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LITERATURE REVIEW
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Ultra-Processed Food can be a Mediator Between Food Security Status and Overweight or Obesity among Adults: A Literature Review

Makanan Ultra-Proses Berperan sebagai Mediator Hubungan Ketahanan Pangan dengan Status Kelebihan Gizi atau Obesitas pada Dewasa: Literature Review

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ABSTRACT

Background: The ultra-processed food (UPF) contributed 20-85% of total daily calories. The consumption of UPF can be triggered by food security status. Many studies revealed that UPF consumption has a direct negative impact on health, mainly in overweight and obesity.
Objectives: To review published studies assessing food security, UPF consumption, and overweight or obesity and find the possible links between those three factors.
Methods: A literature review of scientific articles about food security, UPF consumption, and overweight or obesity, selected systematically according to the PRISMA Diagram. All articles were gathered through medical search engines, including PubMed, ScienceDirect, and Scopus, from December 2021 to February 2022. The bias risk of each selected paper was assessed using the checklist from The Joanna Briggs Institute (JBI) Critical Appraisal. Peer review and group discussions were performed to assess the quality of all articles gathered as objectively as possible using the STROBE Checklist. A narrative synthesis approach was opted to unify all findings across included studies systematically.
Results: Nineteen (19) scientific published papers were filtered. The association between food security status and UPF consumption showed inconsistent findings. However, UPF consumption revealed a consistent association with overweight/obesity, where the higher the UPF intake, the greater odds of being overweight/obese. The relationship between food security status and overweight or obesity tended to have a similar pattern. In high-income countries, the association was negative (the more food insecure, the higher overweight or obesity), while in low- and middle-income countries showed the opposite. The pathway could be: (1) food-insecure adults have higher UPF intake, hence gaining body weight, or (2) food-secure adults have higher UPF intake, hence gaining body weight.
Conclusions: UPF consumption is indicated as a potential mediator for food security status and nutritional status (overweight/obesity) through two pathways involving socio-demographic factors, psychological factors, social protections, and food choice motives.

INTRODUCTION

Obesity has become a global epidemic over the four decades. The prevalence surged up to 40% among adults worldwide, according to the Nutrition Global Report 2020[1]. Other than that, overweight also enormously risen, estimated to be experienced by 1,9 billion adults in developed and developing countries[1,2]. The report also mentioned that in countries with high- and upper-middle-income, obesity prevalence among adults surges up to five times than in lower-middle- and low-income countries[1] as one of the countries with a lower-middle income, over-nutrition prevalence in Indonesia was 13.6% for overweight and 21.8% for obesity in 2017, which accounted for Indonesia's 4th highest prevalence in Southeast Asia Region[2,3].

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Overweight and obesity (overnutrition) surged mainly due to the high consumption of energy-dense food such as ultra-processed food (UPF) and less physical activity[4]. Beyond those two direct factors, overnutrition is triggered by a long-haul process. Globalization, indicated by trade liberalization, massive urbanization, and economic development, shaped the modern food environment[5]. It is characterized by the raised commercial food industry and caused Western supermarkets to be highly available and accessible[5,6]. These modern food environments shifted the dietary pattern from traditional diets high in nutrients toward Western-pattern diets, which tend to be energy-dense foods containing excessive sugar and saturated- and trans-fat [6,7]. The energy-dense foods are generally known as ultra-processed food (UPF), which is commonly made from fresh foods with addictive substances and preservation methods and processed with advanced manufacturing technology to improve sensory characteristics, shelf-life, and selling power[8]. Some examples of UPF products are instant noodles, savory snacks, biscuits and crackers, cake, sugared-sweet beverages (SSB), chips, mass-packaged bread, candy, chocolate, ice cream, fast food, and ready-to-heat or-eat products[7].

In response to the mass marketing and consumption of UPF products, Monteiro et al. (2019) developed the newest system for precisely identifying the food based on their process, especially UPF, namely the NOVA food classification system[7]. The FAO endorses the NOVA (not an acronym) as the most suitable tool to identify UPF consumption in a population[7]. The NOVA subsumes all foods into four classes: unprocessed or minimally processed food (MPF, 1st class), processed culinary ingredients (PCI, 2nd class), processed food (PF, 3rd class), and ultra-processed food (UPF, 4th class)[7]. Examples and other details are available in Appendix 1.

As the nutrition transition is still taking place in developing and developed countries, many studies found negative consequences of UPF consumption on human health outcomes using the NOVA, including overweight and obesity, type 2 diabetes, hypertension, cardiovascular diseases, and cancer[9,10]. Some research performed in developing countries, mainly in urban areas, revealed that the adult population consumed UPF products 20-40% of total calorie intake, mainly from instant noodles, junk food, and sugar-sweetened beverages [8,11,12]. A previous study conducted in Indonesia found that UPF contributed around 16% of total daily calories, while added sugar proportion obtained from these foods was poorly excessive, 23.3% of total daily calories[12,13]. That being said, the WHO recommends limiting added sugar consumption to <10% of total daily calorie intake to reduce the risk of obesity and metabolic diseases[7]. Other findings reported that consumption of UPF was greater in high-income countries, which accounted for daily energy contribution 33 up to 85%[14–17].

