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Research Article

Relationship Between Ultra-Processed Food Consumption and Cognitive Function among Children Ages 7-11 in Terengganu, Malaysia

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ABSTRACT

This study aimed to examine the correlation between Ultra-Processed Foods (UPF) consumption and cognitive function among school-aged children (7–11 years) in Terengganu. A cross-sectional study (n=200; 53.5% girls; ages: 7–8y 13.0%, 9y 11.0%, 10y 17.0%, 11y 59.0%) was employed. Two non-consecutive 24-h recalls (one weekday, one weekend) were coded and foods classified with NOVA; UPF intake expressed as % of total energy. Cognitive function was assessed with Raven's Coloured Progressive Matrices. Spearman's correlation tested UPF–cognition associations (α=0.05). Mean energy intake was 1,623 kcal/day, approximating 84–101% of Malaysian Recommended Nutrient Intakes (RNI) across ages 7–11. UPFs contributed 26.7% of energy (weekday 25.8%, weekend 27.4%). Mean cognitive score was 105.4±18.7, with 28.5% in the average range. No significant correlation was observed between UPF energy share and cognitive scores (rs=0.065, p=0.361). While moderate UPF consumption did not directly impair cognitive function, this study reveals a compelling narrative about the protective role of traditional diets and parental involvement in shaping children's health and cognitive development.

INTRODUCTION

In recent years, Ultra-Processed Foods (UPFs) have become a dominant trend in global dietary patterns, especially among children. This shift is driven by factors such as urbanization and advancements in food processing technologies, which have increased the availability and marketing of convenient food products. According to Popkin *et al.* (2024), UPFs are frequently seen in modern diets and are created from food extracts with artificial flavors, colors, and preservatives added. These food products are heavily marketed, widely accessible, and often displace traditional diets rich in whole and minimally processed foods. In Malaysia, notably in Terengganu, UPFs appear more frequently in children's meals, driven by affordability and accessibility, with indications of an increasing contribution to daily energy intake (Ali *et al.* 2024). This dietary transition underscores the need to reassess the nutritional quality of children's food and its long-term effects on health and development.

In Malaysian research, UPFs are typically defined using the NOVA framework developed by Monteiro and colleagues (Monteiro *et al.* 2018), which classifies foods according to the extent and purpose of processing. In brief, Group 1 covers unprocessed or minimally processed foods; Group 2 covers processed culinary ingredients derived from Group 1; Group 3 covers processed foods made by adding Group-2 ingredients to Group-1 foods; and Group 4 (UPFs) covers industrial formulations made mostly or entirely from substances derived from foods plus cosmetic additives. In Malaysia, NOVA is not a regulatory labelling system and food manufacturers do not designate NOVA groups on packages; therefore, classification is performed using ingredient lists, standard recipes, and product information.

The nutritional inadequacy of UPFs poses several health risks. These foods are high in unhealthy fats, sugars, and sodium, while being low in essential nutrients such as vitamins, minerals, and fibre. As a result, regular consumption of UPFs compromises dietary quality and has been linked to adverse health outcomes (Delgado-Rodríguez *et al.* 2023). High consumption of UPFs has also been suggested to negatively influence cognitive processes such as memory and learning (Ali *et al.* 2024).

Despite global studies linking UPF consumption to cognitive deficits, research in the Malaysian context remains scarce. For example, Liu *et al.* (2023) reported lower Verbal Comprehension Index (VCI) scores among children in China with high UPF intake. However, there is a lack of localized empirical data in Malaysia, especially in rural regions such as Terengganu. This gap is especially significant considering the increasing penetration of UPFs in local diets, which may exacerbate disparities in child development and education. The Nutrition Research Priorities (NRP) outlined in Malaysia's 12th Development Plan (2021–2025) have emphasized the importance of child nutrition, yet studies examining the link between UPF intake and cognitive development remain limited. This study therefore aims to examine the correlation between ultra-processed food consumption and cognitive function among children aged 7–11 in Terengganu, providing evidence to inform school-based nutrition programs and policy actions that safeguard cognitive as well as physical development.

