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Timing Matters: Impact of Meal Timing on Daily Calorie Intake of Office Workers †

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Abstract: This research aims to investigate the role of meal timing on calorie intake. A database of a company's cafeteria was used to track employees' food-purchasing behaviors. The findings show that starting meals early leads to an overall reduction in total daily calorie intake. However, the effect of meal timing differed between meals, with breakfast timing having the most significant impact followed by lunch and dinner timings. In terms of calorie intake per meal, breakfast timing was a decisive factor, followed by dinner, and lunch timing showed a weaker correlation to lunch intake. This result implied that early breakfast and dinner were important in managing calorie intake, while lunch timing had a lower impact. This research is a guide on how to lose weight or boost overall health through an appropriate dietary habit.

Keywords: over-weight; office workers; meal timing; calorie intake

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1. Introduction

The global prevalence of obesity surpassed 1 billion individuals, comprising 650 million adults. "WHO estimates that by 2025, approximately 167 million people will become less healthy because they are overweight or obese" [1]. Being overweight and obese are major risks for non-communicable diseases (NCDs) such as type 2 diabetes and cardiovascular diseases as well as mental health issues. People with obesity are also three times more likely to be hospitalized for COVID-19 [2]. Maintaining an appropriate weight and keeping in good shape contributes to health and work performance and fosters a positive image. However, it is difficult to lose weight, particularly in terms of maintaining the loss. Maximal weight loss is usually achieved at 6 months, but most individuals regain weight thereafter [3]. Roughly 20% of overweight individuals were successful in long-term weight loss [4]. Office workers have challenges including high pressure from intense competition, limited time for exercise, and the burden of heavy workloads. Many weight loss programs do not appeal to men [5], as men prefer weight loss programs that include familiar participants and are convenient to visit frequently [6]. Thus, discovering an easy-to-stick-to-weight management approach in office settings is essential. Herein, to find an appropriate diet method, the role of meal timing needs to be investigated. Therefore, in this study, the impact of meal timing on daily caloric intake and the variations in different meal timings were explored.

2. Literature Review

Research on meal timing encompasses two main perspectives: the medical aspect of the correlation between meal timing and physiological indicators and the behavioral science aspect of how behavioral changes promote overall health.

Medical research on meal timing patterns focused on overnight fasting, breakfast skipping, and late-night eating which were linked to metabolic health parameters, including blood glucose and blood pressure. These associations were mediated through the circadian regulation of metabolic tissues, gut microbial characteristics, and health behaviors such as food intake, physical activity, and sleep [7]. However, these strategies were impractical for office workers compared to altering the time of each meal.

The role of meal timing in energy intake and weight management is not well understood as most relative studies focused on surveys associated with meal frequency or the variability of meal timing between certain days. There has been little evidence that reducing meal frequency was beneficial for reducing energy intake [8,9]. However, other research results showed the associations between the variability of meal timing on weekends versus weekdays and body mass index [10]. Few studies evaluated the association between the timing of breakfast, lunch, and dinner, and caloric intake. The only relevant research was carried out in 2014 in which 59 participants were asked to record their eating behavior for seven days. The results suggested that the timing of meals, particularly eating just before sleeping could lead to weight gain [11]. However, it is important to note that the conclusions of this study were based on a small sample size (N = 59) and a short duration (seven days). Test errors were unavoidable due to manual recording. Thus, further support from larger datasets is necessary to prove the validity of the results. Based on a large-scale dataset obtained from an actual company cafeteria, this study was carried out by using food purchase data to specifically examine the impact of breakfast, lunch, and dinner timing on daily calorie intake and meal-specific calorie consumption.

3. Background

A large archival dataset of individual-level food purchasing records of a large e-commercial firm in China was adopted in this study. The data was offered by the cafeteria located at the headquarters building. The transaction data included user ID, dish ID, calories per serving, serving numbers, transaction date and time, and weight of food. This dataset comprised 67,077 records over three years, during which each employee's calorie intake, food choice, and time were recorded. These records were categorized on a per-person per-day basis, resulting in 10,099 individual observations. Further analysis of the categorized data was conducted on cafeteria transactions on Saturdays (n = 1046), breakfast purchases (n = 7054), lunch purchases (n = 6867), and dinner purchases (n = 5922). Then, a highly detailed view of the user's entire eating habit and insights into the collective eating habits of office workers as a group were obtained.

