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Research paper

Overweight in the pluri-ethnic adolescent population of New Caledonia: Dietary patterns, sleep duration and screen time

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A B S T R A C T

Background: A high prevalence of overweight and obesity has been found in adolescents of New Caledonia and other Pacific Island Countries and Territories. Although Westernization may contribute to the weight gain in populations of Oceanian, Non-European, Non-Asian ancestry (ONENA), little is known about the sociodemographic and lifestyle factors associated with overweight in the Melanesian and Polynesian adolescents of New Caledonia.

Methods: In this cross-sectional study, a pluri-ethnic sample of New Caledonian adolescents (N = 954; age M = 13.2 years) completed a survey to estimate sleep duration, screen time, and dietary pattern using a food frequency questionnaire. Demographic data (gender, ethnicity, socioeconomic status: SES, area of residence) were collected, and anthropometric measures were used to compute weight status.

Findings: We found a higher risk for being overweight in Melanesian (OR = 1.67) and Polynesian (OR = 5.40) adolescents compared with European adolescents, even after controlling for age, SES, area of residence, dietary pattern, sleep duration and screen time. We also found that low SES (OR = 3.43) and sleep duration (OR = 0.65 per hour) were independently associated with overweight status in the European but not in ONENA adolescents.

Interpretation: In this study, the main contribution to being overweight was ethnic background, i.e. being Melanesian or Polynesian. The hypothesis of a genetic influence thus seems attractive and merits further analyses.

Funding: This project was funded by the University of New Caledonia and the Fondation Nestlé France.

Research in context

Evidence before this study: A high prevalence of overweight has been noted in New Caledonian adolescents, notably in Melanesian and Polynesian adolescents (Oceanian, Non-European, Non-Asian ancestry: ONENA). A better understanding of the factors that influence obesity in adolescents is necessary to develop interventions to prevent and manage overweight in this crucial period of life. Overweight results from a long-term energy imbalance between nutritional intake and activity and several factors have been correlated with it, including physical activity, screen time use, sleep deprivation, dietary intake, low socioeconomic status (SES), ethnic background and psychological factors. To date, little is known about the factors associated with overweight in New Caledonia adolescents. Previous studies have shown that the misperception of weight status is frequent in New Caledonian overweight adolescents. Moreover, skipping breakfast was shown to be correlated with overweight in New Caledonian boys. Concerning sociodemographic factors, low SES

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and ethnicity (being Melanesian or Polynesian) were associated with a higher risk of overweight/obesity.

Added value of this study: In this study, we showed that Polynesian, Melanesian and European adolescents living in New Caledonia may differ concerning some of the factors previously correlated with overweight. Five main food consumption patterns were identified: Meats, Fast food, Fruits and vegetables, Sweets, and Dairies and breakfast. Melanesian and Polynesian adolescents showed some differences in dietary patterns compared with their European counterparts. They also had lower sleeping times than their European counterparts. Melanesians had less screen time than European and Polynesian adolescents. A higher risk of being overweight was found for the Melanesian (OR = 1.67) and Polynesian (OR = 5.40) adolescents compared with the European adolescents, even after controlling for age, SES, area of residence, dietary pattern, sleep duration and screen time. We also found that low SES (OR = 3.43) and sleep duration (OR = 0.65 per hour) were independently associated with overweight status in the European but not the ONENA adolescents. Lower consumption of dairy foods and breakfast was associated with overweight in Polynesian and European adolescents, while lower consumption of sweets was correlated with overweight in Melanesian and European adolescents. Higher consumption of fruits and vegetables was also found in European overweight adolescents compared with non-overweight counterparts.

Implications of all the available evidence: The correlation between the pattern of a lower consumption of dairy foods and breakfast and overweight may reflect the skipping breakfast behaviours previously found in New Caledonian adolescents. Higher consumption of fruits and vegetables and lower consumption of sweets may be a strategy used by some overweight adolescents to control their weight but this was not found in all ethnic groups. Regardless of the potentially modifiable behaviours, specific diet interventions targeting adolescents may be useful to prevent obesity in New Caledonia. Even though sleep duration was only correlated with overweight in European adolescents, low sleep duration may have other consequences for well-being. Thus, interventions targeting sleep duration may be useful for all adolescents. Lastly, in this study and in previous studies, the main contribution to being overweight was ethnic background, i.e. being Melanesian or Polynesian. The hypothesis of a genetic influence thus seems attractive and merits further analyses.

1. Introduction

The prevalence of obesity is high in both adults and adolescents of the Pacific Island Countries and Territories (PICTs) [1–3]. As in other countries, overweight in Pacific adolescents has been associated with gender (being female), sugar sweetened beverage consumption, sedentary behaviours [4] and sociocultural influences [5,6]. Overweight and obesity have been correlated with several noncommunicable diseases, such as type 2 diabetes, cardiovascular events, cancer and hypertension [7–9]. Moreover, overweight also seems to be associated with psychological issues like depression [10–13], body dissatisfaction [14,15], disordered eating behaviours [16], low self-esteem [14,17–21], and insufficient sleep duration [22,23].

New Caledonia is a French archipelago in the South Pacific whose pluri-ethnic population has been affected by obesity and the issues surrounding it. The lifestyles of the New Caledonian populations differ greatly among the main ethnic groups, which are distinguished both culturally and socioeconomically [24]. The Melanesians (45% of the population) were the first inhabitants before the colonial era. Today, some of them still follow the traditional Pacific lifestyle, whereas others have also taken on a more Western lifestyle while still staying close to traditional customs. Other communities of European and Polynesian origins (31% and 12%, respectively) have adopted a frankly Western way of life, even though all Polynesian communities still have different cultural practices than Europeans. A high prevalence of overweight has been noted in New Caledonian adolescents [25,26], with a higher prevalence in Melanesian and Polynesian adolescents [24]. However, to date, little is known about the factors associated with overweight in these adolescents.

The major cause of overweight/obesity is often a long-term mismatch between energy intake and expenditure [27,28]. This mismatch has become more prominent today in relation with lifestyle changes, which have been striking in populations of Oceanian, Non-European, Non-Asian (ONENA) ancestry [29]. Indeed, unhealthy eating habits, physical inactivity, screen watching and sleeping patterns may contribute to the current obesity epidemic in PICTs [30], but these trends have never been studied in New Caledonian adolescents.

