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Nutritional Aspects of Late Eating and Night Eating

Annette Gallant · Jennifer Lundgren · Vicky Drapeau

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Abstract The timing of food intake has been investigated as a novel factor in the etiology, maintenance, and treatment of obesity. Indeed, consuming a large proportion of food later in the day and into the night has been associated with higher body weight and may even impair weight loss. The diet quality of late-eaters may be a factor involved in these relationships. Moreover, the nutritional characteristics of the foods consumed during the night may negatively affect metabolic and circadian rhythms that are required for optimal health. This review will first examine the diet quality of late-eaters and describe common foods consumed as nocturnal snacks. Second, this review will briefly acknowledge the potential adverse metabolic and circadian effects of consuming certain foods very late in the evening or during the night.

Keywords Diet quality · Late eating · Night eating · Circadian rhythm · Obesity · Nutrition

Introduction and Context

The temporal distribution of daily food intake tends to be culturally determined; however, epidemiological reports demonstrate similarities in the distribution of food intake within similar cultures. For example, Canadians consume 18 % of total energy intake (TEI) for breakfast, 24 % for lunch, 36 % for dinner and 23 % outside discrete meals [1] whereas Americans reported 24 %, 37 % and 39 % for each discrete meal, respectively [2]. Nonetheless, there is variability in the distribution of food intake across daily meals between individuals and studies have begun to investigate the relationship between the former and body weight.

Observational and experimental reports suggest that the temporal distribution of food intake may be a factor implicated in obesity. Briefly a greater proportion of food intake in the evening was associated with greater BMI, an increased risk of overweight/obesity and reduced weight loss, even after controlling for important covariates such as physical activity, TEI and sleep duration [2–4]. Furthermore, experimental manipulation of the temporal distribution of food intake during a weight loss intervention demonstrated greater weight loss success when a greater proportion of food was consumed earlier in the day compared to later in the day [5]. These data are supported by the association between obesity and extreme delayed eating patterns, such as is observed in night eating syndrome (NES) [6]. Thus, emerging evidence has associated a delayed temporal distribution of food intake with measures of body weight and body weight control.

The potential mediators of the relationship between a delayed temporal distribution of food intake and obesity are still uncertain. Different nutritional aspects of the diet could be involved; however, diet quality, independently of TEI, has not often been considered. The aim of this review was to examine the diet quality of late-eaters and the foods consumed as nocturnal snacks and briefly acknowledge the potential adverse metabolic and circadian effects of consuming these foods very late in the evening or during the night.

Diet Quality of Late- and Night-eaters

Observational Studies

Reports indicate that there is a general rhythm of macronutrient intake throughout the day. Indeed, morning meals tend to

A. Gallant (✉) · V. Drapeau
Department of Physical Education, Laval University, 2300 Rue de la Terrasse PEPS, Suite 0290-F, Québec, QC G1V 0A6, Canada
e-mail: annette.gallant@criucpq.ulaval.ca

V. Drapeau
e-mail: vicky.drapeau@fse.ulaval.ca

A. Gallant · V. Drapeau
The Québec Heart and Lung Research Institute, Laval Hospital, Québec, QC, Canada

J. Lundgren
Department of Psychology, University of Missouri-Kansas City, 5030 Cherry Street, Suite 321, Kansas City, MO 64110, USA
e-mail: lundgrenj@umkc.edu

be relatively high in carbohydrate, midday meals tend to be relatively high in protein and evening meals tend to be relatively high in fat [7, 8]. Moreover, energy density seems to be lowest in the morning and highest in evening [9] and energy density predicts TEI [10]. With this information, it could be expected that individuals who eat later during the day, may consume foods higher in dietary fat and energy density. However, few studies have examined the nutritional qualities of the diet in individuals who report a delayed temporal distribution of food intake, i.e., late- or night-eaters.