4. Economical Model

The daily caloric intake for each employee was calculated by categorizing all transactions. The caloric intake in a meal was evaluated with a function of a predefined time for each meal, as can be seen in Equation (1).

$$\mathrm{DailyCal}_{it} = \alpha_0 + \alpha_1 \Delta \mathrm{Bkf}_{it} + \alpha_2 \Delta \mathrm{Lun}_{it} + \alpha_3 \Delta \mathrm{Din}_{it} + e_{it}, \tag{1}$$

where $\mathrm{DailyCal}_{it}$ refers to the overall calorie intake of employee i on a day. The cumulative sum of calories per serving was also calculated. The dataset was categorized into three distinct meal types: breakfast (6:00–10:59), lunch (11:00–15:59), and dinner (16:00–23:59). Four variables were defined ($\Delta \mathrm{Bkf}_{it}$, $\Delta \mathrm{Lun}_{it}$, $\Delta \mathrm{Din}_{it}$, and ΔAllMeal) which corresponded to the value of breakfast, lunch, dinner, and the sum of the previous three values. The descriptive statistics of all variables appear in Table 1.

These variables quantified the difference in minutes between the timing of each meal and the anchor time which were predetermined with standard values (6:00 for breakfast, 11:00 for lunch, and 16:00 for dinner). By examining these variables, the extent to which individuals deviated from the established meal timings was evaluated with the potential impact on calorie intake patterns. The analogous equations for specific meals were as follows.

$$\mathrm{BkfCal}_{it} = \beta_0 + \beta_1 \Delta \mathrm{Bkf}_{it} + \beta_2 \Delta \mathrm{Lun}_{it} + \beta_3 \Delta \mathrm{Din}_{it} + e_{it}, \tag{2}$$

$$\text{LunCal}_{it} = \zeta_0 + \zeta_1\Delta\text{Bkf}_{it} + \zeta_2\Delta\text{Lun}_{it} + \zeta_3\Delta\text{Din}_{it} + e_{it}, \quad (3)$$

$$\text{DinCal}_{it} = \delta_0 + \delta_1\Delta\text{Bkf}_{it} + \delta_2\Delta\text{Lun}_{it} + \delta_3\Delta\text{Din}_{it} + e_{it}, \quad (4)$$

Table 1. Variable definitions and descriptive statistics.

Variable	Obs	Mean	SD	Median
DailyCal	10,099	923.28	4666.21	730.00
BkfCal	10,099	231.94	331.56	157.00
LunCal	10,099	389.28	3786.02	289.00
DinCal	10,099	302.07	2713.82	141.00
ΔAllMeal	3977	342.97	104.51	330.00
ΔBkf	7073	132.38	139.34	90.00
ΔLun	6873	76.14	46.85	60.00
ΔDin	5935	170.29	74.91	150.00

Nine carry over (β_1, β_2, β_3; ζ_1, ζ_2, ζ_3; δ_1, δ_2, and δ_3) and three baseline coefficients (β_0, ζ_0, and δ_0) were determined for each variable in the data set. β_2, β_3, ζ_1, ζ_3, δ_1, and δ_2 were inter-meal carryover coefficients [12] to assess the influence of the timing of other meals on the caloric content of the current meal. β_1, ζ_2, and δ_3 were the intra-meal carryover coefficient to assess the impact of the timing of the same meal on calorie intake. Inter-meal coefficients showed how the effects between meals were balanced, while the intra-meal coefficient reflects the stability of intake concerning the biological clock. These coefficients were used to assess the impact of meal timing as their absolute sizes indicated the strength of carryover effects and their signs indicated the positive or negative valence of the effects.