It has been well documented that dietary energy intake is one of the major contributors to positive energy balance in children and adolescents [31]. In PICTs, traditional foods like yams, taro, fish, and indigenous fruits and vegetables have been replaced by imported sugar, soft drinks, rice, canned foods and calorie-dense snack foods [6,32–35]. Adding Western foods to the traditional diet can contribute to an increased risk of obesity even in rural areas where lifestyles and diets have remained largely traditional [36]. More generally, dietary change was observed in five Pacific Island nations between 1961 and 2000 and was found to consist of greater food and energy intake with a notable increase in the consumption of fatty foods and meat [34], which may be correlated with the BMI increase observed in the same period. Peer influence and greater autonomy about food choices in adolescence may accentuate the unhealthy diets and weight gain in this group [37,38].

Modernization may also contribute to weight gain, as it has meant easier access to technologies like televisions (TV), personal computers (PC), smartphones and game consoles. Higher screen time has been linked to higher weight status, probably due to decreased energy expenditure, more physical inactivity, increased caloric intake while using screen devices, and increased food-advertising exposure [39–41]. In Vanuatu, the increased measures of adiposity and risk for obesity were associated with ownership of electronic devices [42]. A shift in adolescents' preferences for devices seems to have occurred recently, and the use of smartphones and small connected devices is rising [43,44]. As a consequence, adolescents owning a smartphone are more likely to have high screen time compared with non-owner adolescents [45]. In the Pacific, Maori children were 1.3 times and Pacific children were 1.1 times more likely to watch over 2 h of television per day compared with non-Maori and non-Pacific children [46]. Moreover, the association between high fatness levels and high TV watching was found in Maori and Pacific Island youths in New Zealand [47].

In addition to the putative effect of screen time on weight status, screen use was also associated with shorter sleep duration [48]. Short sleep duration is also a risk factor for obesity, and the relationship between high screen time exposure and the more frequent consumption of foods high in fat, free sugars or salt has been demonstrated [49]. To date, the exact mechanism through which sleep duration affects overweight/obesity is not completely understood. Little is known about adolescent sleep duration in the South Pacific population, with most of the studies conducted in New Zealand. Among New Zealander adults [50,51], children [52], and adolescents [53], the Maori and Pacific Island populations showed shorter sleep durations than the Europeans.

Given that the prevalence of overweight is much higher in the Polynesian and Melanesian adolescents of New Caledonia, we hypothesized that differences would be found between these groups and the adolescents with an European background, who showed a lower prevalence of overweight. The aim of this study was to look for putative links between overweight/obesity and sleep duration, dietary patterns and screen use in the pluri-ethnic adolescent population of New Caledonia.

2. Materials and methods

The sample for this study consisted in 954 adolescents (488 boys, 466 girls) recruited in New Caledonia. Participant ages ranged from 10.5 to 16.1 years (M = 13.22, SD = 1.23). Full descriptive information about the sample is presented in Table S1 and Table S2.

Ethics approval for this project was obtained from the Consultative Ethics Committee of New Caledonia (CCE 2018-06 001) and the project was conducted in accordance with the requirements of the Declaration of Helsinki. Eight secondary public schools were randomly selected to obtain a representative repartition between rural and urban areas, which is 63% and 37%, respectively, in New Caledonia. The selection criterion was school size (N >150) to ensure sufficient data in a single field trip. One or two classes were then randomly selected in each of four grades (levels) by a staff member, for a total of approximately 150 adolescents (6 groups with a mean of 25 students per division). We obtained 89% of the expected data due to parental refusal, no return of the parental agreement or absence of the participants on the days of intervention. Participants completed two anonymous online questionnaires consisting of the measures described above and additional measures on body image or self-esteem, which are not reported here. Data were collected over two consecutive days in order not to disrupt the students' schedules too much. There were missing data because some participants were absent on at least one of the two consecutive days or because they used a wrong anonymous number. Adolescents with missing data (N = 108; 10.2%) were then excluded from analyses (Figure S1). Parents gave informed written consent prior to the adolescents' participation in the study, and all participants received written debriefing information at the end of the study.

In the absence of a validated food frequency questionnaire (FFQ) for New Caledonian adolescents, we used a short FFQ previously used for Aboriginal and Torres Strait Islanders [54]. This FFQ was adopted from another tool developed in Australia to assess dietary intake in children and adolescents up to 16 years old [55]. The short questions on this FFQ are able to discriminate between different categories of food intake and provide information on relative intakes [54]. Moreover, this FFQ has been validated in a pluri-ethnic population composed with non-indigenous Australians (with European background) and Torres Strait Islanders (with a Melanesian background), and it was previously used in New Caledonia [56]. Minor modifications were made by the research team to include foods identified as important in the Melanesian diet. For example, tubers like cassava, yams and taro are consumed instead of white potatoes. The FFQ contains 28 questions on food and beverage intake. The intake frequencies for the individual food items of the FFQ were first converted to daily frequency equivalents (DFEs), calculated by allocating proportional values to the original frequency categories with reference to a base value of 1.0, equivalent to once a day [57]. The scores were calculated as follows: DFE score of 0: never ; 0.07: less than once per week; 0.14: once per week; 0.21: 1–2 times per week; 0.29: 1–3 times per week; 0.36: 2–3 times per week; 0.50: 3–4 times per week; 0.71: 4–6 times per week; 0.79: 5–6 times per week; 1: once a day; 2: 2 times per day; 2.5: 2–3 times per day; 4.5: 4–5 times per day; and 6: more than 6 times per day. The questions were asked on tablets distributed by the team and sometimes computerized in class so that the answers were automatically recorded in the database.

The sleep duration was determined with the following four questions: “What time do you fall asleep on school days?”, “What time do you fall asleep on the weekend?”, “What time do you wake up in the school week?” and “What time do you wake up on the weekend?” There were 13 available categories for the time an adolescent might fall asleep, from “Around 9 pm or before” to “Around 3 am or later” with a 30-minute interval between each category. There were 15 available categories for the wake-up time from “Around 5 am or before” to “Around midday or later” with a 30-minute interval between each category. Answers were converted to numerical values by using the median value of the time interval in the categorized answer or by using 30 min before (respectively, after) for the first (respectively, the last) category. The final sleep duration was the difference between the wake-up time and the falling-asleep time. Answers about sleep duration during the school week and the weekend were first separately processed, and then both factors were combined to get a total sleep duration for the full week as follows: Mean Sleep = 5 x Sleep (Weekdays) + 2 x Sleep (Weekend) divided by 7.