METHODS

Design, location, and time

This cross-sectional study examined the correlation between UPF consumption and cognitive function among primary-school children aged 7–11 years in Kuala Nerus, Terengganu, Malaysia. This restricted the cohort to ages 7–11 to: 1) capture a single developmental stage corresponding to primary school, and; 2) use Raven's Coloured Progressive Matrices (CPM), which is age-appropriate and feasible for this range. Data were collected between August and September 2024 in Kuala Nerus. Children were eligible if they: 1) were 7–11 years old and enrolled in a primary school in Terengganu; 2) had parental consent and child assent; 3) were free from acute illness on assessment days; 4) were in good general health; 5) had no physical limitations that would interfere with participation or test administration (e.g., significant mobility, vision, or hearing impairment); 6) were not following a restrictive diet during the study period (to reduce dietary confounding); and 7) could understand Malay to ensure clear instructions and reduce response error.

Ethical approval was obtained from UMT Human Ethics committee with reference no. UMT/JKEPM/2024/226. Written informed consent was obtained from parents or guardians before data collection.

Sampling

This study was conducted in Terengganu, Malaysia. From the state's nine districts, this study purposively selected Kuala Nerus because of its varied exposure to ultra-processed foods. Within Kuala Nerus, this study used convenience sampling to recruit eligible children from two community areas; Gong Badak and Bandar Baru Kuala Nerus, through local announcements and coordination with community representatives. Recruitment targeted a reasonable spread across the 7–11-year age range and included both sexes. Assuming a 95% confidence level (Z=1.96), an expected proportion of 0.67 based on prior local evidence, and a precision (margin of error) of ±7%, the minimum required sample was 173 children. Allowing for approximately 10% non-response/attrition increased the minimum to about 190. To provide a safety margin and to simplify recruitment across the two neighbourhoods, this study rounded up to a target of 200 children, which was achieved.

Data collection

The research instrument for this study was divided into three parts which were socio-demographic, diet assessment, and cognitive test. Firstly, socio-demographic was asked in the questionnaire. The parts of socio-demographic that were involved in the questionnaire are gender, age, race, religion, marital status, household income, educational status, occupation, and time consumption.

The diet assessment that contributes to this study is 24-hour diet recall. This tool was suitable among the children to recall what they have consumed in the past 24 hours. 24-hour diet recall is also the method that provides the detailed information that can help in this assessment and to reduce the bias in this method, the caregivers also played the role to cooperate and evaluate what the children consume past 24 hours. In addition, children between 7−11 years old were able to remember what they eat before but sometimes they were unable to remember. To get the accurate data, the 24-hour diet recall were determined on 1 day weekday and 1 day weekend.

The test of cognitive function in children was the Raven test. Raven test was the standardized test that able to measure the cognitive ability among the children. For the children among 7−11 years old, colored progressive matrices is the most suitable test. It was designed for the younger children and it consists of 36 items with colored patterns that can attract the younger children to assess it.

The NOVA classification. The NOVA classification was applied to categorize foods based on their purpose and degree of industrial processing. NOVA divides all food and beverage items into four distinct categories: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and Ultra-Processed Foods (UPFs) (Monteiro *et al.* 2022). Specifically, Group 1 includes unprocessed or minimally processed foods (e.g., fresh fruits, vegetables, rice, milk); Group 2 includes processed culinary ingredients (e.g., salt, sugar, vegetable oils); Group 3 comprises processed foods (e.g., canned vegetables, artisanal bread, cheese); and Group 4 includes UPFs, these are industrial formulations made mostly or entirely from substances extracted from foods or synthesized in laboratories, often containing little or no whole foods. In this study, the categorization of foods into these NOVA groups was carried out using the 24-hour dietary recall data entry using Nutritionist Pro software. Each food item was assigned to a group based on its ingredients, level of processing, and intended purpose. UPF consumption was calculated by determining the total energy contributed by Group 4 items relative to total daily energy intake. This study classified all items from two non-consecutive 24-hour recalls using the NOVA system (Monteiro *et al.* 2022), assigning degrees of processing from ingredient lists, standard recipes, and product information because NOVA is not a regulatory labelling scheme in Malaysia. In response to the common issue of inconsistent or missing standardized home recipes (Asma *et al.* 2019) and to maintain consistent coding of mixed dishes, this study combined Group 1 (unprocessed/minimally processed foods) and Group 2 (processed culinary ingredients) into a single "unprocessed/minimally processed + culinary" category. These two groups are typically used together in traditional meal preparation and can be difficult to disentangle without precise recipe breakdowns. This pragmatic step reduces misclassification while preserving the key contrast of interest between processed foods (Group 3) and ultra-processed foods (Group 4, UPFs). The percentage of total energy intake derived from ultra-processed foods was computed using the formula: UPF Contribution (%)=(Total Energy from UPF's (kcal)/Total Daily Energy Intake (kcal))x100.