The factors that drive high calories contribution from UPF are environmental factors, such as food supply chains (production, storage and distribution, and retail and market) and food security at the community level (accessibility, availability, and purchasing power), and individual factors, including socioeconomic status, food choice motives, and household or individual food security status[18,19]. Some studies found that food security status could affect the energy intake from UPF due to the consideration of preferences, price, and practical reasons[6,20,21]. For instance, households experiencing food insecurity consume more nutritious food since they have the good purchasing power to opt for healthy and nutritious foods that tend to be costly. Meanwhile, food-insecure households have less purchasing power, causing them more likely to choose cheap and satiating dishes, such as UPF.

Regarding many previous studies mentioned above, the high UPF consumption can be driven by food security status and eventually cause a negative impact on nutritional status, which raises overweight and obesity prevalence[22–24] considering that UPF consumption can potentially be a mediator factor in food security status that determines the food assurance in households or individuals towards the substantial prevalence of overweight and obesity. Therefore, we aim to review published studies assessing food security, UPF consumption, and overweight or obesity and find the possible links between those three factors.

METHODS

Article Selection Process and Criteria

A literature review method was adopted, while published scientific papers were elected following the flow of the PRISMA diagram (Preferred Reporting Item for Systematic Review and Meta-analysis), described in Figure 1. The following keywords and Boolean operators according to the Medical Subject Heading (MeSH), (food security or food insecurity) and (ultra process* or ultra-process* or ultra process*) and (overweight or obese or obesity), were used to search the data using the three search engines involving PubMed, ScienceDirect, and Scopus. The period of the publications was for ten years, from January 2012 to January 2022, to conform to the latest findings. However, articles published before 2012 were also included in the screening process to review their eligibility. The set of data was gathered from December 2021 to February 2022. Despite the three search engines, PROSPERO was also delved into to anticipate the same literature review existed. Publications were selected by the article's title and abstract, continued by the article's full text following the inclusion and exclusion criteria provided in Table 1.

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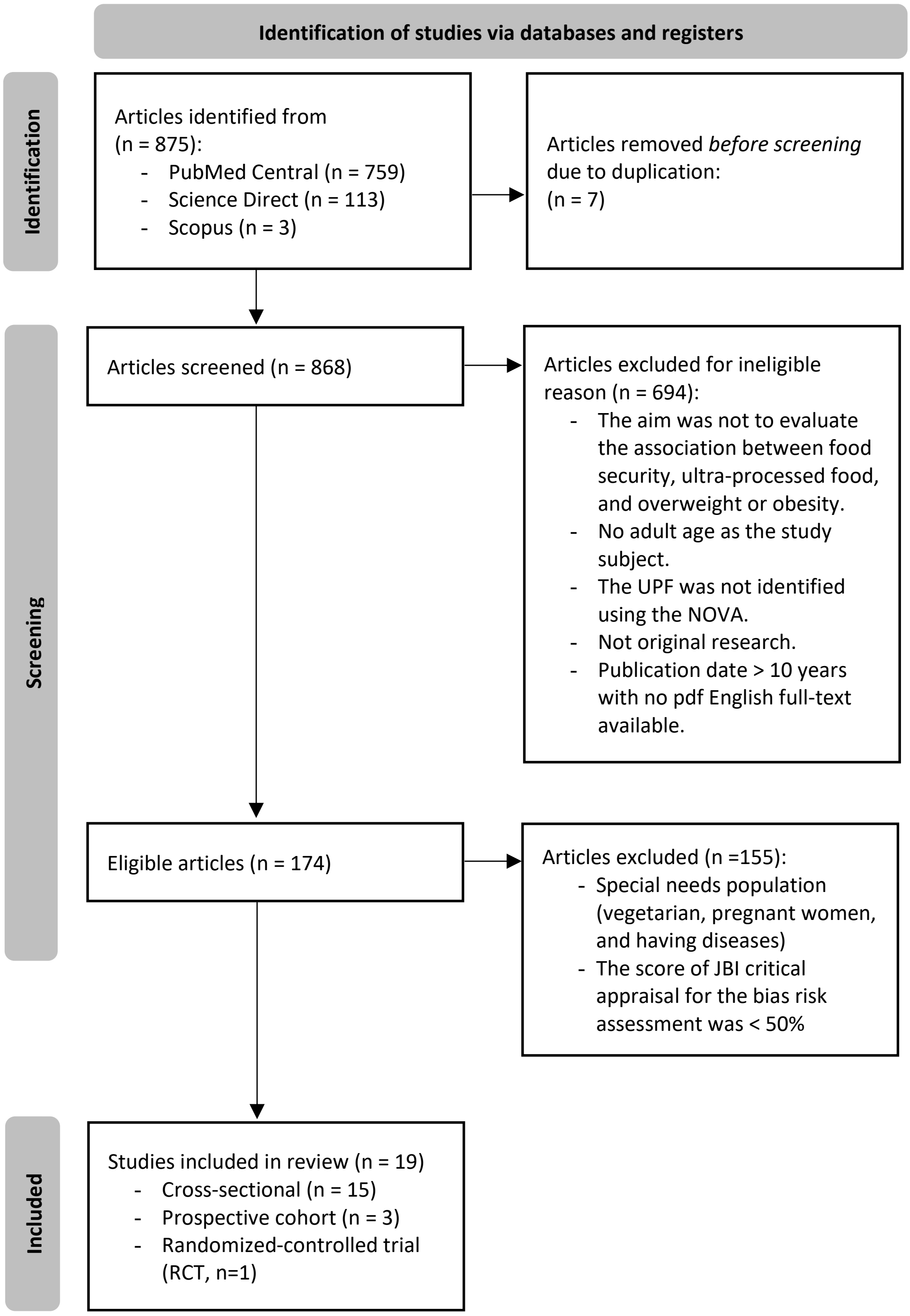