The screen time was determined with the following two questions: “How much time do you spend on a computer or tablet on the weekend?” and “How much time do you spend on computer or tablet during the school day?” There were four available categories for the amount of time an adolescent might use a computer, laptop or tablet screen on school days from “Less than one hour” to “More than 3 h”. There were six available categories for the time an adolescent might use a computer, laptop or tablet screen on weekends from “Less than one hour” to “More than 5 h”. Answers were converted to numerical values by using the median value of the time interval in the categorized answer or by using 30 min before for the first category or 30 min after for the last category. Answers about screen time during the school week and the weekend were first separately processed, and then both factors were combined to get a total screen time during the full week as follows: Mean screen time use = 5 x screen use (Weekdays) + 2 x screen use (Weekend) divided by 7. The same procedure was used for smartphone use with two questions: “If you have a mobile phone, how long are you connected to your phone during a day of the week?” and “If you have a mobile phone, how long are you connected to your phone during a day of the weekend?”

Ethnicity was self-reported by the adolescents and categorized as recommended by the INSERM report on New Caledonia [58], with the exception that we did not allow participants to choose more than one ethnic group. Participants from minor ethnic groups (approximately 5% of the whole sample) were then clustered in the category “Other”.

Socioeconomic status (SES) was indexed on the basis of the occupation of the household reference person (defined as the householder with the highest income) using the National Statistics Socio-Economic Classification [59]. In this study, three categories were retained: managerial and professional occupations (high SES), intermediate occupations (intermediate SES), and routine and manual occupations (low SES).

Based on data from the last census in New Caledonia [60], area of residence was determined using a European standard [61]. Densely populated areas comprising at least 50,000 inhabitants in a continuous zone with more than 500 inhabitants per km^2 were classified as urban. Areas with more than 50,000 inhabitants in a continuous area of over 100 inhabitants per km^2 or areas adjacent to an urban area were classified as semi-urban. Rural areas were defined as those areas that did not fulfill the conditions required to qualify as urban or semi-urban.

All anthropometric measurements were recorded by a member of the research team (trained staff). Height was measured to the nearest 0.1 cm using a portable stadiometer (Leicester Tanita HR 001, Tanita Corporation, Tokyo, Japan). Weight was determined using a scale (Tanita HA 503, Tanita Corporation) to the nearest 0.1 kg, with adolescents weighed in light clothing. Body mass index (BMI) was then calculated by dividing weight (in kilograms) by height (in meters) squared.

For weight status classifications, three BMI-based definitions were used: from the International Obesity Task Force: IOTF BMI-based references [62]; the World Health Organization: WHO BMI-based references [63]; and the French BMI-based references [64]. The BMI z-scores (BMIz) were calculated using the LMS reference values for the IOTF BMI-based classification [65], because this reference showed the best relationship with body fat in New Caledonian adolescents [25].

All analyses were conducted using IBM SPSS v.26, with *p*-values < 0.05 indicating statistical significance. For preliminary demographic analysis, gender differences were assessed with independent-samples t-tests (continuous variables) and chi-squared tests (categorical variables).

The principal component analysis (PCA) was run with all 24 food groups entered as raw frequencies using varimax orthogonal rotation. Factors were retained on the basis of eigenvalues > 1.0, a scree plot of the eigenvalues, and the interpretability of components. Variables with factor loadings $\geq$ 0.4 and $\leq$ -0.4 were considered significant when naming patterns. The patterns produced were transformed to remove skew and converted to z-scores, so factor scores had a standardised mean of zero. Data factorability was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Cronbach's alpha coefficient was used to determine the internal consistency. All participants received a score for all five patterns, with positive scores indicating high consumption of foods associated with that pattern and negative scores indicating lower consumption. For example, the higher the Fruits and vegetables score, the higher an individual's frequency of consuming fruits, vegetables, tubers, soup and fish.

To determine which factors were significantly associated with each dietary pattern, we computed linear mixed models with each dietary pattern score as the criterion variable. To account for intra-class correlation, school were included and treated as random effects in the linear mixed models with no predictors (null model). Results from this model were used to calculate the intra-class correlation coefficient (ICC), which is the proportion of between-school variance to total variance. Second, independent standardized variables (gender, ethnicity, SES, area of residence, BMIz and age) were added to the models as covariables and treated as fixed effects. Ethnicity, gender, area of residence, and SES were previously categorized into groups by creating dummy variables.

Differences in BMIz, sleep duration and screen time were assessed using a 4 × 2 analysis of variance (ANOVA), with ethnicity and gender treated as independent variables, and post-hoc Tukey tests used to follow-up significant differences. Linear mixed models were the used to determine the factors significantly associated with sleep duration or screen time using the method described above.

Last, we used multivariable logistic regression analyses to identify the factors associated with overweight. The variables in the models were age, dietary pattern scores, screen use and sleep duration for continuous variables and SES (low, intermediate and high), ethnicity (European, Melanesian, Polynesian and Other), gender (boy and girl) and area of residence (rural and urban) for categorical variables.

To take into account a possible selection bias because of the missing data for the participants, we also ran sensitivity analysis using varying sample sizes to ensure the robustness of the analyses. Because no measure had no more than 5% of the data missing (Figure S2), we did not perform any imputation methods.

2.1. Role of funding source

The funding sources (University of New Caledonia and the Fondation Nestlé France) had no role in study design, data collection, data analysis, interpretation and writing of the report.

3. Results

3.1. Sociodemographic and anthropometric characteristics

The study population comprised 954 adolescents between 10.5 and 16.1 years old, with 51.2% boys (13.2±1.2 years) and 48.8% girls (13.3±1.2 years). The boys and girls did not significantly differ regarding age, but the boys were significantly taller and heavier than the girls (Table S1). No significant difference was found concerning ethnicity, SES or area of residence repartition according to gender.

When the data were stratified by ethnicity, no difference regarding age or gender repartition was found (Table S2). However, ethnic subgroups differed significantly concerning height, weight, SES and area of residence. Notably, Polynesian and Melanesian adolescents were more likely to live in a rural area and have lower SES than their European counterparts.

3.2. Overweight prevalence

In our sample, overweight/obesity concerned between 25.4% (French reference) and 35.5% (WHO reference) of the adolescents, with a 32.3% prevalence for the IOTF reference (Table 1). Sensitivity analysis for all the participants with measured height and weight (N = 1011) showed no significant variation in weight status repartition ($p > 0.05$ using chi²). Whatever the reference, Polynesian and Melanesian adolescents showed higher overweight/obesity prevalence than adolescents with a European background. Table S3 shows the BMIz average according to ethnicity and gender. The results of a 4 × 2 ANOVA showed no significant interaction between ethnicity and gender, $F(3, 954) = 2.16$, $p = 0.091$, $\eta_p^2 < 0.01$. However, there was a significant main effect of gender [$F(1, 954) = 4.86$, $p = 0.028$, $\eta_p^2 < 0.01$] and ethnicity [$F(3, 954) = 53.01$, $p < 0.001$, $\eta_p^2 = 0.14$]. Tukey testing indicated that Melanesian and Polynesian adolescents had significantly higher BMIz averages than adolescents from European and other ethnic backgrounds ($p < 0.001$ in all cases), while adolescents from European and other origins presented no difference in BMIz average.

