Impact of breakfast skipping on subjective appetite and metabolism. An updated review

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ABSTRACT
Breakfast, the first meal of the day, is considered the most important meal throughout the day. Associations between breakfast skipping and much negative health impacts were described in many previous studies. This review was conducted in order to summarize the updated research findings related to the prevalence and characterization of breakfast skipping and its impact on appetite, energy intake, as well as the metabolism. According to the previous research studies, breakfast was the most commonly skipped meal more than lunch and dinner specifically in the young adult in the university study period. Lack of time was the main reason behind skipping meals, in general, and breakfast in specific, followed by lack of appetite, inability to cook, fasting/religion, and not being hungry. It was found that the irregular omission of breakfast might be effective in energy intake reduction over the next 24 hours and in this day, exercise performance may be compromised. Based on the experimental studies in adults available till now, there is no evidence on the belief that breakfast skipping induces overeating and weight gain. This review highlights the importance of time management skills to be developed early during life to avoid bad feeding habits and breakfast skip in specific. It also calls for further research studies before making conclusions concerning the influences of breakfast on the hormonal organization of appetite.

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Introduction
Unhealthy dietary behaviors were described to have a crucial role in increasing the upcoming risk of chronic diseases [1]. Breakfast identified as “the first meal of the day, consumed within 2 hours of waking, before starting daily activities.” Breakfast was recommended to contain 20%–35% of daily energy needs [2]. It is considered the most important meal of the day as a part of a healthy balanced diet [3]. Habits relating to breakfast consumption are significantly associated with physiological, psychological, and social health dimensions [4].

Several studies reported associations between breakfast skipping and negative mode, fatigue at noon, worsens memory and higher body mass index as well as increased prevalence of obesity-related chronic illness [5–7]. Adding another negative impact on health such as deficient total energy, vitamins and minerals [8], increased risk of central adiposity [9], and risk of insulin resistance and cardio-metabolic disorders [10]. If the stomach is kept empty for a long time, the body will suffer a deficiency of proteins and glucose. Then blood sugar will drop down followed by mood changing [11]. In an Italian population-based study, there is a positive association between headache and meal skipping, especially due to the irregular intake of breakfast was evidenced [12].

This review was conducted to examine and summarize the updated research findings related to the prevalence and characterization of breakfast skipping and its impact on appetite, energy intake, as well as the metabolism.

What Does it Mean by “Breakfast?”
The simple definition of breakfast is “the first meal of the day,” which is consistent with the etymology to “break” the “fast”. However, this is not acceptable from a scientific view, where the reality that there is no unique general accepted definition of breakfast which participating in the conflicting findings
in this area [13]. Where there is no specific time or contents of the breakfast, someone could take the breakfast immediately after waking up, other one could take it a little bit late in the early afternoon. As well as, someone can drink coffee with milk only as breakfast, other take sandwich, and other take eggs, meat, and jam.

These diversities of opinion caused problems when systematic searching have examined breakfast behaviors or suggested breakfast eating, and allowed person interpretation concerning what shapes breakfast. This is beneficial from a sociological point-of-view. However, physiological health needs more precise and consistent operational definition. As an example, some studies have used solid foods only as breakfast and neglected other highly calorific beverages available, even with the fact that there are “differences in gastric emptying rate and metabolic response to different nutrients in solid versus liquid form [14].” “A calorie is a calorie,” the balance of net energy does not differentiate between ingested nutrients or calories regarding chewing or not. In the future, it could become possible to define meals regarding a definite combination of nutrients, a reasonable beginning point to describe fundamental situations of breakfast could depend on the amount and timing of energy spent. Betts et al. [15] reported that an amount of 209.2 kJ (50 kcal) is an appropriate starting spot to dismiss common behaviors that would not be recognized as a meal by most of the people. On the other hand, timing issue is more difficult and based on “time of day, time of waking, and/or the intervals that differentiate separate eating occasions.” The definition of breakfast as “morning feeding” depends simply on light/dark cycles independent of sleep/wakes cycles. It is complex by diversity in these variance sequences due to “geographical/seasonal differences in daylight hours or cultural/vocational differences in sleeping patterns (e.g., night-shift staff).”

A duration of 2 hours after waking up was used in the definition of the breakfast meal and has been differentiated from snacks by a cut-off point of 1,087.8 kJ (260 kcal) and independent consumption cases secluded on the basis of a 45 minutes period [16,17]. Generally, it is sensible for an operational definition of breakfast to exemplify as “the first meal consumed within 2 hours after prolonged sleep in any 24 hours duration,” which represents the extended daily time consumed in the fasted-situation and the only time when most of the people are really post-absorptive [17,18].