In one observational study, adult late-sleepers, who were also late-eaters (35 % of TEI after 20 h00), consumed fewer daily servings of fruit and vegetables (1.9 vs. 3.4) and consumed greater weekly servings of sugar soda (4.5 vs. 1.3), fast food meals (5.2 vs. 3.0), and caffeinated beverages (13.0 vs. 7.3), compared to early-eaters (20 % of TEI after 20 h00) [3]. Despite these differences, TEI and the relative macronutrient contribution to the diets were similar in early- and late -eaters [3]. Similarly, relative macronutrient intakes were not different between early- eaters (<33 % of TEI between 17 h00 – 0 h00) and late-eaters (≥33 % than <33 % of TEI between 17 h00 – 00 h00) but in contrast with the former study, there were no differences in daily servings of fruit or vegetable across groups [2]. However, eating ≥33 % after 17 h00 may be a typical eating pattern in this population (US) and not indicative of late-eaters considering a mean of 39 % of TEI was consumed for dinner as observed in the US population [2]. This population-based research is too limited to make any firm conclusions regarding the diet quality associated with a delayed temporal distribution of food intake. Thus, examining the diet quality in known late- and night-eaters, such as shiftworkers, evening chronotypes or individual with nigh eating syndrome, may shed more light on this issue.

The Case of Shiftworkers

Shiftworkers, although not necessarily habitual late-eaters, represent a good model to investigate diet quality of late- or night-eaters. Accordingly, individuals who work at night are frequently required to consume food at an atypical time, i.e., late in the evening and or during the night. It is well documented that shiftworkers are at greater risk for health problems, namely metabolic and cardiovascular complications and cancer [11]. Because of these health implications, the diets of shiftworkers have been extensively investigated. Most reviews have concluded that although there are obvious differences in eating patterns between shiftworkers and regular workers, e.g., meal size, meal frequency, meal timing, nevertheless the diet quality in general is not different [12–14].

The Case of Evening Chronotypes

In contrast to shiftworkers, other individuals may be more biologically driven to eat later in the day. This includes individuals characterized as an evening chronotype, an "evening-type". Evening chronotypes are individuals with an innate evening preference and who perform optimally in the evening. This chronotype is identified by validated self-report questionnaires and/or behavioral or physiological rhythms [15, 16]. Several studies have reported associations between an evening preference and late-eating [4, 17, 18]. Late-eaters were more likely to be evening chronotypes [4] and evening chronotypes consumed 50 % more energy after 20 h00 than morning-types [17]. Moreover, evening chronotypes consumed a greater percent of their TEI for dinner (43 % vs. 32 %), which was also 2-hours later than morning-types [18]. Thus, evening chronotypes represent an interesting phenotype to investigate diet quality of late-eaters.

Several studies have explicitly investigated the diet quality of the evening chronotype [19–22]. These studies reported less healthy diets among these individuals. Specifically, adolescent evening chronotypes reported greater consumption of fast foods and caffeinated drinks and lower consumption of dairy products compared to morning chronotypes [22]. Also, adult evening chronotypes consumed less fish and fruit and consumed more chocolate and soft-drinks than their morning chronotype peers [21]. Moreover, in this latter study and others, a low score on the circadian preference scale (low score is indicative of an evening chronotype) was associated with a greater relative fat intake and less relative protein and carbohydrate intakes, fewer servings of dairy products and less relative intakes of many vitamins and minerals, e.g. calcium, potassium, vitamin A, vitamin D [19–21]. In contrast with these studies, there were no differences in the macronutrient content of the diets between evening and morning chronotypes in two studies [4, 17]; however, diet quality was not the primary outcome of these studies and additional nutritional aspects of the diet were not assessed. Taken together, there is evidence showing that evening chronotypes types may have less healthful diets compared to morning chronotypes.

The Case of Night Eating Syndrome (NES)

NES is a pathological example of chronic late- or night-eating. In individuals with NES, late-eating manifests as a delayed circadian distribution of food intake (≥ 25 % of TEI after the evening meal) and/or nocturnal ingestions of food [23•]. Indeed, the circadian rhythm of individuals with NES is delayed by approximately 1.5 hr [24] and is accompanied often by disturbed and inefficient sleep, albeit a typical sleep onset and offset [25, 26]. Moreover, these individuals often report reduced morning appetite [27] and a specific diurnal variation in mood whereby their mood worsens as the day progresses [28]. NES is also associated with obesity [6] and poor diabetic management [29]. NES is uncommon and is only estimated to affect 0.5 % to 5.7 % of the general population [30–34]. Because of this, the disorder is understudied and very few have examined the nutritional quality of the diet or of the foods consumed at night in these chronic late-eaters.

