from a background with separated parents (almost 21 % lived with only one of their parents). Finally, compared with cluster 1, cluster 4 (high fruit and vegetables and SSB) participants were more likely to be from a somewhat more advantaged background, with parents born abroad. They were also more likely to have excess weight but not crossing the overweight threshold (categorised as 'normal weight').

## Discussion

Our results show that risk behaviours in adolescents tend to cluster in specific patterns, in both healthy and unhealthy ways. Clusters 1 and 4 showed associations of rather healthy behaviours, with opposed behaviours regarding SSB consumption, while clusters 2 and 3 showed associations of rather unhealthy behaviours. However, none of the clusters presented all of either healthy or unhealthy behaviours. Overall, our results are consistent with others that investigated clustering of risk behaviour in adolescents, showing co-occurrence of both healthier and less healthy profiles[10,17], with some discrimination between addictive (smoking and alcohol consumption) and other lifestyle behaviours (diet, physical activity and sedentary behaviour)[26,27].

Cluster 1 displayed an overall healthy profile, with high physical activity, low sedentary behaviour, low smoking and low alcohol consumption. This cluster is somewhat similar to 'healthy' patterns observed in other studies in

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**Table 3** Association between socio-demographic characteristics with non-communicable disease-related behavioural risks clustering in the PRALIMAP-INÈS study (*n* 1391)

| | Cluster 2 *v.* Cluster 1 | | Cluster 3 *v.* Cluster 1 | | Cluster 4 *v.* Cluster 1 | | |
|---|---|---|---|---|---|---|---|
| | OR | 95 % CI | OR | 95 % CI | OR | 95 % CI | *P* |
| Sex | | | | | | | |
| Boy | 1·78 | 1·34, 2·37 | 1·67 | 1·2, 2·33 | 1·39 | 0·99, 1·95 | 0·0004 |
| Girl | 1·00 | – | 1·00 | – | 1·00 | – | |
| Age | | | | | | | |
| Less than 15 years | 0·86 | 0·6, 1·22 | 0·28 | 0·16, 0·47 | 0·67 | 0·43, 1·04 | <0·0001 |
| 15 years or more | 1·00 | – | 1·00 | – | 1·00 | – | |
| Curriculum | | | | | | | |
| General high school | 1·00 | – | 1·00 | – | 1·00 | – | <0·0001 |
| Vocational high school | 1·41 | 1·01, 1·96 | 3·64 | 2·51, 5·28 | 2·34 | 1·59, 3·43 | |
| Middle school | 0·95 | 0·62, 1·47 | 1·16 | 0·6, 2·25 | 1·42 | 0·83, 2·42 | |
| Socio-demographic class | | | | | | | |
| Highly less advantaged (1 2) | 1·70 | 0·78, 3·71 | 0·66 | 0·24, 1·83 | 0·79 | 0·28, 2·23 | 0·0041 |
| Less advantaged (3 4 5) | 0·89 | 0·66, 1·19 | 0·60 | 0·42, 0·86 | 0·65 | 0·45, 0·92 | |
| Advantaged (6 7 8) | 1·00 | – | 1·00 | – | 1·00 | – | |
| Highly advantaged (9) | 1·13 | 0·6, 2·13 | 1·65 | 0·8, 3·39 | 1·96 | 1·04, 3·72 | |
| Professional status of the main breadwinner | | | | | | | |
| Blue collar | 0·92 | 0·7, 1·22 | 1·09 | 0·78, 1·53 | 0·96 | 0·69, 1·34 | 0·83 |
| Other profession | 1·00 | – | 1·00 | – | 1·00 | – | |
| Number of parents having achieved high school degree | | | | | | | |
| None | 1·04 | 0·75, 1·45 | 0·79 | 0·54, 1·16 | 0·99 | 0·66, 1·47 | 0·0654 |
| One parent | 1·00 | – | 1·00 | – | 1·00 | – | |
| Two parents | 0·57 | 0·36, 0·91 | 0·47 | 0·26, 0·83 | 0·73 | 0·43, 1·24 | |
| Number of parents born in France | | | | | | | |
| None | 1·39 | 0·82, 2·35 | 0·59 | 0·28, 1·27 | 2·95 | 1·73, 5·05 | <0·0001 |
| One parent | 1·10 | 0·71, 1·7 | 1·14 | 0·68, 1·89 | 0·94 | 0·55, 1·6 | |
| Two parents | 1·00 | – | 1·00 | – | 1·00 | – | |
| Family situation | | | | | | | |
| Not living with the parents | 1·57 | 0·51, 4·84 | 3·14 | 1·03, 9·56 | 3·20 | 1·05, 9·72 | 0·0481 |
| Living with one parent | 1·39 | 0·87, 2·22 | 2·05 | 1·22, 3·46 | 1·82 | 1·07, 3·1 | |
| Living with both parents | 1·00 | – | 1·00 | – | 1·00 | – | |
| BMI | | | | | | | |
| Normal weight | 1·50 | 1·05, 2·12 | 0·99 | 0·63, 1·54 | 1·79 | 1·2, 2·67 | 0·0146 |
| Overweight | 1·00 | – | 1·00 | – | 1·00 | – | |
| Obese | 0·89 | 0·63, 1·26 | 0·79 | 0·53, 1·19 | 0·80 | 0·52, 1·22 | |