It is important to note that UPF intake in this study was measured based on its contribution to energy intake (kcal/day). The analytic export from the dietary software provided energy totals by NOVA group but did not retain aggregated gram weights by group; therefore, a grams-per-day summary could not be reported. While this study assessed UPF intake based on energy contribution (kcal/day), which is a commonly accepted method in nutritional epidemiology, it is acknowledged that measuring UPF in g/day can offer additional insight, particularly in capturing volume-based consumption. Given the study's focus on caloric adequacy and nutrient contribution in a population of school-aged children, the kcal-based approach was considered appropriate and aligned with the study objectives.

The principle of the Goldberg method cut off points. The application of the Goldberg method involves several key components which were Basal Metabolic Rate (BMR), Physical Activity Level (PAL), and cut off points. Basal metabolic rate is estimated through predictive equations such as Schofield or Harris-Benedict equations, which account for factors like age, gender, weight, and height. Then, physical activity represents the ratio of Total Energy Expenditure (TEE) to BMR. It accounts for energy expended using physical activity and the various based on an individual's lifestyle and activity level. According to RNI, for children aged 7 to 11 years, a PAL value of 1.6 is commonly used to represent moderate activity levels. The cut-off points are established based on the ratio of EIrep to BMRest, adjusted for the expected range of TEE. For children, these cut-off points are typically defined as <1.2 classified under-reporting, 1.2–2.4 was normal, and >2.4 was over-reporting. In this study, dietary intake data from 200 respondents aged 7 to 11 years were analyzed using the Goldberg method. The method categorized the respondents into three groups (under-reporting, normal and over-reporting) based on their energy intake reporting.

The cognitive function assessment. The final section of the assessment focuses on cognitive evaluation using Raven's Coloured Progressive Matrices (CPM), a widely recognized non-verbal intelligence test designed to measure cognitive performance. The test comprises 36 questions, divided into three sets (A, AB, and B), each containing 12 items arranged in increasing difficulty. Each question presents an incomplete drawing, and the respondent must select the correct missing piece from six possible options. Scoring is straightforward: one point is awarded for each correct response, while incorrect answers receive zero points. Each respondent's raw score is then compared to a standardized reference table, which determines their percentile rank relative to their biological age. The total score for the three sets of puzzles will be calculated by summing up the points that were earned from the three sets of puzzles. The standard score was then divided into three categories: average (90–109), "high average/superior/very superior" (above 109), and "extremely low/borderline/low average" (below 90) (Mok & Tung 2022).

Data analysis

The socio-demographic data were analyzed using frequencies and percentages. Normality of the data was assessed with the Kolmogorov-Smirnov Normality Test. Numerical variables were described either by the mean and standard deviation or by the median and interquartile range, depending on the distribution of the data. All data were organized in Microsoft Excel and analyzed using the Statistical Package for Social Sciences (SPSS) version 30.0. To assess the relationship between ultra-processed food consumption and cognitive function, both Spearman's and Pearson's correlation tests were employed. If the data met the assumption of normality, Pearson's correlation was used, whereas Spearman's correlation was applied for non-normally distributed data, as it provides a more accurate measure in such cases. A significance level of $p<0.05$ was set for all statistical tests.