Indeed, data are very limited regarding the diet quality associated with night eating behaviors e.g., nocturnal ingestions, evening hyperphagia, or NES. Individuals with evening hyperphagia and/or who eat late at night (anything past 11 PM) reported a lower relative daily intake of protein (−0.5 %) and a greater daily intake of sodium (+350 mg) than individuals without these eating behaviors [35]. These differences were more pronounced when restricted to very late night eaters whereby these individuals consumed 500 mg more of sodium, 0.9 % less protein and 33.8 mg more of cholesterol than those who did not report this pattern of eating. In contrast, there were no differences in daytime macronutrient intakes between individuals with and without NES [36] or between individuals with and without nocturnal ingestion [37].

Late- and Night-eaters: Results from Quality Cohort

Research from our group has observed that children with night eating symptoms consumed a less healthy diet than children without these symptoms (Table 1). We measured night eating symptoms with the Night Eating Questionnaire (NEQ) in children (aged 8 – 10 yr) participating in a prospective cohort investigating obesity risk factors in youth (the QUALITY cohort [38]). The NEQ measures night eating symptom severity on a continuous scale and can identify specific night eating behaviors [39]. In addition to the NEQ, three 24-hour diet recalls were administered by telephone and 317 children had both NEQ and dietary data. Important to the context of this review, the NEQ score in children has previously been associated with a delayed meal-related distribution of energy intake [40]. After excluding 143 under-reporters using methods described by Huang et al. [41] and Noel et al. [42], children with higher NEQ scores had a greater percent of fat intake, greater sodium intake, fewer servings of fruits and vegetables (Table 1) and a higher occurrence of unhealthy snacks (high sodium, high saturated fat, low fruit and vegetable, etc.) compared to children with lower NEQ scores (Fig. 1). Moreover, children who reported nocturnal ingestions of food ($n=9$) reported consuming a greater percent of TEI from fat (37 % vs. 32 %, $p=0.009$) compared to children without this behavior. The greater fat intake tended to come from daytime and evening snacks rather than meals. Thus, these results suggest that children with night eating symptoms, indicative of a delayed meal-related distribution of energy intake, and specific night eating behaviors, report less healthy eating habits.

In contrast to habitual intake (greater relative fat intake among night-eaters), the foods consumed during nocturnal ingestion tend to be consistently rich in carbohydrates, such as breads and cereal product and sweets. In the second wave of testing for QUALITY (2008 – 2010), in 953 adults (53 % female) and 516 pre-adolescents (10 – 12 years old, 45 % female), 88 adults (9 %) and 26 children (5 %) reported nocturnal ingestion of food. Accordingly, the most frequently reported foods consumed during nightly awakenings were

Table 1 Nutritional data regression models (standard least squares) with the dependent variable NEQ score

Dietary characteristics	NEQ score 1st tertile	NEQ score 2nd tertile	NEQ score 3rd tertile	*p*-value for linear trend
NEQ score (range 0 – 21)	4.5±1.5	8.0±0.9	12.3±2.2	-
Age, yrs	9.6±1.0	9.5±1.0	9.6±1.0	0.86
BMI *z* – score	0.6±1.0	0.4±1.0	0.6±1.0	0.31
Energy intake, kcal	1774±348	1861±412	1873±350	0.27
Fat, %	31±4	33±4	35±5	**0.005**
Carbohydrate, %	53±6	53±5	50±7	0.11
Saturated Fat, %	35±4	36±5	37±5	0.78
Protein, %	17±4	16±2	16±3	0.21
Sodium, mg	2468±792	2616±814	2785±639	**0.07**
Calcium, mg	870±225	923±294	932±311	0.79
Fruit and vegetable, servings/day	5.3±2.1	4.8±2.1	4.6±1.7	**0.03**
Dairy products, servings/day	1.8±0.8	2.1±0.9	2.1±1.0	0.43
Grain products, servings/day	4.5±1.5	5.1±1.8	4.7±1.4	0.91
Meat and alternatives, servings/day	2.1±0.8	2.1±0.9	2.3±1.1	0.29
High-sugar beverages, ml/day	108±105	105±139	123±139	0.17
Snacks, no./day	4.6±1.6	4.9±2.3	5.1±2.1	0.14