Is Breakfast Skipping a Common Issue?

Dubois et al. [19] defined meal skipping as the omission of the intake of one or more of the ordinary three chief meals during the day. Skipping meal commonly occurs among young adults when compared with other age groups. Silliman et al. [20] and Sakamaki et al. [21] reported a high prevalence of meal skipping among young adult population ranged from 24% to 87%.

Several studies reported that recurrent missed breakfast among different age groups was more than lunch and dinner. Among the sample of Americans from different ages, the rate of breakfast skipping was the highest (10.7%) comparing with lunch skipping (8.6%) and dinner skipping (5.8%) [22,23]. Another study among college students at the University of North Carolina, Charlotte reported that almost half (44.2%) of the students never take their breakfast comparing with lunch (3.5%) and dinner (2.3%) [24]. Australian young adults reported eating breakfast less than 5 days per week, compared with 10% of children and 33% of all adults (>18 years) [25].

These results provide evidence that people from various age groups experience various rate of meal skipping. It is important to report that most of the studies focused more on the breakfast meal than either the lunch or dinner meals [26].

Reasons Behind Breakfast Skipping

Lack of time was the main reason behind skipping meals as recorded in several studies. In nine studies, time was reported as the main reason for meal skipping when comparing with the other reasons, particularly among the young adult. During this age period transmission, including leaving the family home, involving in more education, and/or starting a job frequently happen, the young adult might skip some meals during these events [27]. These new environments with different demands need from young adults to learn a number of skills, such as prioritizing tasks and dealing with these new responsibilities [28]. These results confirmed that time shortage has a negative influence on various eating behaviors [29].

Afolabi et al. [30] reported that 48%, 19%, and 13% of Nigeria university students skipping meals due to lack of time, appetite, and inability to cook, respectively. Deliens et al. [31] described the impact of time shortage on the university students as they reported that students would rather spend time on activities than cooking, especially when they have
to cook only for themselves. So, lack of time could be the main reason for varied prioritization with healthy eating behaviors poorly prioritized [26,31]. Fasting/religion and money were mentioned by about 20% and 15% of Nigerian University students as a reason for skipping meals, respectively [32]. Among the scare studies conducted in Saudi Arabia in this regard, was the study of Eldisoky which revealed that about half of Saudi Arabia University students skipping meals because they did not feel hunger while one-third of them don’t have time and one-fifth skip meals because they want to control weight [33].

When it came to skipping the breakfast, in specific, the study conducted by Shaw revealed that 52% of adolescent reported lack of time in the morning as the main reason for skipping breakfast [34]. Danquah et al. [35] reported that lack of time, not being hungry, and eating late at night were the reasons behind skipping breakfast in 57%, 22%, and 5% of Ghanaian university students. In the study conducted by Lee and Yoon [36] on Korean University students, the second cause of skipping breakfast after the lack of time (noted by 61%) was the habit (17.6%).

**Impact of Skipping Breakfast on Subjective Appetite**

High protein breakfast consists of 50% protein, 30% carbohydrate, and 20% fat was reported to have more benefits on mood, alertness, and attention. It resulted in a positive mood and higher performance test scores compared with those of breakfast with adequate protein. This might be attributed to that high-protein breakfast resulted in more stable glucose and insulin than adequate protein breakfast [37]. It was also stated that protein keeps blood sugar levels while carbohydrate is important to offer energy to the body [38,39].

Worldwide, there was a common thought that missing breakfast causing an increase in the desire for food, which stimulating overeating at following meals and inducing weight gain [10]. Few studies in adults have been carried out about breakfast skipping and energy balance-associated variables such as appetite and ad libitum energy intake [40–42]. These studies consistently showed some influences on subjective appetite so that the variables such as “sensations of hunger, desire to eat, and prospective consumption” are estimated as higher in breakfast skipping comparing with breakfast eating conditions. Adding to that, the timing and duration of these effects vary in part due to the difference across studies [40–42]. The study conducted by Leidy et al. [41] showed that when lunch consumption was kept stable across breakfast conditions these effects on appetite, especially prospective consumption, lasted 8 hours after breakfast (or breakfast skipping). In another two studies, the influence of skipping breakfast compared with eating a standard breakfast on ad libitum lunch intake was examined, one of these two studies reported that lunch intake was higher after breakfast skipping [40–43].