5. Results

A positive correlation between meal timing and daily calorie intake was found which suggested that delaying the start of meals led to an overall increase in total daily calorie intake. The fixed effects (FE) model was used to examine the cumulative effects of meal timing represented by ΔAllmeal (the sum of ΔBreakfast, ΔLunch, and ΔDinner). A significant coefficient was 0.540 (t = 5.18). The impact of ΔBreakfast was the most pronounced with a significant coefficient of 0.739 (t = 5.42), while the effects of ΔLunch (t = 0.77, coefficient = 0.258) and ΔDinner (t = 1.00, coefficient = 0.213) were smaller and not statistically significant. These results are shown in Table 2.

Table 2. Regression results (daily calorie intake).

Variable	(1) OLS	(2) FE	(3) FE_robust	(4) RE	(5) RE_robust	(6) MLE	(7) PA	(8) BE
ΔAllMeal	0.433 [a] ** (2.19) [b]	0.540 *** (5.18)	0.540 * (1.88)	0.583 *** (6.03)	0.583 ** (2.13)	0.584 *** (6.03)	0.598 *** (5.70)	0.806 *** (3.31)
ΔBkf	0.998 ** (2.32)	0.739 *** (5.42)	0.739 * (1.91)	0.774 *** (6.08)	0.774 ** (1.98)	0.775 *** (6.08)	0.789 *** (5.65)	0.842 *** (2.59)
ΔLun	1.753 *** (3.56)	0.258 (0.77)	0.258 (0.32)	0.449 (1.40)	0.449 (0.63)	0.451 (1.40)	0.553 (1.57)	2.172 * (1.92)
ΔDin	−1.249 *** (−4.38)	0.213 (1.00)	0.213 (0.72)	0.195 (0.96)	0.195 (0.72)	0.195 (0.96)	0.178 (0.80)	0.014 (0.02)

[a] This number shows the coefficient. [b] This result represents t-value. The asterisks (*) indicate * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

In terms of breakfast calorie intake, only ΔBreakfast showed a significant effect (t = 5.96, coefficient = 0.407), while the deviations for lunch and dinner indicated non-significant effects. This suggested that people did not consider future meal timings when consuming breakfast (e.g., taking in more calories in breakfast when lunch was expected to be eaten late). Surprisingly, for lunch, none of the deviations for breakfast, lunch, or dinner showed significant effects. Regarding dinner, both breakfast (t = 3.40, coefficient = 0.238) and dinner (t = 2.76, coefficient = 0.303) timings showed significant effects, while lunch timing did show a significant influence. These results are shown in Tables 3–5.

Table 3. Regression results (breakfast).

Variable	(1) OLS	(2) FE	(3) FE robust	(4) RE	(5) RE robust	(6) MLE	(7) PA	(8) BE
ΔBkf	0.590 *** (2.79)	0.407 *** (5.96)	0.407 ** (2.05)	0.470 *** (7.46)	0.470 ** (2.31)	0.467 *** (7.39)	0.464 *** (7.45)	0.749 *** (5.17)
ΔLun	0.767 *** (3.38)	0.167 (0.99)	0.167 (0.55)	0.278 * (1.75)	0.278 (1.10)	0.268 * (1.68)	0.261 * (1.66)	0.629 (1.25)
ΔDin	−0.757 *** (−4.76)	0.093 (0.87)	0.093 (0.43)	0.022 (0.22)	0.022 (0.12)	0.027 (0.27)	0.030 (0.30)	−0.444 (−1.64)

The asterisks (*) indicate * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 4. Regression results (lunch).

Variable	(1) OLS	(2) FE	(3) FE robust	(4) RE	(5) RE robust	(6) MLE	(7) PA	(8) BE
ΔBkf	0.093 (1.12)	0.094 (1.26)	0.094 (1.12)	0.055 (0.80)	0.055 (0.69)	0.051 (0.75)	0.043 (0.61)	−0.191 (−1.25)
ΔLun	0.661 *** (3.61)	−0.134 (−0.73)	−0.134 (−0.53)	−0.033 (−0.19)	−0.033 (−0.16)	−0.011 (−0.07)	0.044 (0.25)	0.701 (1.32)
ΔDin	−0.377 *** (−3.40)	−0.183 (−1.57)	−0.183 * (−1.72)	−0.149 (−1.38)	−0.149 (−1.40)	−0.148 (−1.38)	−0.150 (−1.34)	0.147 (0.52)

The asterisks (*) indicate * $p < 0.1$; *** $p < 0.01$.