RESULTS AND DISCUSSION

Sociodemographic characteristics

A total of 200 children aged 7−11 years were involved in the study. Table 1 shows the demographic characteristics of the respondents.

The majority of the respondents were aged 11 years (59%), followed by 10 years (17%), 9 years (11%), and smaller proportions aged 7 and 8 years (6.5% each). In terms of gender, girls slightly outnumbered boys, accounting for 53.5% of the participants compared to 46.5% boys. All participants were Malay, reflecting the cultural homogeneity of the Terengganu population. This uniformity ensures consistency in cultural and dietary habits but limits the generalizability of the findings to other ethnic groups in Malaysia. Parental education levels revealed a well-educated cohort, with 55.5% of fathers and 53% of mothers holding at least a diploma, bachelor's degree, or higher. Secondary school education was the next most common attainment, with 38.5% of fathers and 40% of mothers having completed this level.

Fathers were predominantly employed in the private sector (42%), followed by government roles (36%), with smaller proportions engaged in business (6.5%) or other occupations (15.5%). Mothers, on the other hand, were more likely to work in government positions (43.5%) or serve as homemakers (35%). Fewer mothers were employed in the private sector (12.5%) or business activities (9%).

Household income levels indicated socioeconomic diversity within the sample. A significant proportion of families (40%) earned less than RM4,849 per month, placing them in the lower-income bracket. Around 38% reported incomes between RM4,850 and RM10,959, while 22% earned above RM10,960.

The distribution of siblings revealed that most participants came from families with three (28%) or four (29.5%) siblings. Larger families with six or more siblings were less common, accounting for 16% of the sample. Family size trends offer valuable insights into household dynamics, including resource allocation and dietary practices.

Dietary accuracy evaluation

The analysis revealed that 41.5% of respondents under-reported their energy intake, highlighting a significant prevalence of inaccuracies. Notably, 52.5% of respondents fell

Table 1. Demographic characteristics of respondents

Characteristic	n (%) (n=200)
Age (years)	
7	13 (6.5)
8	13 (6.5)
9	22 (11.0)
10	34 (17.0)
11	118 (59.0)
Gender	
Boy	93 (46.5)
Girl	107 (53.5)
Ethnicity	
Malay	200 (100)
Chinese	0 (0.0)
Indian	0 (0.0)
Others	0 (0.0
Educational level of father	
No education	0 (0.0)
Primary school	0 (0.0)
Secondary school	77 (38.5)
STPM/Matriculation/A-level	9 (4.5)
Diploma/Bachelor/Master/PhD	111 (55.5)
Other	3 (1.5)
Educational level of mother	
No education	0 (0.0)
Primary school	0 (0.0)
Secondary school	80 (40.0)
STPM/Matriculation/A-level	14 (7.0)
Diploma/Bachelor/Master/PhD	106 (53.0)
Other	0 (0.0)
Occupation of father	
Government employment	72 (36.0)
Private	84 (42.0)
Business	13 (6.5)
Others	31 (15.5)
Occupation of mother	
Government employment	87 (43.5)
Private	25 (12.5)
Business	18 (9.0)
Others	70 (35.0)
Household Income (RM)	
Less than RM4,849	80 (40.0)
RM4,850–RM10,959	76 (38.0)
RM10,960 and above	44 (22.0)
Siblings	
1	6 (3.0)
2	19 (9.5)
3	56 (28.0)
4	59 (29.5)
5	28 (14.0)
6	13 (6.5)
7	13 (6.5)
8	4 (2.0)
9	2 (1.0)

STPM: Sijil Tinggi Persekolahan Malaysia; RM: Ringgit Malaysia

within the normal reporting range, representing the most reliable subset for evaluating energy and nutrient intake. A smaller group (6.0%) over-reported their energy intake, likely due to portion-size misestimations, overestimation of food consumption, or a desire to appear health-conscious. While under-reporting was the most prevalent issue, it underscores the complexity of dietary assessments, particularly among children, who often rely on caregivers for reporting or have limited understanding of portion sizes. As Schnermann *et al.* (2024) noted, even as children grow older, many continue to struggle with estimating appropriate quantities, further complicating dietary data accuracy. Primary analyses retained all recall records to characterise energy and nutrient intake comprehensively, in line with guidance from Mirnalini *et al.* (2008). This approach avoids selection bias associated with excluding under- or over-reporters and captures the full spectrum of dietary behaviours in the cohort.