3.3. Dietary pattern

Results of PCA yielded KMO = 0.877 and the items had sufficiently high correlations for PCA (Bartlett's test of sphericity = $\chi 2$ (276) = 4860, $p < 0.001$). Furthermore, the 24 items used in the PCA showed good consistency (Cronbach's alpha = 0.73). The number of components decided upon was confirmed by an examination of the scree plot, which showed an inflection at the sixth component. PCA identified five dietary patterns that explained 47.3% of the variance in the respondents' diets (see Table 2).

The label assigned to the components was based on items with high loadings within each component and the interpretability of factors. These included: (1) Meats, (2) Fast food, (3) Fruits and vegetables, (4) Sweets, and (5) Dairies. It should be noted that the third component, Fruits and vegetables, included fruits and vegetables as well as tubers, soups and fish, and it seems to represent the traditional ONENA diet. Also, the fifth pattern Dairies included cheese and yoghurt, as well as breakfast cereal with milk, and it could thus be interpreted as Dairies and breakfast pattern. Sensitivity analysis was conducted for all participants who responded to the FFQ (N = 1031) and similar dietary patterns were found (Table S4).

Table 1
Weight status of New Caledonian adolescents stratified by ethnic background and gender.

Weight status according to reference used*		Whole sample N=954		Melanesian N=429				European N=368				Polynesian N=97				Other N=60			
				Boy N=214		Girl N=215		Boy N=196		Girl N=172		Boy N=49		Girl N=48		Boy N=29		Girl N=31	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
IOTF ref.	U	74	7.8	10	4.7	7	3.3	20	10.2	31	18.0	1	2.0	0	0.0	2	6.9	3	9.7
	N	594	62.3	135	63.1	122	56.7	146	74.5	113	65.7	18	36.7	21	43.8	17	58.6	22	71.0
	OV	187	19.6	40	18.7	63	29.3	22	11.2	23	13.4	10	20.4	17	35.4	6	20.7	6	19.4
	OB	99	10.4	29	13.6	23	10.7	8	4.1	5	2.9	20	40.8	10	20.8	4	13.8	0	0.0
French ref.	U	17	1.8	2	0.9	2	0.9	5	2.6	7	4.1	1	2.0	0	0.0	0	0.0	0	0.0
	N	695	72.9	149	69.6	146	67.9	163	83.2	143	83.1	18	36.7	28	58.3	20	69.0	28	90.3
	OV	242	25.4	63	29.4	67	31.2	28	14.3	22	12.8	30	61.2	20	41.7	9	31.0	3	9.7
WHO ref.	U	18	1.9	2	0.9	2	0.9	5	2.6	8	4.7	1	2.0	0	0.0	0	0.0	0	0.0
	N	598	62.7	123	57.5	117	54.4	152	77.6	131	76.2	16	32.7	16	33.3	18	62.1	25	80.6
	OV	202	21.2	47	22.0	64	29.8	27	13.8	24	14.0	7	14.3	21	43.8	6	20.7	6	19.4
	OB	136	14.3	42	19.6	32	14.9	12	6.1	9	5.2	25	51.0	11	22.9	5	17.2	0	0.0

* *ref: reference, U: underweight, N: normal weight, OV: overweight, OB: obese*

Table 2
Factor loadings of the food groups in the dietary patterns (principal components) identified in New Caledonian adolescents.

	Principal Component				
	Meats	Fast Food	Fruits and vegetables 'ONENA traditional'	Sweets	Dairies and breakfast
%variance explained	**11.0**	**10.6**	**9.3**	**8.8**	**7.6**
Pork	0.642				
Red meat	0.627				
Chicken meat	0.588				
Canned meat	0.573				
Delicatessen	0.458				
Pasta & rice	0.456			0.433	
Fish	0.452		0.442		
Beans	0.404				
Fast food (hamburger, pizza, take-away food)		0.716			
French fries		0.707			
Salty snack/Potato chips		0.618			
Egg		0.537			
Fruits			0.729		
Vegetables			0.712		
Tubers			0.600		
Soup			0.433		
Candy		0.417		0.621	
Cake & pastries				0.606	
Sugar sweet beverage				0.577	
Bread				0.504	
Cheese					0.597
Milk					0.577
Breakfast cereal					0.566
Yoghurt					0.558

Table 3
Mixed linear models of dietary patterns and background factors.

	Meats		Fast Food		Fruits and vegetables traditional ONENA diet		Sweets		Dairies and breakfast	
	β	p	β	p	β	p	β	p	β	p
Age (years)	0.040	0.216	-0.084	0.008	-0.036	0.230	0.121	0.001	-0.115	<0.001
Rural area$	-0.028	0.501	0.079	0.089	0.104	0.004	0.035	0.624	-0.080	0.031
Girl†	-0.172	<0.001	-0.040	0.202	-0.007	0.828	0.033	0.299	-0.112	<0.001
Melanesian‡	0.100	0.021	0.161	<0.001	0.261	<0.001	0.205	<0.001	-0.214	<0.001
Polynesian‡	0.061	0.103	0.028	0.442	0.003	0.933	0.098	0.009	-0.088	0.012
Other‡	0.034	0.313	0.047	0.152	0.003	0.918	0.012	0.723	-0.018	0.579
Low SES§	0.040	0.334	0.148	<0.001	0.039	0.316	0.018	0.657	-0.005	0.904
Mid SES§	-0.001	0.981	-0.015	0.676	-0.004	0.904	0.010	0.769	0.003	0.935
BMIz	0.047	0.178	-0.050	0.139	0.116	<0.001	-0.116	0.001	-0.072	0.031
ICC		0.001		0.049		0.092		0.039		0.047

ICC: Intra-class correlation coefficient. Reference is: † boy, ‡ European, $ urban area, § high SES.