Figure 1. Flowchart of article screening process using PRISMA diagram

The food classification system of NOVA defines and categorizes the food depending on its nature and extent of industrial processing, namely MPF, PCI, PF, and UPF. The details of how the food was categorized using the NOVA were described in Appendix 1. The use of the NOVA to identify UPF, as mentioned by Monteiro et al. (2019)[7], since UPF was tricky to identify and tended to be misclassified, needs to be precisely assessed. In response to that issue, the NOVA came up as the most applicable method to examine the food depending on the processing degree and related components that should be limited-consumed, such as sugar, oils, and salt.

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Table 1. Inclusion and exclusion criteria of the scientific articles' screening

	Criteria
Inclusion criteria	• The article aimed to appraise the association between: a. Food security and UPF consumption; or b. UPF consumption and overweight or obesity; or c. Food security and overweight or obesity. • An adult over 18 years of age, except when the studies involved all age groups in any country and ethnicity. • Ultra-processed food in this review was identified and classified using the NOVA food classification system, which was detailed in Appendix 1. • Original research published in a peer-reviewed journal from 2012 to 2022, with English full-text available.
Exclusion criteria	• Involving special needs subjects from the adult population, for instance, athletes, vegetarians, and pregnant or lactating women. • The score bias risk of critical appraisal was < 50%, assessed using the Joanna Briggs Institute (JBI).

Data Extraction and Bias Risk Assessment

As shown in Figure 1, 875 published papers were obtained from the three search engines. All articles (n = 875) were recorded to Mendeley Desktop version 1.19.8, and duplicates were then checked and removed. The 868 remaining articles were screened to assess their eligibility based on the inclusion criteria, resulting in 174 articles being left. In sequence, 155 articles were excluded for some reasons mentioned in Figure 1. In the end, 19 articles were proposed to be reviewed in the paper. All papers involved in the review were evaluated for their quality, including the bias risk using the checklist from The Joanna Briggs Institute (JBI) Critical Appraisal for the analytical cross-sectional study (8 criteria should comply), cohort studies (11 criteria should comply), and randomized controlled trial (RCT) (13 criteria should comply). The minimum score for the paper that could be included in this review was 50%. Resource persons who were in charge of performing the assessment were two reviewers who worked independently.

Data Synthesis

This review was focused on three parts. The first part elucidated a mechanism of food security and its effect on UPF consumption. The second part explained UPF consumption and its impact on overweight and obesity. The third part elaborated on mechanisms of UPF consumption as a mediator that potentially affects food security status for overweight and obesity. Considering the limited number of studies involved in this review yet using various study designs, no quantitative meta-analysis was conducted. Therefore, a narrative synthesis approach was opted to unify all findings across included studies systematically. Study characteristics were later classified according to the three different aims.

The study characteristics are as follows: author, date of publication, study design, the country where the study was conducted, period of study, sample size and population, food security status (the tool used), UPF exposure (the dietary method used), and overweight or obesity (definition and data collection). The 19 articles were then organized into three sections based on the specified aim of the study, as follows: (1) three articles focused on investigating food security and its association with UPF consumption, (2) three articles explained food security to overweight or obesity, and (3) 13 articles aimed to evaluate the role of UPF consumption in overweight or obesity. Peer review and group discussions were then performed to assess the quality of all articles gathered as objectively as possible using the STROBE Checklist for cross-sectional, cohort, and RCT.

RESULTS AND DISCUSSIONS

All scientific papers were displayed in Tables 2, 3, and 4. Table 2 provides the study findings investigating the association between food security and intake of UPF. Out of three, two studies were performed in Brazil, and one was conducted in Canada. All studies were survey studies using a cross-sectional design. The main findings showed three different patterns. First, food insecurity did not influence UPF intake. Examining the connection between food insecurity and UPF consumption is relevant and modifiable, depending on the subject's characteristics and food environments around their living area, especially accessibility and quality of the food offered[20]. Second, the more severe food insecurity, the less energy contribution from UPF ($p < 0.001$). The possible reason is the economic restriction, causing food insecure households to have limited access to all foods, including fresh foods and UPF[21]. It has also been mentioned that food-insecure households tend to consume more regional food or available food harvested from their cultivation in the backyard field, such as fruits and vegetables. This condition causes on reducing to purchase of UPF from the market[21]. Third, the more severe food insecurity, the higher energy contribution from UPF ($p = 0.002$ in children 1-8 years, 0.049 in children 9-18 years, 0.003 in women, and 0.009 in men). Financial constraint still becomes a main possible factor regarding that finding. In some dwelling areas, healthy food often is more costly, less accessible, and rarely available in food-insecure households[23,25]. In contrast, instant and fast food categorized as UPF offer more affordable prices, marketed using fascinating advertisements and promo[6]. That being said, unhealthy food environments and financial constraints affect food-insecure urban households who prefer healthier foods such as UPF[25].