Data are means±SD

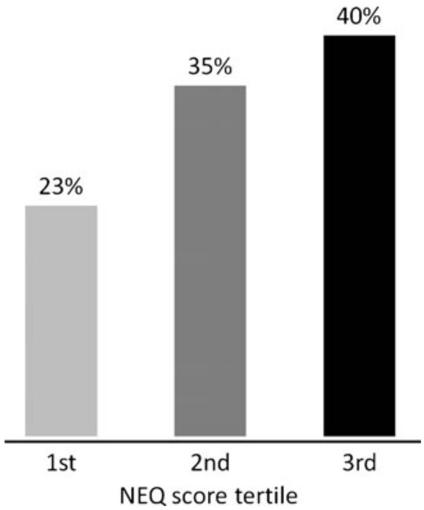

Fig. 1 Percent of children who reported eating snacks (n=142) with at least one unhealthy snack, separated by NEQ score tertiles (χ^2=3.6, p= 0.17). An unhealthy snack was based on the saturated fat and sodium content of the snack and could not be a fruit or vegetable or a dairy product

sugary foods and sweets, breads and cereal products and dairy products (Table 2). Children also reported a high frequency of fruit consumption which was not observed among adults. There were no differences in food choices between men and women, except for a tendency for fewer women to report consuming sugary foods and sweets upon awakening (43 % vs. 27 %).

Reports from other studies are in agreement with our observations that foods consumed during the night tend to be rich in carbohydrates. This phenomenon is observed in individuals with NES where the carbohydrate content of the nocturnal meal was reported to be 70.3 % in one study [28] and 61.5 % in another [37], values much higher than the carbohydrate component of daytime meals (46.6 %). Nocturnal ingestions in sleeping-related eating disorder were also reported to be rich in carbohydrates but were also sometimes foods that were both high-carbohydrate and high-fat (breads, pies, sweets etc.) [43–45]. Likewise, shiftworkers tended to eat more carbohydrates during the night shift than when they were working the day shift (100 g more, 51 vs. 46 % of total energy intake) [46]. A final example is that pre- adolescent girls chose high-carbohydrate foods (53.8 – 68.8 % of energy from carbohydrates) when the foods were consumed after 11 PM [47]. Taken together, there seems to be a consistent trend of choosing foods rich in carbohydrate, when foods are eaten late in the evening or during the night.

Table 2 Percent of adults and children who reported consuming these foods during nocturnal ingestions children (10 – 12 yrs)

	Individuals who reported consuming these foods during nocturnal ingestions, n (%[†])	
	Adults (n=88)	Children (n=26)
Sugars and sweet foods	**31 (35)**	**8 (31)**
Fats and fatty foods	6 (7)	1 (4)
Salt and salty foods	6 (7)	1 (4)
Dairy products	**45 (51)**	**12 (46)**
Fruits	13 (15)	**11 (42)**
Vegetables	1 (1)	0 (0)
Meats	2 (2)	0 (0)
Breads and cereal products	**28 (32)**	**13 (50)**
Soft drinks	7 (8)	0 (0)
Chocolate	8 (9)	0 (0)

50 % female in adults, no sex differences in food choices

[†] Percent of individuals who reported nocturnal ingestions

Diet Quality of Late and Night Eating: Metabolic and Circadian Effects Beyond Energy Value

There may be metabolic consequences of eating certain foods late at night, beyond those related to TEI *per se*. There is evidence of exaggerated glucose and insulin responses to foods eaten during the late evening or night, likely attributable to relative insulin resistance during this time [48, 49]. More specifically, high carbohydrate foods with a high glycemic index (GI) may further exaggerate the glucose response to the late-evening meal [50]. Indeed, postprandial glucose area under the curve (AUC) was highest after a high GI evening meal compared to a low GI evening meal [50]. Moreover, the relative insulin resistance at night [51] may also lead to increased postprandial plasma triglyceride (TAG) concentration by the reduced activation of lipoprotein lipase, a TAG-clearing enzyme. This has been shown in several studies that examined the postprandial response to foods consumed during either a simulated [48, 52] or real-life shift-work context [53]. These authors concluded that high-fat meals should also be avoided during the night, at least in the unadapted shift-worker.

Although this suggests eating a certain type of food in the evening or night could compromise metabolic health, other studies have shown different results. The macronutrient composition of a nocturnal meal had no impact on postprandial metabolism in a cross-over study where men were fed a high carbohydrate (65 % carbohydrate, 20 % fat) and a high fat (40 % carbohydrate, 45 % fat) nocturnal meal for seven days. Indeed, despite several altered postprandial hormone responses after the nocturnal meals (pancreatic peptide, thyroid-stimulating hormone, cortisol, and leptin), no differences were attributed to the macronutrient composition of the diet [54]. Therefore, it seems that eating during the night may produce metabolic consequences that may be worsened by intake of unhealthy, palatable foods (high sugar, high fat).