Mixed linear regressions of dietary patterns and background factors are shown in Table 3. In all mixed models, the intra-class correlation between schools was poor (ICC < 0.1). The first pattern, Meats, explained 11.0% of the variation in the adolescent diets, and high scores were associated with ethnic background (being Melanesian) and gender (being a boy), but not with SES, age, area of residence or BMIz. The second pattern, Fast food, explained 10.6% of the variation in the adolescent diets, and high scores were associated with younger age, being Melanesian and having low SES. In the third dietary pattern, Fruit and vegetables, the traditional Pacific diet, high scores were associated with being Melanesian, living in a rural area, and high BMIz. The score for the fourth

Table 4
Sleep durations for New Caledonian adolescents stratified by ethnic background and gender.

Ethnicity	Gender	Sleep duration on weekdays (hours/day)		Sleep duration on weekends (hours/day)		Average sleep duration (hours/day)		N
		Mean	SD	Mean	SD	Mean	SD	
Melanesian	Boy	8.05	1.48	8.48	2.07	8.17	1.35	214
	Girl	8.14	1.22	9.01	1.75	8.39	1.08	215
	Total	8.10	1.36	8.74	1.94	8.28	1.23	429
European	Boy	8.44	1.16	8.84	2.00	8.55	1.12	196
	Girl	8.51	1.23	9.33	1.50	8.74	1.07	172
	Total	8.47	1.19	9.07	1.79	8.64	1.10	368
Polynesian	Boy	7.69	2.01	7.46	2.20	7.63	1.73	49
	Girl	7.94	1.08	8.39	1.93	8.07	1.05	48
	Total	7.81	1.62	7.92	2.11	7.84	1.45	97
Other	Boy	8.26	1.27	7.91	2.48	8.16	1.40	29
	Girl	8.32	1.28	9.10	1.80	8.54	1.15	31
	Total	8.29	1.27	8.53	2.22	8.36	1.28	60
Total	Boy	8.18	1.43	8.49	2.12	8.27	1.34	488
	Girl	8.27	1.23	9.07	1.70	8.50	1.10	466
	Total	8.22	1.34	8.77	1.95	8.38	1.23	954

SD: Standard deviation

pattern, Sweets, was positively associated with ethnic background (being Melanesian or Polynesian) and older age and negatively associated with BMIz. The score for the last pattern, Dairies and breakfast, was negatively associated with older age, rural area, being a girl, being Melanesian or Polynesian, and BMIz, but not with SES.

3.4. Sleep duration

Table 4 shows the sleep duration average on weekdays and weekends according to ethnicity and gender. The results of a 4 × 2 ANOVA for average sleep duration showed no significant interaction between ethnicity and gender, $F(3, 954) = 0.52$, $p = 0.783$, $\eta_p^2 < 0.01$. However, there were significant main effects of ethnicity [$F(3, 954) = 13.33$, $p < 0.001$, $\eta_p^2 < 0.01$] and gender [$F(1, 954) = 8.09$, $p = 0.005$, $\eta_p^2 < 0.01$]. Tukey testing indicated that Polynesian adolescents had significantly lower sleep duration than Europeans (p < 0.001), Melanesians (p = 0.007) and adolescents from other ethnic backgrounds ($p = 0.047$). Melanesian adolescents showed lower sleep duration than Europeans ($p < 0.001$) but higher than Polynesian adolescents ($p = 0.007$). No difference was found between adolescents from other origins and Melanesian or European counterparts. Sensitivity analysis was conducted for all participants who responded to this part of the survey (N = 1031) and similar results were found (Table S5), except that no significant effects of gender were found ($p = 0.253$).

After controlling for age, SES, area of residence and BMIz in a mixed linear regression (schools ICC = 0.012), the association between sleep time average and gender remained significant ($\beta = 0.097$, $p = 0.002$). Similarly, the ethnicity effect on sleep duration was confirmed for Polynesians (β = -0.149, $p < 0.001$) and Melanesians (β = -0.090, $p = 0.038$). Moreover, a significant negative relationship was found between age and sleep duration (β = -0.126, $p < 0.001$) and between BMIz and sleep duration (β = -0.098, $p = 0.004$).

3.5. Screen use

Fig. 1 and Table S6 show the screen time (PC/tablet and smartphone) average on weekdays and weekends according to ethnicity and gender. The results of a 4 × 2 ANOVA for PC/tablet screen time showed no significant interaction between ethnicity and gender, $F(3, 954) = 0.94$, $p = 0.418$, $\eta_p^2 < 0.01$. Moreover, the main effect of gender was not significant, $F(1, 954) = 0.07$, $p = 0.798$, $\eta_p^2 < 0.01$, but the main effect of ethnicity was [$F(3, 954) = 24.72$, $p < 0.001$, $\eta_p^2 < 0.01$]. Tukey testing indicated that the adolescents of other origins had significantly higher screen time than European ($p = 0.016$), Melanesian ($p < 0.001$) and Polynesian ($p = 0.011$) adolescents. Melanesian adolescents showed lower screen time than all the other groups ($p < 0.001$). No difference was found between European and Polynesian adolescents. Sensitivity analysis using a higher number of adolescents (N = 1010) showed the same results (Table S7).

Concerning smartphone use, the results showed no significant interaction between ethnicity and gender, $F(3, 954) = 0.23$, $p = 0.878$, $\eta_p^2 < 0.01$. Moreover, the main effect of ethnicity was not significant [$F(1, 954) = 2.46$, $p = 0.061$, $\eta_p^2 < 0.01$], but the main effect of gender was [$F(3, 954) = 7.19$, $p = 0.023$, $\eta_p^2 < 0.01$]. Student's *t*-test indicated that the gender difference was only significant between Melanesian boys and girls. Sensitivity analysis (Table S7) showed a significant effect of gender ($p = 0.021$) and ethnicity ($p = 0.008$) with a higher smartphone use for adolescents from other origins compared with Melanesian adolescents ($p = 0.036$).

For total screen time (smartphone + other screen use), the results showed a significant main effect of ethnicity, $F(3, 954) = 12.50$, $p < 0.001$, $\eta_p^2 = 0.04$. However, there was no significant main effect of gender [$F(1, 954) = 1.40$, $p = 0.236$, $\eta_p^2 < 0.01$] and no significant interaction between ethnicity and gender [$F(3, 954) = 0.65$, $p = 0.582$, $\eta_p^2 < 0.01$]. Tukey testing indicated that Melanesian adolescents had significantly lower total screen time on average than European (p < 0.001) and Polynesian ($p = 0.005$) adolescents and those from other origins ($p < 0.001$). No differences were found between the other ethnic groups of adolescents. Sensitivity analysis (Table S7) showed the same results except that Tukey post-hoc analysis indicated that European had lower total screen time than adolescents from other origins ($p = 0.004$).