Table 3 provides 13 published articles evaluating the effect of UPF consumption on overweight and/or obesity, carried out in the United Kingdom (2

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papers), Brazil (2 papers), Spain (1 paper), French (2 papers), United States (2 papers), Canada (1 paper), Malaysia (1 paper), Australia (1 paper), and South Korea (1 paper). Out of 13, three studies used a study design prospective cohort, one study used RCT, and the remaining nine studies used a cross-sectional design. There were two points of the main findings: (1) energy intake from UPF consumption did not affect overweight or obesity, and (2) calorie from UPF was linked to overweight or obesity, in which the higher UPF consumption, the greater risk for overweight or obesity. The odds ratio (OR) or hazard ratio (HR) of overweight was varied, ranging from 1.11 (95%IC 1.08–1.14) to 1.48 (95%IC 1.25–1.76), and obesity ranged from 1.09 (95%IC 1.05–1.13) to 1.98 (95%IC 1.26–3.12).

Table 4 shows three publications evaluating the impact of food security status on the households or individuals' level of nutritional status, including overweight or obesity. All studies used a cross-sectional design and were conducted in Vietnam (1 paper), Lebanon (1 paper), and the Netherlands (1 paper). The main finding was that adults who experienced food insecurity had greater odds for overweight or obese than adults who experienced food security (OR ranging from 1.73–2.49). The connection between those two variables is somehow affected by covariates or mediators that should be adjusted, such as socioeconomic status, living conditions, and diet quality[26,27]

Consumption of UPF and Its Impact on Overweight or Obesity

Both overweight and obesity, as reported by the WHO, have been determined as the leading risk factor for metabolic diseases such as hypertension, dyslipidemia, diabetes mellitus (type 2), cardiovascular diseases, and cancer[28]. A narrative review and some systematic reviews also found a consistent finding where energy contribution from UPF is associated with overweight or obesity and NCDs such as cardiovascular and coronary heart diseases, cerebrovascular diseases, hypertension, and metabolic syndrome[14–17]. Nevertheless, the articles were derived from observational studies, which could not explain the plausible mechanism. However, UPF determined by the NOVA was considered a scientific concept to evaluate the foods within the 'healthiness' context, including dietary pattern and its determination of dietary quality and quantity[7].

Several possible mechanisms have been observed to assess the impact of UPF consumption on overweight or obesity[29,30]. The first possible mechanism is the characteristics of UPF products which are usually accompanied by a greater intake of salt and calories, notably from trans- and saturated fats and sugars, whereas a low intake of micro-nutrients and fiber[29]. Those additive substances that accounted for UPF had more palatability to be consumed more frequently, even in a larger portion[31]. In sub-sequence, consumption of UPF in a high portion will automatically increase energy intake and lead to obesity and the development of NCDs[29–32]. The second potential mechanism was onto a biochemical pathway involving the food additives commonly used in UPF, such as emulsifiers, monosodium glutamate, and food coloring[30]. These led to intestinal mucus barrier disruption, producing chronic inflammation and resulting in metabolic syndrome[29,30]. Consuming a modern Western diet (vs. traditional diet), indicated by more processed foods and UPF, might also increase food additives consumption, transform the diverse combination of bacteria in the intestine, and result in a more dysfunctional metabolic status[29,32].

Food Security Status and the Effect on Overweight or Obesity

The food insecurity effect on overweight or obesity can be explained through various complex pathways. A systematic review explained the potential pathways between low food security and obesity[22]. The review assumed that food-secure adults had a good dietary intake (quality and quantity). Hence, the focus was on food-insecure adults. The first pathway is about the main reason for the high consumption of PF, and UPF was determined by the economic accessibility of the foods[22]. The study revealed a positive association between low food security and obesity, which more probably occurs in the settings where commercial PF and UPF were low-cost[22]. Those foods were consumed more by low food secure individuals if they were cheaper and more satiating than fresh and nutritious foods in local markets or including food aid. Thus, low food security can be a risk factor for over-nutrition.

The second pathway explained the two pathways proposed quantities and diversity of food consumption linked to obesity in low food-secure individuals[22]. One, changes in diet diversity led to weight gain since the low food-secure individuals were likely to substitute nutritious, relatively costly, with cheaper and energy-dense foods that were more satiating. The linear association also showed that the dietary diversity score decreased as food security worsened. Second, because of variations in eating patterns, individuals with low food security might experience metabolic adaptations, leading to higher body fat[22].

The third pathway explained inter-personal food choice and distribution[22]. The high demand for energy-dense foods triggered the massive distribution of PF and UPF in the market. It shaped an obesogenic environment and over consumption of energy. However, a negative association showed between low food security and obesity, especially among adults who were relatively "conservative" and defended consuming traditional foods (fresh foods)[22]. It resulted in lower consumption proportions of the PF and UPF. The last pathway is a less physical activity which might contribute to the positive association between low food security and obesity[22]. It might be due to low food security individuals spending less time doing physical activities in their leisure time.