Flint et al. [44] reported that visual parallel scales were used to evaluate appetite sensibilities (starvation and glut), which deliver a numerous and credible evaluation of individual appetite. Several studies established the patterns of appetite during the morning when breakfast is taken, as well as when breakfast is misplaced [45,46]. It was noted that the personal appetite for following meals seems didn’t influence by the previous skipping of breakfast, which means that consumption of breakfast only delivers a transient repression of food desire [47,48]. Chowdhury et al. [49] reported that the calculation of the composite appetite score from visual parallel scales revealed that appetite differs over time ($p < 0.01$); however, there were no other main effects or interactions. Fasting appetite scores did not vary between groups or trials, and no interaction impacts were obvious (all $p > 0.2$). On the other hand, the subcomponents of the appetite score (desire to eat, hunger, fullness, and prospective consumption), showed main influences of time (all $p < 0.01$), without any main impacts of trial or group (all $p > 0.1$) for any component. Similarly, there were no interaction effects for any of the ranking apart from a trial × group interaction for fullness ($p = 0.04$). There were also no main influences or interactions for fasted ratings (all $p > 0.1$). They indicated that continuous morning fasting does not motivate chronic adaptations that increase hunger or energy intake (EI) or trigger negative metabolic consequences [49].

During 2015, two studies conducted by Clayton et al. [45,50] aimed to determine how the 24-hour personal appetite outlines reacted to breakfast eating or missing, with ad libitum or standardized (in the second study) lunch and dinner meals where the breakfast representing 25% energy supplies was taken at 08:00 clock, and lunch and dinner meals at 12:30 and 18:00–19:00 clock, respectively. All appetite sensations (hunger, fullness, desire to eat, and prospective food consumption) showed a
main influence of the trial and time as well as an interaction influence. They reported increasing hunger, desire to eat, and prospective food consumption, as well as reducing fullness, in the period after breakfast (0.5–4.5 hours) during breakfast omission group compared with those during breakfast consumption. Also, they reported raising fullness at 7 hours during breakfast omission comparing with that during breakfast consumption (BC) ($p < 0.05$). The data were divided to three parts: breakfast to lunch (0–4.5 hours), lunch to dinner (5–11 hours), and after dinner (11.5–24 hours) [45,50]. These analyses showed variance between trials for all subjective appetite variables between breakfast and lunch ($p < 0.01$). Also, fullness was increased between lunch and dinner during no breakfast (BO) compared with that during BC ($p < 0.05$) [45,50].

These studies reported a decreasing in appetite during the morning when breakfast was taken compared with omitting breakfast. Yet, eating an “ad libitum lunch meal” stabilizer food desire to a similar range, regardless of consuming breakfast, so this influence remained during the rest of the day. A similar response was noted when standardized lunch (with 35% of energy requirements) and dinner (with 40% of energy supplies) meals were delivered so maintaining the energy shortage produced by breakfast skipping. These findings revealed that the inaccurate regulation of subjective appetite is a result of an energy deficit. However, it should be noted that subjective appetite sensibilities do not constantly portend following energy assimilation [51,52].

**Effect of Breakfast Skipping on Appetite-Regulating Peripheral Hormones**

Part of the organization of appetite included numerous intestines peptides and among them the appetite motivator hormone ghrelin as well as hormones linked with satiation and satiety, like “peptide YY (PYY), glucagon-like peptide-1 (GLP-1), glucose-dependent insulinotropic polypeptide, cholecystokinin, and leptin.” Recognition of the reaction of such hormones to energy stability inconstancy could deliver worthy data about nutritional interferences (e.g., breakfast skipping) will be acceptable out of the laboratory atmosphere [53] (see . 1). Astbury et al. [40] reported that the orexigenic hormones, GLP-1 and PYY were superior up to 30 minutes after consuming a 1,050 kJ meal. Figure 1. Hormones regulating appetite. The energy balance system involves long-term afferent signals from fat (leptin) and pancreatic cells (insulin) and short-term, meal-related afferent signals from the gut, including inhibitors of feeding [PYY, GLP-1, and cholecystokinin (CCK)] and the stimulator of feeding (ghrelin). These inputs are integrated within the brain. Adapted after permission from Flier [59].
liquefied meal two and half hours later to breakfast intake, comparing with later to breakfast skipping. Yet, no variations in the orexigenic hormone ghrelin were reported. Also, missing breakfast led to an increase in glucose and insulin as a result of the liquefied meal, compared with breakfast eating. This inhibition of glycemic reaction to the second meal of the day, recognized as the “second meal effect” which linked to glycogen storing [54]. In consistent, Gonzalez et al. [55] reported a trend in increasing glucose and insulin response to a 1,500 kJ liquefied meal ate 3 hours later to skipping, comparing with eating breakfast, even that active GLP-1 levels didn’t not diverse between experiments.