When controlling for age, SES, area of residence and BMIz in a mixed linear regression (schools ICC = 0.047), the association between total screen time and gender remained non-significant and a positive association was found for adolescents from other ethnicities ($\beta = 0.067$, $p = 0.038$) compared to Europeans. Moreover, a positive correlation was found with age ($\beta = 0.278$, $p < 0.001$) but no correlation was found with SES, living area or BMIz.

3.6. Overweight predictors

Results of the multiple logistic regression examining the relationship between the adolescents' weight status (being overweight) and the five identified dietary patterns, screen time and

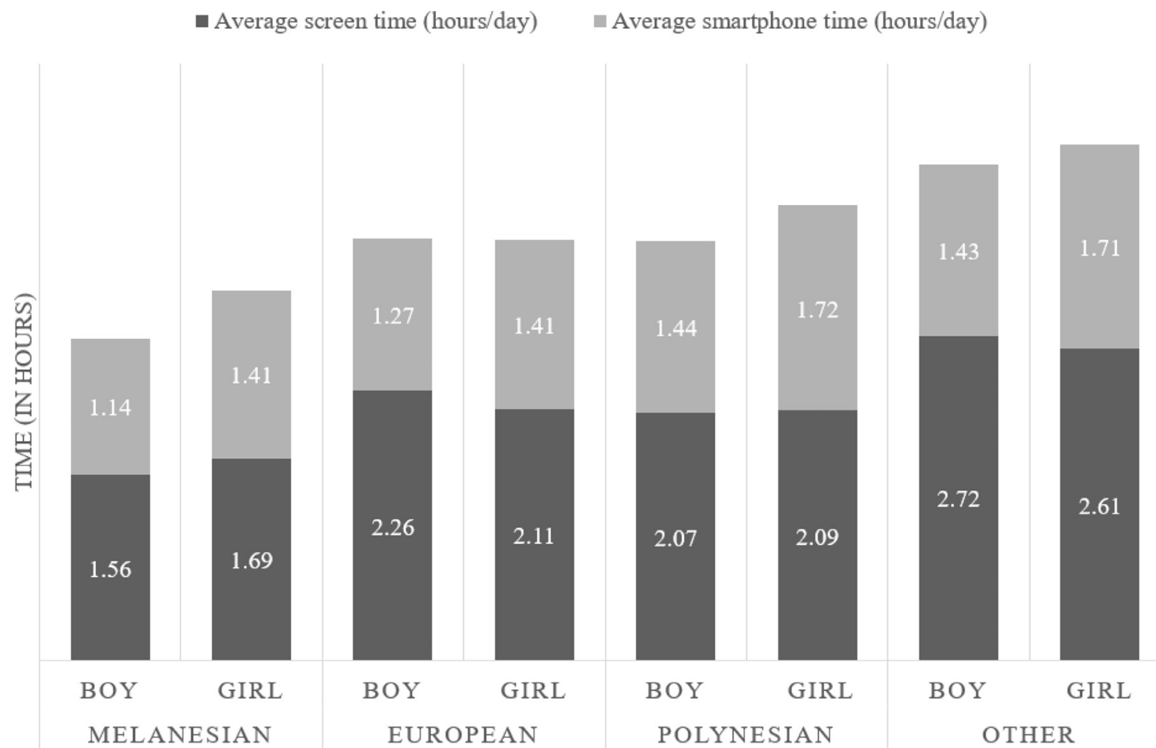

Fig. 1. Total screen time (in hours/day) for New Caledonian adolescents stratified by ethnic background and gender.

sleep duration, controlled for ethnic background, age, gender, SES and area of residence, are presented in Table 5. For the whole sample, Polynesian and Melanesian adolescents were more likely to be overweight than their European counterparts (OR = 5.40 and OR = 1.67, respectively), and less likely to be underweight (Table S8, OR = 0.07 and OR = 0.27 respectively). Moreover, adolescents with lower SES were more likely to be overweight (OR = 2.16), but this trend was found in the whole sample and the European adolescent subgroup only. Melanesian adolescents with higher screen time were less likely to be overweight (OR = 0.74), and this trend was not found in the other ethnic subgroups or the whole sample. In the European adolescent subgroup, higher sleep duration was correlated with a lower risk of being overweight (OR = 0.65), and higher risk of being underweight (Table S8, OR = 1.55).

Dietary pattern analysis showed that the Meats and Fast food patterns were not independently associated with overweight in the whole sample or any of the ethnic subgroups. However, adolescents with high scores in the Fruits and vegetables pattern were more likely to be overweight in the European subgroup and the whole sample (OR = 2.06 and OR = 1.19, respectively). Correlations between the Sweets and the Dairies and breakfast patterns and being overweight were found: participants with higher scores for the Sweets pattern were less likely to be overweight in the whole sample (OR = 0.78) and the European (OR = 0.60) and Melanesian (OR = 0.81) adolescents. Similarly, participants scoring high in the Dairies and breakfast pattern were less likely to be overweight in the whole sample (OR = 0.83) and the European (OR = 0.52) and Polynesian (OR = 0.49) adolescents. No correlation was found between dietary patterns and being underweight in the whole sample or the European and Melanesian subgroup (Table S8).

4. Discussion

This study in a pluri-ethnic population of adolescents living in New Caledonia revealed five dominant dietary patterns, with some of them found to be associated with overweight. Sleep duration and screen time were evaluated and correlations with weight status were explored. Results showed that ethnicity and low SES remained the main factors for being overweight in New Caledonia.

To our knowledge, this is the first study examining the dietary patterns of New Caledonian adolescents from 10.5 to 16 years old. Five main food consumption patterns were identified: Meats, Fast food, Fruits and vegetables, Sweets, and Dairies and breakfast. In most studies, an unhealthy Western dietary pattern has been associated with higher intakes of red and processed meats, refined grains, sweets and desserts, high-fat dairy products and fast food, while an healthy pattern has been found to consist of higher intakes of fruits, vegetables, whole grains, fish, poultry, and low-fat dairy products [66–69]. In our sample, the Meats (including red meat and canned meat), Fast food and Sweets patterns seemed to represent unhealthy or Western-like patterns, whereas the Fruits and vegetables and Dairies and breakfast patterns may have represented healthy patterns.