Table 2. Original articles assessing food security status as an exposure and Ultra-Processed Food (UPF) consumption as an outcome

First Author, Year	Design of the Study	Country	Sample Size, Population	Exposure Measure	Outcome	Main Finding
de Araujo, 2018	Cross-sectional	Brazil	2,817 adults≥ 20 years	Brazil Food Insecurity Scale (EBIA)	UPF consumption in daily and weekly	There was no effect of food insecurity on the consumption of UPF, even after being adjusted by confounders. Food insecure households tended to consume less vegetable and fruit intake (PR = 0.68, 95%IC: 0.58–0.79) and beans (PR = 0.78, 95%IC: 0.63–0.97).
Schott, 2020	Cross-sectional	Brazil	594 adults≥ 18 years	Brazil Food Insecurity Scale (EBIA)	UPF consumption	The more adults experienced food-insecure, the lower calorie contributed to UPF intake (p < 0.001).
Hutchinson, 2021	Cross-sectional	Canada	15,909 individuals, 1 – 64 years	The Household Food Security Survey Modul (HFSSM)	UPF consumption	• The severity of food insecurity was strongly associated with % energy from UPF in all age groups (p = 0.002 in children 1-8 years, 0.049 in children 9-18 years, 0.003 in women, and 0.009 in men). • The proportion of UPF intake was more significant, and diet quality was poorer in food-insecure households than in food-secure households, notably in the adults and children group.

IC: Interval Confidence, MPF: Minimally Processed Food, PR: Prevalence Risk, UPF: Ultra-Processed Food

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Table 3. Original articles Ultra-Processed Food (UPF) consumption as exposure and overweight or obesity as an outcome

First Author, Year	Design of the Study	Country	Sample Size, Population	Exposure Measure of UPF consumption	Outcome	Main Finding
Adams, 2015	Cross-sectional	United Kingdom	2,174 adults≥ 18 years	A four-day food diary	• Overweight 25.0 – 29.9 kg/m^2 • Obesity ≥ 30.0 kg/m^2	• Higher intake of PI is attributed to a lower BMI and decreased overweight and obesity risk (OR 0.97, 95%IC 0.96–0.99). • Greater intake of PI and MPF combined would decline the odds of overweight and obesity (OR 0.99, 95%IC 0.98–0.99). • Energy intake of MPF or UPF did not associate with BMI significantly.
Louzada, 2015	Cross-sectional	Brazil	30,243 individuals, ≥ 10 years	Multiple days of 24-hour food records	• Adults ≥ 20 years: 25.0 – 29.9 kg/m^2 were overweight, and ≥ 30.0 kg/m^2 was obesity • Adolescents < 20 years: Z-scores of BMI-for-ages from the WHO	The UPF intake in the top quintile (4th quintile) had a significantly higher 0.94-points of BMI (95%IC 0.42–1.47), a greater risk for obesity (OR = 1.98, 95%IC 1.26–3.12), and overweight (OR = 1.26, 95%IC 0.95–1.69) than the UPF intake in the lowest quintile.
Mendonca, 2016	Prospective Cohort	Spain	8,451 adults, middle-aged	SFFQ, 136 food items	• 25.0 – 29.9 kg/m^2 was overweight • ≥ 30.0 kg/m^2 was obesity	The highest quartile of UPF intake attributed to a greater risk of thriving overweight or obesity (HR adjusted = 1.26, 95%IC 1.10–1.45, p-trend = 0.001) than subjects in the lowest quartile of UPF consumption.
Julia, 2018	Cross-sectional	France	74,470 individuals, All age groups (≤25 - ≥65 years)	A three-day, 24-hour food record	• 25.0 – 29.9 kg/m^2 was overweight • ≥ 30.0 kg/m^2 was obesity	• Higher UPF intake was related to the greater prevalence of overweight and obesity (p < 0.001). • The highest UPF energy contribution (4th quintile) had lower fruit and vegetable consumption yet higher amounts of sweet products and soft drinks (p-trend < 0.001).

Juul, 2018	Cross-sectional	United States	15,977 adults, 20–64 years	A 24-hour food recall	• BMI:
					  • 25.0 – 29.9 kg/m^2 was overweight
					  • ≥ 30.0 kg/m^2 was obesity
					• Abdominal obesity:
					  • Men: WC ≥ 102 cm
					  • Women: WC ≥ 88 cm
						Consumption of UPF ≥ 74.2 vs. ≤ 36.5% of total daily calories was related to:
						• 1.61 points higher BMI (95%IC 1.11–2.10)
						• 4.07 cm greater WC (95%IC 2.94–5.19)
						• Greater odds of overweight (OR 1.48, 95%IC 1.25–1.76), obesity (OR 1.53, 95%IC 1.29–1.81), and abdominal obesity (OR 1.62, 95%IC 1.39–1.89), all p-trend < 0.001).

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First Author, Year	Design of the Study	Country	Sample Size, Population	Exposure Measure of UPF consumption	Outcome	Main Finding
Nardocci, 2018	Cross-sectional	Canada	19,363 adults≥ 18 years	Multiple days of 24-hour food recalls	• 25.0 – 29.9 kg/m² was overweight • ≥ 30.0 kg/m² was obesity	The UPF consumption ≥ 32% is in the highest quintile (4th quintile) and tended to have more obesity than the lowest quintile (OR adjusted = 1.32, 95%IC 1.05–1.57).

Canada, 2018	Prospective Cohort	Brazil	11,827 Adults, 35–74 years	FFQ, 114 food items	• BMI:
					  • 25.0 – 29.9 kg/m² was overweight
					  • ≥ 30.0 kg/m² was obesity
					• Abdominal obesity:
					  • Men: WC ≥ 102 cm
					Women: WC ≥ 88 cm
						• The UPF consumption in the fourth quartile was related to a 20% greater risk of incident overweight (RR = 1.27, 95%IC 1.07–1.50), 2% greater risk of incident obesity (RR = 1.20, 95%IC 0.85–1.21), and 33% higher risk of waist gains (RR = 1.33, 95%IC 1.12–1.58).
						• The UPF intake > 17.8% of total energy contributed to 15% of cases of waist gains and incident overweight/obesity.