OR and 95 % CI obtained using multinomial logistic regression with cluster 1 as reference.

both adolescents and adults[27–30], suggesting these behaviours may be carried on into adulthood. However, participants in cluster 1 also reported a somewhat low frequency of fruit and vegetables consumption. Interestingly, this cluster also displayed a higher proportion of obese participants compared with other clusters, while some authors have reported an association of healthier lifestyles with normal weight[27]. Given the cross-sectional nature of our study, we may hypothesise that cluster 1 likely includes participants trying to lose weight or having already entered into overweight and obesity management programmes, which would involve modifications of both diet, physical activity and sedentary behaviour[31]. However, the low consumption of fruit and vegetables would tend to suggest that dietary modifications in these participants were more focused on the reduction of the consumption of less healthy products than on the increase of healthier food groups.

The second rather healthy cluster of behaviours was cluster 4, which combined higher frequency of consumption of fruit and vegetable, lower frequency of consumption of sugary products and low engagement in smoking or alcohol consumption. In contrast, they also displayed a higher frequency of consumption of SSB and had average physical activity and sedentary behaviour. Yet, they were more likely to have a normal weight compared with the other clusters. Compared with participants in cluster 1 specifically, one of the main differences appears to reside in the consumption of fruit and vegetables, which would tend to confirm their interest in preventing weight gain and help in weight management in the long term[32,33]. Dietary interventions aiming at modifying fruit and vegetables intakes specifically have shown mixed results, stressing the difficulty of devising efficient strategies in adolescents, in line with our results concerning cluster 1[34]. The other main difference pertains to the rather high consumption of SSB in cluster 4. Consumption of SSB has been consistently associated with weight gain and obesity, including in children and adolescents[35,36], questioning the long-term impact of the pattern of behaviour displayed in cluster 4. A longitudinal analysis of the weight trajectory of each cluster would help determining whether the overall healthy

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pattern of cluster 4 would counter-balance the negative effects of high SSB consumption.

Cluster 3 displayed both higher smoking and alcohol consumption associated with higher age which may prefigure the same pattern observed in adults, suggesting that such patterns may initiate relatively early in life. Several studies have observed a similar co-use of tobacco and alcohol in adolescents[37–39], and some suggest that these patterns are maintained throughout the life course[15]. This finding is particularly concerning, as tobacco and alcohol have been found to have synergistic effects, in particular in the case of cancer[11,40]. Though the mechanisms of initiation of the risk behaviour remain largely unexplored, nicotine addiction at an early age is thought to be associated with higher engagement with risky behaviour, in particular during the early adulthood transition[41]. This hypothesis of engagement in risky behaviour is strengthened by the occurrence of episodes of alcohol intoxication, along with a regular alcohol consumption pattern in this cluster. While the effects of binge drinking on long-term chronic diseases are not fully understood yet, this combination of both chronic and binge consumption of alcohol suggests that this particular group may be at risk of premature death not only from chronic diseases such as cancer but also from alcohol-related injuries[42].