The Fruits and vegetables pattern was dense in fruits, vegetables, tubers, soup and fish, and it therefore could be considered as the traditional ONENA diet [70]. In rural areas, high scores for traditional ONENA Fruits and vegetables pattern and low scores for the Dairies and breakfast pattern were observed. These trends can be partly explained by the availability and affordability of these products [56,71]. Fruits and vegetables are commonly cultivated in rural areas by traditional Melanesian family farms or bigger European farms and thus are widely available and affordable. Food can be purchased but is also available for subsistence consumption, comprising subsistence production plus gifts and exchanges [72]. In contrast, cheese and yoghurt are not produced in rural areas of New Caledonia and may be expensive and not always available. Melanesian adolescents showed a major difference in dietary patterns compared with their European counterparts. They consumed more meat, fast food, fruits and vegetables and sweets and consumed less dairy, even after controlling SES, age and place of res-

Table 5
Multiple logistic regression for predictors of being overweight.

		Whole sample N=954 R^2=0.134		Melanesian N=429 R^2=0.069		European N=368 R^2=0.165		Polynesian N=97 R^2=0.131	
		OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p
Ethnicity	Melanesian	1.67 (1.07–2.61)	0.023						
	Polynesian	5.40 (3.13–9.30)	<0.001						
	Other	1.75 (0.90–3.40)	0.101						
	European	1.00							
SES	Low	2.16 (1.42–3.30)	<0.001	1.38 (0.70–2.72)	0.351	3.43 (1.67–7.07)	<0.001	1.08 (0.29–4.01)	0.913
	Mid	1.39 (0.80–2.41)	0.262	1.02 (0.42–2.48)	0.972	0.77 (0.26–2.29)	0.635	2.49 (0.39–15.91)	0.334
	High	1.00		1.00		1.00		1.00	
Area of residence	Urban	0.86 (0.59–1.26)	0.445	0.70 (0.37–1.33)	0.279	1.63 (0.75–3.51)	0.215	1.11 (0.37–3.35)	0.851
	Rural	1.00		1.00		1.00		1.00	
Gender	Boy	0.87 (0.64–1.19)	0.382	0.66 (0.43–1.02)	0.060	1.05 (0.54–2.07)	0.880	1.40 (0.53–3.69)	0.499
	Girl	1.00		1.00		1.00		1.00	
Age (years)		1.14 (1.00–1.29)	0.048	1.14 (0.96–1.36)	0.139	1.16 (0.88–1.53)	0.280	0.88 (0.60–1.29)	0.523
Sleeping duration (hours/day)		0.93 (0.83–1.05)	0.267	1.07 (0.90–1.27)	0.464	0.65 (0.48–0.87)	0.004	0.97 (0.70–1.36)	0.866
Screen use (hours/day)		0.88 (0.76–1.01)	0.069	0.74 (0.59–0.92)	0.008	0.96 (0.73–1.26)	0.742	0.86 (0.58–1.28)	0.462
Nutrition	Pattern 1 factor score: Meats	1.06 (0.91–1.23)	0.434	1.14 (0.94–1.38)	0.178	1.47 (0.97–2.21)	0.067	0.83 (0.52–1.32)	0.427
	Pattern 2 factor score: Fast food	0.93 (0.80–1.109	0.388	0.84 (0.69–1.02)	0.072	1.33 (0.77–2.30)	0.305	0.90 (0.55–1.48)	0.678
	Pattern 3 factor score: Fruits and vegetables	1.19 (1.02–1.40)	0.032	1.05 (0.85–1.30)	0.657	2.06 (1.36–3.10)	0.001	1.32 (0.81–2.15)	0.270
	Pattern 4 factor score: Sweets	0.78 (0.66–0.92)	0.004	0.81 (0.66–0.99)	0.040	0.60 (0.38–0.97)	0.036	1.25 (0.75–2.08)	0.396
	Pattern 5 factor score: Dairies and breakfast	0.83 (0.71–0.98)	0.029	0.97 (0.77–1.21)	0.766	0.52 (0.35–0.78)	0.002	0.49 (0.30–0.82)	0.006

OR: adjusted odds ratio; CI: confidence interval

idence. The high consumption of fruits and vegetables may reflect the traditional Pacific diet of the Melanesian adolescents, but the high consumption of meats, fast food and sweets compared with their European counterparts was surprising and needs further investigation. Polynesian adolescents showed some differences with their European counterparts, with a higher score in the Sweets pattern and a lower score for the Dairies and breakfast pattern. Last, girls showed lower scores for the Meats and Dairies patterns than boys. It should be noted that the study design and the FFQ we used did not allow us to estimate the total energy intake of the participants. It was difficult to determine whether a given ethnic group's higher consumption in a specific pattern was associated with a higher energy intake or whether the higher and lower scores in some patterns balanced each other. The Melanesian adolescents' scores were especially higher on average in four patterns (Meats, Fast food, Fruits and vegetables and Sweets), whereas they had a lower score on average in the last pattern (Dairies).

Our results showed that the European adolescents scoring high in the Fruits and vegetables pattern were more likely to be overweight. No causal relationship could be determined because of the cross-sectional study design; however, an explanation may be that the European adolescents who were already overweight may have increased fruits and vegetables uptake or declarations of uptake. These behaviours may be a strategy to avoid weight gain or to lose weight. In this case, this strategy was not used by Polynesian or Melanesian adolescents, because the fruits and vegetables consumption of these subgroups of adolescents was not associated with the overweight odds ratio, possibly because of less weight consciousness, less parental intervention or less motivation to avoid weight gain. Similarly, adolescents scoring high in the Sweets pattern were less likely to be overweight in the whole sample and in the Melanesian and European subgroups, but not in the Polynesian subgroup. Once again, this might be a strategy to avoid weight gain for overweight adolescents. Another trend is that the European and Polynesian adolescents with lower scores in the Dairies pattern were more likely to be overweight. This pattern consists of cheese and yoghurt but also milk and breakfast cereals and, as previously explained, overweight adolescents may avoid eating high-fat products like cheese. Moreover, dairy products are not typical of the ONENA traditional diet [70]. Another explanation is that this pattern may reflect the relationship between breakfast skipping and overweight, previously described in New Caledonian adolescents [24]. No specific dietary patterns were found to be associated with underweight condition in our samples.

We showed that Melanesian and Polynesian adolescents had lower sleep durations (20 min and 40 min less, respectively) than their European counterparts, who slept about 8 h and half per night. These results were very similar to those obtained by Galland et al. [53], who showed that New Zealand Europeans slept about 8 h and 20 min and that bedtimes were later for Maori and Pacific adolescents (15 and 41 min, respectively). We found a negative correlation between age and sleep duration, and this trend was observed by other authors in the Pacific area [53]. Short sleep durations have been associated with a greater risk of developing overweight/obesity and a significant change in BMIz at all ages [23,73,74]. However, a recent report showed that the relationship between sleep time and weight status should be interpreted with caution, as higher BMI may precede less sleep [75], and thus we do not know if one is the cause of the other or the other way around. In our sample, the association between sleep duration and overweight was only found in the European subgroup, with the odds of being overweight increased by 50% per hour of less sleep. Interestingly, no association was found between sleep duration and weight status in the Melanesian or Polynesian adolescents. These results are in line with observations by Reither et al. [76], in a large survey (N= 30,133) that showed that the relationship between sleep duration and BMI in the U.S. adolescents may differ across ethnicities and genders. They found a negative association between BMI and sleep duration in white, Hispanics and Asian boys; no such association in black boys and white, Hispanic and Asian girls; and a positive association in black girls [76].