Hall, 2019	Randomized controlled trial	United States	20 Adults, 18–50 years	Randomized to receive either UPF (2 weeks), in subsequence followed by non-UPF diet (2 weeks)	Changes in body weight, fat mass, fat-free mass	Intake of calories and body weight changes had a strong correlation (r = 0.8, p < 0.001), with participants during the UPF diet experiencing body weight gain of 0.9 ± 0.3 kg (p = 0.009) and during the non-UPF diet having body weight loss 0.9 ± 0.3 kg (p = 0.007).
Ali, 2020	Cross-sectional	Malaysia	167 Adults, 18 – 59 years	Two days 24-hour food recall data	• 25.0 – 29.9 kg/m² was overweight • ≥ 30.0 kg/m² was obesity	Ultra-processed food consumption and nutritional status had no significant relationship (r = -0.004, p = 0.954).

Rauber, 2020	Cross-sectional	United Kingdom	6,143 Adults, 19 to 96 years	Multiple days of food diary	• BMI:
					  • 25.0 – 29.9 kg/m² was overweight
					  • ≥ 30.0 kg/m² was obesity
					• Abdominal obesity:
					  • Men: WC ≥ 102 cm
					Women: WC ≥ 88 cm
						• The greater calories intake from UPF was related to a greater 1.66-points of BMI (95%IC 0.96–2.36) and 3.56-points of WC (95%IC 1.79–5.33), and a 90% greater risk of being obese (OR = 1.90, 95%IC 1.39–2.61), than the lowest UPF consumption.
						• A 10% increment of UPF intake affected a BMI increment of 0.38 kg/m² (95%IC 0.20–0.55), WC increment of 0.87 cm (95%IC 0.40–1.33), and 18% greater risk of obesity (OR = 1.18, 95%IC 1.08–1.28).

Machado, 2020	Cross-sectional	Australia	7,411 adults≥ 20 years	Two non-consecutive days of 24-hour food recalls	• BMI:
					  • 25.0 – 29.9 kg/m² was overweight
					  • ≥ 30.0 kg/m² was obesity
					• Abdominal obesity:
					  • Men: WC ≥ 102 cm
					Women: WC ≥ 88 cm
						Compared to the 1st quintile of UPF intake, the 4th quintile had significantly higher 0.97-points of BMI (95%IC 0.42–1.51), higher 1.92-points of WC (95%IC 0.57–3.27), higher odds for obesity (OR = 1.61; 95%IC 1.27–2.04), and abdominal obesity (OR = 1.38; 95%IC 1.10–1.72).

First Author, Year	Design of the Study	Country	Sample Size, Population	Exposure Measure of UPF consumption	Outcome	Main Finding
Beslay, 2020	Prospective Cohort	France	110,260 adults≥ 18 years	Three days of non-consecutive web-based 24-hour records	• 25.0 – 29.9 kg/m² was overweight • ≥ 30.0 kg/m² was obesity	A higher risk of overweight was accounted for each 10% increment of UPF intake (HR = 1.11, 95%IC 1.08–1.14) and obesity (HR = 1.09, 95%IC 1.05–1.13).

Sung, 2021	Cross-sectional	South Korea	7,364 adults, 19 to 64 years	UPF consumption, assessed using a 24-hour food recall	• BMI:
					  • 25.0 – 29.9 kg/m² was overweight
					  • ≥ 30.0 kg/m² was obesity
					• Abdominal obesity:
					  • Men: WC ≥ 102 cm
					Women: WC ≥ 88 cm
						The UPF consumption in the highest quintile had 0.61 kg/m² higher BMI (p = 0.0047), 1.34 cm higher WC (p = 0.0146), 51% greater risk of being obese (OR = 1.51, 95%IC 1.14–1.99), and 64% higher odds of abdominal obesity (OR = 1.64, 95%IC 1.24–2.16) than the lowest quartile among women. However, no association was found in men.

BMI: Body Mass Index (kg/m²), FFQ: Food Frequency Questionnaire, HR: Hazard Ratio, IC: Interval Confidence, MPF: Minimally Processed Food, OR: Odds Ratio, SFFQ: Semi-quantitative Food Frequency Questionnaire, UPF: Ultra-Processed Food, WC: Waist Circumference (cm).