Table 5. Regression results (dinner).

Variable	(1) OLS	(2) FE	(3) FE robust	(4) RE	(5) RE robust	(6) MLE	(7) PA	(8) BE
ΔBkf	0.316 (1.36)	0.238 *** (3.40)	0.238 (1.11)	0.256 *** (3.96)	0.256 (1.16)	0.259 *** (4.01)	0.263 *** (3.89)	0.284 * (1.82)
ΔLun	0.325 (1.22)	0.226 (1.31)	0.226 (0.54)	0.277 * (1.70)	0.277 (0.73)	0.286 * (1.75)	0.307 * (1.80)	0.842 (1.56)
ΔDin	−0.114 (−0.92)	0.303 *** (2.76)	0.303 ** (2.21)	0.312 *** (3.03)	0.312 ** (2.53)	0.313 *** (3.04)	0.313 *** (2.92)	0.311 (1.07)

The asterisks (*) indicate * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

6. Robustness of Model

To ensure the robustness of the model and its result, we conducted the robustness test using various econometric models. In addition to the fixed effects (FE) model, the results using seven alternative models including ordinary least squares (OLS), robust fixed effects (FE robust), random effects (RE), maximum likelihood estimation (MLE), population averaged (PA) and between effects (BE) were compared. The results are shown in Tables 3–5.

The results of these models showed that the seven models consistently supported the significant impact of meal timing on daily calorie intake. Similar consistency was observed for meal-specific calorie intake. The results of all models indicated a significant relationship between breakfast timing and calorie intake. Similarly, for lunch timing, seven to eight models yielded consistent results. For dinner timing, five to six models showed consistent findings. These consistent results across multiple models validated the robustness and reliability of the result of this study regarding the effects of meal timing on calorie intake.

7. Conclusions

The role of meal timing in overall calorie intake among office workers was investigated in this study. The effect of the timing of meals was validated using data from a large company cafeteria. The findings revealed that having meals early, particularly breakfast, played a significant role in reducing caloric intake. Instead of skipping or reducing dinner, having an early breakfast and an early dinner was effective in reducing calorie intake during dinner. Delaying lunchtime did not significantly affect calorie intake and daily calorie intake. This result showed healthier choices for individuals facing time constraints and having a busy work schedule. Evidence-based guidance was confirmed for individuals looking to lose weight or improve their overall health in this study. Importantly, the suggested meal timing can promote feasible and effective weight management in the daily routines of employees.

Though empirical data was analyzed to identify effective strategies for reducing calorie intake, the underlying medical mechanisms still need to be verified. Therefore, based on the findings of this study, it is necessary to explore how to decrease the body mass index (BMI) or improve overall health. The optimal dietary composition for achieving these outcomes also needs to be found out. For health management, the differential effects of meal timing on weekdays versus weekends are also required to be researched. Additionally, more data including health conditions and gender are necessary to provide a more comprehensive understanding of the relationship between meal timing and health management. Obese males intake twice as many calories between 10 PM and 4 AM compared to normal males [13]. Compared to obese females, normal-weight females eat dinner later on the weekends [14]. By incorporating these factors, additional insights can be obtained for personalized health management strategies for office workers.

The research findings of this study can be applied to the establishment of individual weight loss goals. Companies can adjust work schedules to encourage healthy diet habits and reduce the risk of chronic diseases associated with heavy work. By fostering a supportive environment that promotes healthy behaviors, companies can improve employees' working performance and enhance overall productivity and well-being in the workplace.

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Institutional Review Board Statement: Ethical review and approval were waived for this study due to the data containing only cafeteria order information in daily life scenario. It is not medical study.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is unavailable due to privacy or ethical restrictions.

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