In 2018, Chowdhury et al. [49] conducted the first study to detect acute energy intake and metabolic and appetite responses in a laboratory-based protocol following a sustained intervention of morning fasting or daily breakfast consumption in lean adults. They reported no difference in the magnitude or time course of the responses between all groups from baseline to follow-up for any parameter except for GLP-1, which showed a tendency for a trial × group interaction impact (p = 0.06, η² = 0.16). This is in agreement with a similar observation for individual peak GLP-1 concentrations (p = 0.05, η² = 0.14). The specific disparity of fasted, peak, or nadir values did not show any interaction effects for any other parameters. Plasma adiponectin showed high variability in measurement, with a trend for a trial group interaction (p = 0.07, η² = 0.12). The mean concentration cross baseline and follow-up trials was 9,472 ± 3,343 ng/ml and 9,582 ± 3,284 ng/ml in the breakfast group and 7,919 ± 3,426 ng/ml and 9,097 ± 4,082 ng/ml in the fasting group, respectively [49].

The different GLP-1 findings explained by measuring the total or the active GLP-1 [25]. Thomas et al. [47] detected if habitual breakfast patterns affect the hormonal organization of food desire as a result to a typical lunch took 4 hours after breakfast consuming/skipping. Ghrelin levels did not influence by the skipping or eating breakfast; however, increasing in PYY and GLP-1 levels were recorded. Clayton et al. [45] study reported improved the glycemic reaction to a standardized lunch in typical breakfast skippers, indicating that “some metabolic adaptation” could happen over time. Another study showed no variation in acylated ghrelin or GLP-1 concentrations either 1·5 or 3·5 hours after a standardized lunch.

Generally, these studies reported that breakfast minimally influences the orexigenic food desire hormone ghrelin, with some clues that breakfast could raise anorexigenic hormone patterns, as a result of sequent standardized feeding. Though breakfast skipping might influence eating habit, and providing a typical meal does not permit for appetite hormone profiles to be evaluated. This issue was detected as “the Bath Breakfast Project” [17]. These research studies determined “the glycemic, orexigenic and anorexigenic hormonal reactions” 3 hours later to breakfast consuming/skipping and 3 hours later to an ad lib lunch in thin and fatty peoples. Eating breakfast represses acylated ghrelin, related to increasing in PYY, glucose, GLP-1 and insulin, compared with breakfast omitting, in thin and fatty persons [56]. Later to an ad lib lunch, the levels of PYY were increased with no changes in GLP-1 (assessed in the thin group only) [53]. Inconsistent, acylated ghrelin concentrations were more in the breakfast consuming experience after lunch in thin and the fatty persons. Also, in the of Clayton et al. [45] study, they stated that breakfast eating in the early morning showing no influence on acylated ghrelin or GLP-1, 4 hours after an ad lib lunch.

These results suggested that the hormonal indicators of appetite are rapidly repressed by breakfast, however, varieties between breakfast consuming/skipping reduced after lunch, this consistent with individual appetite feelings. Similar results were found in the levels of hormone during the afternoon, and independent of breakfast eating. But, there is a clue of a long anorexigenic response to breakfast, mainly PYY. Another study revealed decreasing in the post-prandial insulin sensibility after 2 weeks of breakfast skipping [57]. While Betts et al. [58] study reported no variation in fasted insulin sensibility, also there was no variation in fasted PYY, acylated ghrelin, GLP-1, or leptin after 6 weeks of both consuming and skipping breakfast.

**Summary**

This review provided evidence on that breakfast is considered as the most commonly skipped meal, specifically in the young adult in the university study period. It also declared that the perceived lack of time was the main reason for omitting this important meal. The review, therefore, highlights the importance of time management skills to be developed early during life to avoid bad feeding habits. It was found that irregular omission of breakfast might be effective in energy intake reduction over the next 24 hours if the breakfast is habitually con-
sumed and in this day, exercise performance may be compromised.

Based on the experimental studies in adults available till now, there is no evidence on the belief that breakfast skipping induces overeating and weight gain. Further research is still needed before making conclusions for concerning the influences of consuming breakfast on the hormonal organization of food desire. Also, more studies are vital to identify the long-term influence of breakfast on the hormonal organization of food desire.

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