In addition to the metabolic challenge of a nocturnal meal, certain nutrients may feedback more strongly to the circadian system and entrain (synchronize or desynchronize) the peripheral circadian system, particularly when food is consumed during an atypical circadian phase [55]. Briefly, this atypical feeding pattern may influence rhythms of gene expression in peripheral tissue (and their downstream metabolic and humeral targets) and uncouple these rhythms from the central circadian pacemaker in the brain, the suprachiasmatic nucleus, thus creating internal desynchronization and leading to metabolic disease [56]. Reviews have elaborated on this topic [57–59, 60•, 61•, 62, 63] and the term "chrono-nutrition" has been used to describe the relationships between feeding, nutrition and the circadian system [60•].

Most evidence on these relationships stems from animal studies and indicates that molecules related to the regulation of glucose metabolism seem to be involved in this phenomenon. Indeed, the insulin signal seems to be an important player in the entrainment of the expression rhythms of clock genes in the peripheral tissues [60•]. However, insulin may not be an *essential* player as high blood glucose levels led to a phase advance in the expression of genes that regulate tissue-specific circadian rhythms (clock genes) in insulin deficient rats and mice [64, 65]. Accordingly, adenosine monophosphate-activated protein kinase (AMPK), an enzyme which maintains energy homeostasis, is another potential mediator between the nutrient signals and circadian clocks [66]. Moreover, dietary salt may indirectly influence the circadian entrainment through its effect on glucose absorption [60•, 67]. Chemicals involved in glucose metabolism seem to be important players in the entrainment of peripheral circadian clocks; however, there is still much work needed in this area, particularly among humans.

Some research on humans has shown that carbohydrates may have a strong effect on metabolic and humeral rhythms. In one study, a high carbohydrate meal (75 % CHO, 1600 kcal) was served either for breakfast (08:30) or for dinner (21 h30). The morning meal impacted the central pacemaker because it phased-advanced the core body temperature (CBT) by 1 hour. In contrast, the evening meal had no effect on the CBT but it either shortened or attenuated the melatonin rhythm [68, 69]. However, it cannot be determined whether this effect was due to the carbohydrate content of the meal or due to the energy content of the meal *per se*. For example, it is not known if a similar effect would be observed if the meal was high in fat or was balanced in macronutrient content. In a further study, diurnal rhythms of appetite hormones were altered after restricting carbohydrates to the evening while controlling energy intake throughout the rest of the day [70]. Thus, meal timing and potentially carbohydrate intake can influence the circadian system.

In accordance with this, altered rhythms of appetite hormones have been observed among individuals with NES. Individuals with NES had attenuated rhythms of cortisol, ghrelin and insulin, phase-delayed rhythms of leptin, insulin and cortisol and phase-advanced rhythms of ghrelin [24]. Importantly, the leptin-ghrelin rhythms and the glucose-insulin rhythms were uncoupled, which indicates internal physiological desynchronization. Future studies in humans are needed to determine if specific nutrients can create clinically significant changes in circadian regulation in humans and, if so, the extent of their impact on metabolic health and energy balance. Moreover, it is important to test if nutrients or nutritional strategies can be used to minimize or reverse the effect of circadian desynchronization, a problem thought to occur in individuals who eat at night.

Conclusions and Future Directions

The literature regarding the temporal distribution of food intake and body weight control is beginning to emerge. However, there are too few studies to make any firm conclusions regarding the diet quality of late- or night-eaters. Most studies have focused on the diet quality of evening chronotypes and results seem to be consistent, i.e., evening chronotypes eat less healthy diets. In contrast, almost no studies have examined the diet quality of individuals with NES, a more severe disorder of late-eating and, consequently, conclusions cannot be made. Nonetheless, individuals who consume food very late in the evening and into the night tend to select high-carbohydrate foods during these eating occasions. Palatable foods, such as foods with a high glycemic index and/or high fat foods, that are eaten during the night may negatively influence postprandial metabolism and may have a negative impact on the peripheral circadian system, creating internal desynchronization. Future research needs to focus on aspects of chrono-nutrition in humans, including the impact of late-eating or night-eating on health, body weight control and the circadian system. This information could help to develop novel nutritional interventions to treat NES or at least minimize the negative metabolic impact of meals eaten late in the evening.

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Compliance with Ethics Guidelines

Conflict of Interest Annette Gallant, Jennifer Lundgren, and Vicky Drapeau declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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