Table 4. original articles assessing food security status as exposure and overweight or obesity as an outcome

First Author, Year	Study Design	Country	Sample Size, Study Population	Exposure Measure	Outcome	Main Finding
Vuong, 2015	Cross-sectional	Vietnam	250 adults ≥ 18 years	The 15-item Latin American and Caribbean Household Food Security Scale (ELCSA)	• Overweight 25.0 – 29.9 kg/m² • Obesity ≥ 30.0 kg/m²	Food security status was not associated with body weight (p = 0.40).
Jomaa, 2017	Cross-sectional	Lebanon	378 mothers of children < 18 years	Arabic-translated Household Food Insecurity Access Scale (HFIAS)	Obesity ≥ 30.0 kg/m² and Abdominal obesity: WC ≥ 80 cm	After adjusting for socioeconomic correlates, mothers who experienced food-insecure had 1.73 greater odds of obesity (95%IC 1.02–2.92) than mothers who experienced food-secure.
Velde, 2020	Cross-sectional	Netherlands	250 adults≥ 18 years	18-item United States Department of Agriculture Household Food Security Survey Module (USDA HFSSM)	• Overweight 25.0 – 29.9 kg/m² • Obesity ≥ 30.0 kg/m²	• Adults who experienced food insecurity had a 2.49 more significant chance of being obese (95%IC 1.16–5.33) in the unadjusted model compared to its counterpart. • The living situation, diet quality, and smoking status partially mediated the relationship between food insecurity and obesity (proportion mediated: 15.4%, −18.6%, and −15.8%, respectively).

IC: Interval Confidence, OR: Odds Ratio, WC: Waist Circumference (cm)

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Ultra-Processed Food as a Potential Mediator of Food Security Status and Overweight or Obesity

Generally, there are two potential pathways of UPF intake as a mediator between overweight and obesity. First, food-secure adults tended to consume higher energy from UPF, gaining body weight. That pattern might occur in many low to middle-income countries. Second, food-insecure adults tended to consume higher energy from UPF, affecting weight gain. The pattern is primarily observed in many high-income countries. However, in a more complex framework, some driving factors determined the high consumption of UPF from food security status.

One of the driving factors is the ease of access to modern and wet markets, affordability of UPF price, and food choice motives of adults, such as convenience, health, practicality, etc. .[6,33]. As mentioned in some studies, modernization in the food markets and shops is dominated by PF and UPF products, sold with several engaging marketing related to price and packaging[5,6]. However, a study reported that the energy contribution from UPF among Jakarta's adults is less than one-fifth of total energy intake[12]. Therefore, many other factors must also mediate food security status to overweight or obesity[20,26,33,34]. As found by previous research, the total diet quality score did not mediate food insecurity status to obesity, even after adjusting with covariates[20]. That finding supported that the role of dietary intake in mediating food security and over-nutrition is only a partial mediator and can be more influenced by other non-dietary factors.

Secondly were sociodemographic factors, including gender, age, marital status, and living conditions[34]. Regarding gender differences, some researchers suggested that the food-insecure group had a greater prevalence of obesity, which is evident more in married women[20,33,34]. Those findings could be attributed to motherhood, related to the mother's role in the community or society to feed the family first. Food-insecure women, especially mothers, might adopt unhealthy coping mechanisms to protect their children and family, increasing the risk of imbalanced body weight[20,33,34]. Third, psychological factors such as perceived stress, binge eating, and food choice motives, especially in women and adults, also played a role as mediators for overweight and obesity[20,35].

Fourth, the role of social protection in mediating food security status to overweight or obesity was determined by two factors. First is the domination of energy-dense food in the in-kind foods, and second is cash transfers that affect people's food choices motives and lead to less healthy food consumption[36,37]. An RCT study distinguished the effect of in-kind foods and cash transfers in food-insecure adults[36]. The main finding was that the in-kind foods group tended to have greater calories than the cash-transfer group. It is reasonable since PF and UPF, such as palm oil, soy and chili sauce, instant noodle, canned fish, corned beef, instant tea, and sweetened condensed milk36 commonly dominate the component in-kind foods. Although limited studies investigated the effect of in-kind foods on UPF consumption and nutritional status, a previous report recommended replacing foods high in saturated fat, sugar, and salt with micro-nutrient fortified commodities[36].

Conversely, the cash transfer group had a better dietary quality through higher consumption of fruit, vegetable, eggs, milk, and dairy[36]. The opposite finding was found in another cohort study, where cash-transfer receivers tended to have greater odds of being obese after four years followed-up[37]. Not related to UPF, yet most cash-transfer receivers used the money to buy a bulk of staple foods and consume the foods in a bigger portion[37].

They were assessing food security status towards excess body weight involved broader aspects. The UPF, through various designs of the study, showed a consistent finding to have a strong association with overweight or obesity. However, heterogeneous people's characteristics, social aid, food environment, food choice motives, and other factors also have different roles as mediators between food security status and over-nutrition. Finally, we provide recommendations for the community, academe, researcher, health promotor, and policymaker. First, adults should be aware of reading food labels before buying or consuming UPF products, especially calorie content, added sugar, and total fats, including saturated and trans-fat. The second is to initiate and encourage healthy lifestyle practices beyond physical activity and healthier food intake. For instance, individual skills in affordable but nutritious foods, preparing healthier home food, and reading food labels, especially for UPF products, through various social media, including video education, webinar, or wellness classes. The third is to develop and enlarge food diversification to promote various and balanced diets and minimize the risk of food insecurity among individuals or households.

After all, strengths and limitations are found in this review. To the best of our knowledge, this literature review is the first review in observing UPF consumption as a potential mediator for food security status to overweight or obesity among adults. Second, the published articles in this review comprised various study designs, from cross-sectional design to cohort perspective to RCT, and were performed in many different developed and developing countries. However, the limitation of this review is that many publications were found to use secondary data, which only had limited dietary intake data. For instance, the use of non-multiple 24-hour food recall accounted for the dietary intake data did not represent habitual intake. Second, most of the studies in this review are from Western countries since the research from developing countries is still limited. Thus, it is not easy to generalize the findings, especially for developing countries.