Total energy intake and UPF consumption

The mean total energy intake on weekdays was 1,678 kcal (±885), indicating slightly higher caloric consumption during the structured school week. This could be attributed to more regular meal patterns, including school-provided lunches and a more organized schedule. On weekends, the mean total energy intake was 1,567 kcal (±749), reflecting a decrease compared to weekdays. This reduction may result from less structured meal times and greater variability in eating habits, influenced by weekend routines and lifestyle (Table 2).

The weekly average total energy intake was 1,623 kcal (±819), falling within the Recommended Nutrient Intake (RNI) for Malaysian children aged 7–11 years. According to the RNI, daily caloric needs for children in this age group range from 1,610 to 1,930 kcal, depending on factors such as activity level,

Table 2. Total energy intake for weekday, weekend, and weekly average for 7–11-year-old subjects

Days	Total energy intake (kcal) mean±SD/Median (IQR) (n=200)
Weekday	1,678 (885)
Weekend	1,567 (749)
Weekly average	1,623 (819)

SD: Standard Deviation

growth requirements, and individual metabolic differences. These results suggest that, on average, the children in the study met their basic energy requirements.

The variation in caloric intake between Table 3 summarises ultra-processed food intake from NOVA Group 4 only (expressed as percentage of total energy and as kilocalories) for weekday, weekend, and weekly average. The analysis of UPF consumption revealed an average contribution of 26.7% to total caloric intake. This figure is lower compared to urban areas and other countries, where UPF consumption is significantly higher. For instance, Yang *et al.* (2023) found that 33% of energy intake among children in Kuala Lumpur originated from UPFs, while Carroll *et al.* (2024) reported figures as high as 67.6% in the United States. The relatively lower UPF consumption in Terengganu may reflect differences in food availability, cultural preferences, and awareness of healthy eating practices. This disparity may stem from traditional dietary practices in rural areas, which prioritize fresh, home-cooked meals. Additionally, cultural preferences and parental awareness play crucial roles in shaping children's dietary habits. For instance, higher parental education levels are associated with healthier dietary choices for children (Rodoman *et al.* 2024).

The study underscores the adverse health effects of UPFs, which are high in sugar, unhealthy fats, and sodium while lacking essential nutrients such as fiber, potassium, and vitamins. Excessive UPF consumption has been linked to obesity, cardiovascular issues, and poor cognitive development (Chadha *et al.* 2024). Although Terengganu shows relatively low UPF consumption, socioeconomic factors and urbanization trends could influence dietary patterns over time. Socioeconomic and cultural factors significantly influence dietary patterns and caloric intake distribution. In Terengganu, traditional home-cooked meals still dominate weekday dietary habits, particularly for school-going children. However, the growing consumption of snacks, fast food, and convenience foods during weekends and celebrations has contributed to dietary shifts. The excessive sodium, unhealthy fats, and refined carbohydrates found in these processed foods are major contributors to obesity and other health problems (Santos *et al.* 2024). When comparing energy intake levels between rural areas like Terengganu and urban populations such as Kuala Lumpur, lower caloric intake was observed in Terengganu. Urban populations generally report higher caloric intakes, attributed to greater access to fast food outlets and packaged snacks. Conversely, rural areas like Terengganu rely more on home-prepared meals. This disparity highlights the influence of lifestyle, physical activity, and dietary preferences. According to the Malaysian Healthy Eating Index, children experiencing food insecurity consume substantially less energy and nutrients compared to their peers (Tay *et al.* 2023). Although the average energy intake in Terengganu aligns with recommended guidelines, the balance of macronutrients requires further evaluation. A healthy distribution of carbohydrates, proteins, and fats is essential for supporting growth and cognitive function. Complex carbohydrates, such as whole grains, are critical for sustained energy and enhanced cognitive performance. Future research should investigate macronutrient distribution to ensure optimal dietary quality.