Cluster 2 displayed a risk behaviour combination of low fruit and vegetable consumption, high sedentary behaviour and rather high consumption of sugary products and beverages while having rather low levels of smoking and alcohol and moderate physical activity. This cluster was also associated with higher rates of normal weight. A similar pattern was identified in a study by Mandic *et al.* in New Zealand adolescents, including both a healthy weight and low adherence to dietary, physical activity and sedentary behaviour recommendations[30]. Sedentary behaviour has been found to be associated with adiposity in adolescents in cross-sectional studies, but results from longitudinal and interventional studies showed more mixed results[43]. On the other hand, as previously stated, fruit and vegetables consumption has been found associated with reduced weight gain over time, somewhat questioning the long-term weight evolution of participants in this cluster.

Associations between clusters and socio-demographic variables tended to show that both elements of family structure and level of disadvantage were related to NCD risk behaviours in our population.

Co-occurrence of risk behaviours and their association with lifestyle variables observed in this study may conform to the health lifestyle theory, posing that health behaviours are an expression of the interplay between individual agency and social structure[44]. Indeed, the clustering of health behaviours in this study showed somewhat variable associations with socio-demographic and cultural backgrounds, with social disadvantage and family situation (living with both *v.* one or none of the parents) associated with both rather healthy (cluster 1 and cluster 4, respectively) and less healthy (cluster 2 and cluster 3, respectively) behaviours.

For example, participants in cluster 3 (smoking and alcohol consumption) displayed a higher probability of living with only one or none of their parents, and a lower probability for both parents to have achieved high school compared with cluster 1. Moreover, they were more likely to be older and in vocational high schools. Finally, they were less likely to be from disadvantaged backgrounds. Overall, we may hypothesise that adolescents in this cluster would be more likely transitioning into adulthood, with adults in the family being less regarded in the construction of their social interactions, and with somewhat higher personal financial resources. Studies have suggested that peer pressure is highly involved in risk behaviour initiation and participation[45,46], and some have suggested that adolescent smoking was more influenced by friends smoking than parents[47,48].

On the other hand, cluster 4 (displaying rather healthy behaviours) was independently associated with being more advantaged, having both parents originating from abroad and living with none or only one of the parents compared with cluster 1. This may suggest that family structure, social status and migration trajectories may influence the behaviours in children in differing ways. Interestingly, though a study suggested an association between migration in the parents and second-generation smoking and alcohol consumption in Ireland[49], we did not find significant associations between cluster 3 and place of birth of parents. Though the methods differ between the study by Das-Munshi *et al.* and ours, these results may suggest different trajectories in second generations related to diverging migration-related experiences in different countries.

Strengths of our study include the investigation of multiple NCD-related risk behaviours, including diet, physical activity, sedentary behaviour, smoking and alcohol consumption, using complementary indicators (two indicators per behaviour whenever possible), and their associations with socio-demographic variables.

However, some limitations need to be acknowledged. First, dietary consumption only recorded frequency of consumption of a limited number of food groups, therefore not allowing for the in-depth investigation of dietary patterns. However, the indicators that were used have been found to discriminate adequately between healthier and less healthy diets in adolescents[50]. Second, though we included two indicators relating to addictive behaviour (smoking and alcohol consumption), we did not include measures of other addictive behaviours, and in particular marijuana exposure. Finally, our analysis was limited to cross-sectional associations, and long-term health trajectories associated with cluster membership should be further investigated.

## Conclusion

Our analyses show that risk behaviour patterns in adolescents in a French sample are clustered in both healthier and

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less healthy ways, with a complex interplay with socio-demographic factors. Social inequalities appear to play a key role in the patterns of behaviour observed in our study, which is concerning in particular in overweight adolescents already presenting higher risks of adult NCD. Future studies should investigate the longitudinal association between these clusters and weight trajectories, to help identifying targeted prevention strategies in youth.

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