CONCLUSIONS

Generally, intake of UPF was found to be consistently connected to higher odds of obesity in developed and developing countries. Besides, the relationship between food security and overweight or obesity tended to be consistent, whereas food-insecure adults tended to have higher odds of obesity than food-secure adults. Regarding the findings, UPF consumption was indicated as a potential mediator for food security and nutritional status (overweight or obesity). We have

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several suggestions for the subsequent study to use actual data with a study design that can explain the causality of the UPF intake role in mediating the links between food security and overweight and obesity. Second, it will be much better to carry out a systematic review and meta-analysis to examine the effect of UPF consumption on overweight and obesity in all age groups.

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Appendix

1. **Unprocessed or Minimally Processed Food (MPF, Group 1)**
   Unprocessed food
   Edible parts of food from plants (fruit, seeds, leaves, stems, roots, tubers) or animals (muscle, fat, eggs, milk), and fungi, algae, origin obtained directly from nature or after separation from nature.
   Minimally processed food
   Unprocessed foods are altered by industrial processes such as removal of inedible or unwanted parts, drying, powdering, squeezing, crushing, grinding, fractioning, steaming, poaching, boiling, roasting, pasteurization, chilling, freezing, placing in containers, vacuum packaging, non-alcoholic fermentation, and other methods that do not add salt, sugar, oils or fats or other food substances to the original food.
   The example
   - Fresh, squeezed, chilled, frozen, or dried fruit and leafy and root vegetable grains such as brown, white rice, corn cob or kernel, wheat berry, or grain
   - Legumes such as beans, lentils, and chickpeas
   - Starchy roots and tubers such as potatoes, sweet potatoes, and cassava
   - Fungi such as fresh or dried mushrooms
   - Fresh, powdered, chilled, or frozen eggs, meat, poultry, fish, and seafood
   - Fresh or pasteurized fruit or vegetable juices (no added sugar or flavors)
   - Fresh, powdered, or pasteurized milk, plain yogurt, tea, coffee, and drinking water (with no added sugar, sweeteners, or flavors)
   - Grits, flakes, or flour made from corn, wheat, oats, or cassava
   - Herbs and spices used in culinary preparations, such as thyme, oregano, mint, pepper, cloves, and cinnamon, whole or powdered, fresh or dried
   - Foods made up of two or more items in this group, such as: (1) dried mixed fruits, granola made from cereals, nuts, and dried fruit with no added sugar, honey, or oil; (2) wheat or corn flour fortified with iron and folic acid.
2. **Processed Culinary Ingredients (PCI, Group 2)**
   Substances are obtained directly from group one foods or nature by industrial processes such as pressing, centrifuging, refining, extracting, or mining. The substances used to prepare, season, and cook group 1 food.
   The example
   - Vegetable oils crushed from seeds, nuts, or fruit
   - Butter and lard obtained from milk and pork
   - Sugar and molasses obtained from cane or beet; honey extracted from combs and syrup from maple trees
   - Starches extracted from corn and other plants
   - Products consisting of group 2 items, such as salted butter, and group 2 items with added vitamins or minerals, such as iodized salt.
3. **Processed Foods (PF, Group 3)**
   Food is made by adding salt, oil, sugar, or other groups of two ingredients to group 1 foods, using preservation methods such as canning and bottling. Processes and ingredients are designed to increase the durability of group 1 foods and make them more enjoyable by modifying or enhancing their sensory qualities. They may contain additives that prolong product duration, protect original properties, or prevent the proliferation of microorganisms.
   The example
   - Canned or bottled vegetables and legumes in brine
   - Salted or sugared nuts and seeds
   - Salted, dried, cured, or smoked meats and fish, and canned fish
   - Fruit in syrup (with or without added antioxidants
   - Freshly made unpackaged bread and cheeses.
   - Street food or traditional food, processed by adding a bulk of sugar or salt and cooking with deep-frying, baking, grilling, or boiling in hours with additional fat sources such as coconut milk, butter, margarine, or mayonnaise.
4. **Ultra-processed Foods (UPF, Group 4)**
   Formulations of foods and ingredients, most of exclusive industrial use, are made by a series of industrial processes, requiring sophisticated equipment and technology. Industrial food processing completes unprocessed or raw foods less perishable, more comfortable to consume, and more palatable. These processes include hydrogenation, hydrolysis, extruding, molding, reshaping, and pre-processing by frying and baking. These processes use additives at various stages of manufacture whose functions include making the final product hyper-palatable.
   The example:
   - Sweet, fatty, or salty packaged snack, instant sauces, chocolate, candies, ice cream, margarine and spreads, bread and buns, biscuits, pastries, cakes, and cake mixes, sweetened breakfast cereals, and energy bars.
   - Sugar-sweetened beverages include energy drinks, milk drinks, fruit yogurts and drinks, carbonated soft drinks, instant coffee, and tea drinks.

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▪ French fries, pies and pasta and pizza dishes, poultry and fish nuggets and sticks, sausages, burgers, hot dogs, and other reconstituted meat products, and powdered and packaged instant soups, noodles, and desserts, meat, and yeast extracts, pre-prepared meat, fish, vegetable, and cheese dishes.

Appendix 1. The NOVA Food Classification System, adopted and cited from Monteiro et al (2019)[7]

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