Table 3. Percentage of ultra-processed food consumption (NOVA Group 4) for weekdays, weekends, and weekly average for 7–11-year-old subjects

% UPF consumption	% of UPF	Intake of UPF (kcal) mean±SD/Median (IQR) (n=200)
Weekday	25.8	433 (432.7)
Weekend	27.4	430 (430.7)
Weekley average	26.7	431 (324.9)

SD: Standard Deviation; UPF: Ultra-Processed Foods

Efforts to reduce UPF consumption must address not only the availability of healthier alternatives but also the cultural and economic barriers influencing dietary choices. Public health campaigns, like those highlighted by Mescolotto *et al.* (2024), have proven effective in raising awareness about the risks associated with UPFs. To address these challenges, schools must play a pivotal role in promoting healthier eating habits. Incorporating nutrition education into the curriculum and providing balanced meals can significantly improve dietary quality. Policies restricting the sale of processed snacks and sugary drinks in school canteens are essential. Parents should be encouraged to model healthy eating behaviors and involve children in meal preparation to foster positive attitudes towards nutritious food.

Cognitive function

Table 4 summarises the distribution of Raven's scores. The mean cognitive score was 105.4±18.7. Most respondents scored average to superior: average (28.5%), high average (26.0%), and superior (27.0%), together 81.5% of the sample. A smaller proportion fell below the normative mean: low average (5.5%), borderline (5.0%), and extremely low (6.0%), making 16.5% in total. Only 4 (2.0%) were very superior. Overall, the distribution indicates generally adequate non-verbal cognitive performance in this cohort, while the lower-performing subgroup (≤ low average) warrants focused support.

The distribution of cognitive scores observed in this study aligns with findings from prior research. For instance, Wei and Ali (2018) reported that 94% of children in their study exhibited average cognitive function. In contrast to settings reporting a higher prevalence of low scores (e.g., 34% poor non-verbal IQ in Thailand; Sandjaja *et al.* 2013), only 16.5% of our participants were ≤ low average (low average 5.5%, borderline 5.0%, extremely low 6.0%). Differences across studies may reflect sampling frames, urban–rural mix, test versions and norms, assessment timing, or contextual determinants such as parental education, household income and nutrition access. Even so, the lower-performing subgroup in our sample warrants targeted academic and health supports.

Numerous studies emphasize the link between dietary habits and cognitive development. Several pathways could link UPF-rich patterns to child brain function. First, meals dominated by refined starches and added sugars can trigger rapid glycaemic swings, which are associated with short-term decrements in attention and working memory in children (He *et al.* 2018). Second, diets high in saturated/trans-fat and heat-derived compounds (advanced glycation end-products) promote systemic inflammation and oxidative stress, processes that may impair synaptic plasticity and hippocampal-dependent learning (D'Cunha *et al.* 2022). Third, selected food additives including emulsifiers, non-nutritive sweeteners and certain colourants, and excess sodium have been implicated in gut-microbiome perturbation and altered gut–brain signalling (Song *et al.* 2023). Fourth, UPFs can displace essential nutrients; omega-3 fatty acids, iron, zinc and B-vitamins, needed for membrane integrity, myelination and neurotransmitter synthesis (Gould *et al.* 2013). Finally, the hyper-palatable sensory profile and marketing of UPFs engage neural reward circuitry and can undermine executive control over food choice in youth (Via & Contreras-Rodríguez 2023). In our sample, UPF contributed a moderate share of energy and intakes often occurred within traditional mixed meals, factors that may attenuate these pathways, consistent with the absence of a detectable correlation between UPF energy share and non-verbal cognitive scores in this cohort (Liu *et al.* 2022; Peña-Jorquera *et al.* 2024).