Although screen time showed ethnic differences in our study, no correlation between screen time and being overweight was found in the whole sample. Melanesian adolescents seem to have lower screen time than their European counterparts. Moreover, Melanesians with higher screen time were less likely to be overweight than the Europeans, but the magnitude of this association was weak (OR = 0.74). It should be noted that most studies report a positive relationship between TV watching and overweight [77], but we only examined PC/tablet and smartphone screen time in our survey. Concerning computer use/game time, van Erkis found no evidence for a relationship with BMI/BMIz [77]. Moreover, a recent review revealed insufficient evidence of an association between overall screen time or non-television screen time and greater adiposity [78].

In this study, the main factor for overweight was ethnic background, i.e. being Melanesian (OR = 1.67) or Polynesian (OR = 5.40), which makes attractive the hypothesis of a genetic influence. Recent studies about the relationship between the CREBRF gene variant and BMI gain [79–81], indicated that the hypothesis of a thrifty gene should be explored for people of Polynesian background in New Caledonia. The absence of this variant in the Melanesian population of Solomon Islands [81], and the particularity of the gut microbiome in the rural Melanesian population of Papua New Guina [82], suggest another possible mechanism to explain weight gain. The high consumption of the traditional ONENA diet (fruits, vegetables, tubers, fish) of the Melanesian adolescents in this study and a genetic influence [82], might have led to a specific microbiome with higher energy extraction from carbohydrate-rich diets. The modernization of New Caledonia has led to the higher consumption of processed food (fast food and sweets) by Melanesian adolescents, which might then have led to overweight because of this specific microbiome.

Another possible way to explain our results was to consider the physical activity (PA) of the adolescents. It has been shown that low PA may be correlated with overweight in adolescent populations [1,38,40,56]. PA may differ across ethnic subgroups and thus explain the disparities in overweight prevalence. Indeed, relatively low PA was found in New Caledonian Melanesian adolescents [83], with a rural/urban difference [84]. Future investigations are needed in New Caledonia to determine whether PA is lower in Melanesian and Polynesian adolescents compared with their European counterparts.

While our study has strengths, including the anthropometric measurement of all participants, there are limitations to consider when interpreting our findings. First, the data are cross-sectional, and thus no causal relationships could be determined. Due to the size of the sample, the sociodemographic characteristics of the participants might be slightly different from the total school-going adolescent population. Concerning the short FFQ used, social desirability bias may have led overweight adolescents to overreport or underreport food consumption [85]. Moreover, the design of the FFQ did not allow us to determine the total energy intake. This FFQ was also validated in a specific population in Australia, so it may not reflect some of the specificities of the New Caledonian adolescent diet. Also, we did not assess PA, which can have an impact on weight status. Concerning sleep time duration, FFQ and screen use, we obtained self-declarative data and the results should thus be considered with caution. Despite these limitations, this is the first study to examine concomitantly the impacts of sleep duration, screen time and diet on overweight in a pluri-ethnic Pacific population of adolescents.

Conclusion

The prevalence of overweight/obesity is high in New Caledonian adolescents, particularly Polynesian and Melanesian adolescents. Regardless of the potential modifiable behaviours, specific diet interventions targeting adolescents may be useful to prevent obesity in New Caledonia. Interventions to diminish the consumption of fast food and sweets in Melanesian and Polynesian adolescents may also be useful, as would interventions targeting breakfast intake in Polynesian and European adolescents. Although sleep duration was correlated with overweight only in European adolescents, low sleep duration may have other consequences for well-being. Thus, interventions targeting sleep duration may be useful for all adolescents. However, our results are compatible with a genetic influence on weight gain, although research concerning genetic variant and/or microbiome influence remains challenging.

Contributors

SF and OG conceived and designed the experiment. SF and GW analysed the data. SF wrote the original draft. All the authors collected the data and reviewed, edited and approved the final manuscript.

Data sharing statement

The datasets collected during the current study are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2020.100025.

Appendix

Résumé

Contexte: Les adolescents de la Nouvelle Calédonie présente une forte prévalence de l'obésité et du surpoids, comme dans beaucoup de Pays et Territoires des Iles du Pacifique. Bien que l'occidentalisation puisse contribuer à la prise de poids des populations d'ascendance Océanienne, non Européenne et non Asiatique (ONENA), peu de choses sont connues sur les facteurs socio-démographiques et le mode de vie associés au surpoids chez les adolescents mélanésiens et polynésiens de la Nouvelle-Calédonie.

Méthodes: Dans cette étude transversale, un échantillon pluri-ethnique d'adolescents néo-calédoniens (N = 954; âge moyen de 13,2 ans) a participé à une enquête pour estimer le temps de sommeil, le temps d'écran et le régime alimentaire. Des données démographiques (sexe, origine ethnique, statut socio-économique (SSE) et zone de résidence) ont été recueillies et des mesures anthropométriques (taille et poids) ont été utilisées pour déterminer le statut pondéral.

Résultats: Nous avons trouvé un risque plus élevé de surpoids chez les adolescents mélanésiens (OR = 1.67) et polynésiens (OR = 5,40) par rapport aux adolescents d'origine européenne, même après contrôle de l'âge, du statut socio-économique (SSE), de la zone de résidence, du régime alimentaire, de la durée du sommeil et du temps d'écran. Nous avons également constaté qu'un SSE bas (OR = 3.43) et la durée du sommeil (OR = 0.65 par heure) étaient indépendamment associés au surpoids chez les adolescents d'origine européenne mais pas chez les adolescents ONENA.

Interprétation: Dans cette étude, la principale contribution au surpoids reste l'origine ethnique, c'est-à-dire être mélanésien ou polynésien. L'hypothèse d'une influence génétique semble donc séduisante et mérite des analyses complémentaires.

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Editor note: *This translation in French was submitted by the authors and we reproduce it as supplied. It has not been peer reviewed. Our editorial processes have only been applied to the original abstract in English, which should serve as reference for this manuscript.*

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