Table 4. Cognitive function categorized by grades

Raven's test	n (%)
Average cognitive score (mean±SD)	105.4±18.7
Category of academic performance	
Extremely low (<70)	12 (6.0)
Borderline (70–79)	10 (5.0)
Low average (80–89)	11 (5.5)
Average (90–109)	57 (28.5)
High Average (110–119)	52 (26.0)
Superior (120–130)	54 (27.0)
Very Superior (>135)	4 (2.0)

SD: Standard Deviation

The relationship between UPF consumption and cognitive function

The findings indicate no statistically significant correlation between UPF consumption and cognitive scores (r=0.065, p=0.361). These results suggest that UPF consumption, as a standalone factor, does not substantially influence cognitive development within this population.

One possible reason for this finding is the relatively low UPF consumption (24.5%) in this population compared to other studies, such as 33% in Kuala Lumpur (Yang *et al.* 2023) and 67.6% in the U.S. (Carroll *et al.* 2024). The type of UPFs consumed in Terengganu may also differ, with rural children having more access to minimally processed items like bread and dairy rather than highly processed snacks common in urban settings.

Additionally, short-term UPF exposure may not be sufficient to show cognitive effects, as dietary-related cognitive impairments often develop over time. Future longitudinal studies are needed to assess the long-term impact of UPFs on cognitive function. While this study primarily focuses on the relationship between UPF consumption and cognitive function, it is important to acknowledge that UPFs are typically low in essential micronutrients, including vitamins (such as vitamin A, vitamin C, and folate) and minerals (such as iron, zinc, and calcium). Cognition in school-aged children hinges on key micronutrients. Iron underpins myelination, mitochondrial metabolism, and monoamine synthesis; deficiency is linked to weaker attention, memory and school performance (Gutema *et al.* 2023). Zinc supports neurogenesis, synaptogenesis; low status has been associated with deficits in attention/psychomotor function (Ben-Mimouna *et al.* 2018; Warthon-Medina *et al.* 2015). Folate with vitamins B12/B6 drives one-carbon metabolism and DNA methylation; poor status (and raised homocysteine) relates to weaker memory/attention, while repletion can benefit deficient groups (Kennedy 2016). Vitamin C acts as antioxidant and catecholamine cofactor; higher status associates with better cognitive performance (Travica *et al.* 2017). Vitamin A (retinoic acid) regulates gene expression and plasticity; deficiency impairs learning/memory in experimental models (Li *et al.* 2025). Calcium signalling is central to neurotransmitter release and long-term potentiation; disturbances impair memory processes (Valdés-Undurraga *et al.* 2023). Because ultra-processed foods often displace these nutrients, UPF-heavy patterns may affect cognition via nutrient dilution alongside glycaemic, inflammatory, and gut–brain pathways (Granero & Guillazo-Blanch 2025). Diets dominated by UPFs may therefore contribute to hidden hunger and long-term health risks. A more detailed analysis of micronutrient profiles in UPFs will be explored in future research.

Despite the presence of UPFs in children's diets, many still consume nutrient-rich traditional meals, which may counteract potential negative effects. Essential nutrients like iron, zinc, and omega-3 fatty acids support brain development and may protect against cognitive decline (Fu *et al.* 2024).

CONCLUSION

This study revealed that Ultra-Processed Food (UPF) consumption constitutes a significant but relatively low proportion of children's diets in Terengganu. Among the 200 respondents, cognitive function was predominantly within the average range, with a small subset achieving "very superior" cognitive performance. Importantly, no statistically significant correlation was found between UPF consumption and cognitive scores, highlighting that other factors, such as lifestyle, cultural practices, and broader dietary patterns, may play more influential roles.

These findings underscore the critical importance of raising awareness among parents and caregivers about the role of balanced nutrition in supporting cognitive development and overall health. Effective nutrition education programs and community-level interventions can foster healthier dietary habits and mitigate potential risks associated with UPF consumption.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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