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ORIGINAL RESEARCH

Food order and carbohydrate distribution: effects on glycemia in healthy young women

M. Moscati[1]

1 Italy

1. ABSTRACT

The analyzed study compared, in 18 healthy young Japanese women, two days with the same foods and the same total nutrients: three traditional mixed meals or five eating occasions, with carbohydrates distributed in smaller portions and consumed after vegetables and proteins. The crossover design, in which each participant follows both conditions, showed a reduction in the amplitude of glycemic oscillations, post-meal peaks, the incremental area under the glycemic curve, and the time spent above 7.8 mmol/L in the five-meal model.In paragraph 3.1 of “The Choice to Live in Health or Illness” by Dr. A. Colonnese and R. Panzironi, the publication contributes to the narrative that carbohydrate distribution and food order can attenuate postprandial glycemic excursions. Independent crossover studies and systematic reviews confirm, above all, the acute effect of consuming carbohydrates after vegetables and proteins. There is also data consistent with an effect of the previous meal on the subsequent glycemic response. However, the specific contribution of the subdivision into five meals cannot be separated from that of food order, and evidence of diabetes prevention or long-term complications is not available.

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MISSION

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Through articles, reviews, in-depth analyses and expert contributions, the Journal champions evidence-based medicine and science, fostering a correct interpretation of scientific data and countering misinformation. Every piece of content is developed with the aim of translating the complexity of research into understandable, useful and applicable information, while keeping intact the principles of accuracy, transparency and scientific independence.

Free from political, industrial and commercial influence, the journal stands as an authoritative and independent editorial space, dedicated to promoting scientific culture, professional development and the growth of health awareness among the public.

2. ANALYZED STUDY

The research question was whether, given the same total calories and nutrients, distributing carbohydrates across five eating occasions and consuming them after vegetables and proteins would reduce glucose fluctuations compared to three meals where all foods were consumed together. The hypothesis was relevant because post-meal glucose spikes constitute a significant part of glycemic variability, that is, the magnitude by which glucose rises and falls throughout the day.The relevance to the book's section is precise: the research documents that a strategy consisting of smaller carbohydrate portions, more frequent eating intervals, and a vegetable protein carbohydrate sequence is associated with smaller acute glycemic excursions. However, it cannot establish which component of the strategy is responsible for the effect, because the modifications were applied together. Furthermore, it cannot demonstrate that this method prevents diabetes or its complications.

3. MATERIALS AND METHODS OF THE ORIGINAL STUDY

A randomized, open-label, crossover clinical trial was conducted between May and July 2025. Eighteen healthy Japanese female students were recruited, with a mean age of 21.4 ± 0.8 years, a mean weight of 50.1 ± 5.4 kg, and a mean body mass index of 20.2 ± 1.9 kg/m². Individuals with type 1 or type 2 diabetes, those using medications capable of affecting glucose metabolism, and women who were pregnant or potentially pregnant were excluded.Each participant wore an intermittent and continuous glucose monitoring system for six days, which measures glucose in the interstitial fluid—the fluid between cells—rather than directly in the blood. On the fourth and fifth days, they consumed the same foods following two patterns assigned in random order. The conventional pattern consisted of three meals, with all food consumed together within 15 minutes. The experimental pattern involved five occasions: breakfast divided into two parts, lunch divided into two parts, and dinner; during each occasion, foods were consumed in the order of vegetables, proteins, and carbohydrates.The daily intake was identical in both patterns: 1,822 kcal, 77.8 g of protein, 52.6 g of fat, 284.5 g of carbohydrates, and 27.2 g of fiber. The primary outcome was MAGE, or the mean amplitude of glycemic excursions. Glycemic peaks, standard deviation, coefficient of variation, incremental area under the glycemic curve after each meal, and the time spent above, within, or below predetermined glucose ranges were also evaluated. The sample size was calculated for MAGE, and differences were analyzed using t-tests.

4. RESULTS

All 18 participants completed the study. With the five-meal plan, the average 24-hour glycemia was not substantially different compared to the three-meal plan: 5.20 ± 0.14 versus 5.25 ± 0.14 mmol/L. The total incremental area over 24 hours also showed no appreciable difference. In other words, the change did not clearly lower the average daily glucose level, but it did modify the profile, making it less characterized by rapid and large increases.The MAGE decreased from 3.49 ± 0.32 mmol/L with three meals to 2.56 ± 0.13 mmol/L with five meals, with $p < 0.01$. The standard deviation of glucose decreased from 1.07 ± 0.08 to 0.84 ± 0.04 mmol/L. The maximum recorded value was also lower, 7.35 ± 0.25 instead of 8.96 ± 0.40 mmol/L, and the glycemic peak after breakfast, lunch, and dinner was reduced in the experimental plan.The effect was particularly evident in the hours immediately following lunch and dinner. For example, after dinner, the incremental area under the curve at 180 minutes decreased from 314 ± 35 to 114 ± 19 mmol/L × min, while at 300 minutes it was 361 ± 37 versus 148 ± 24 mmol/L × min. The time above 7.8 mmol/L, a threshold equivalent to 140.4 mg/dL, decreased from 4.2 ± 1.0% to 1.4 ± 0.6% of the day, with $p < 0.01$. The time in the 3.9–7.8 mmol/L range and the time below 3.9 mmol/L showed no relevant differences.

5. INTERPRETATION

In simple terms, the experimental protocol did not clearly reduce the average amount of circulating glucose throughout the day, but it did reduce the magnitude and speed of certain spikes after meals. This is the segment of the book's narrative that the study directly documents: a different organization of meals can attenuate acute glycemic variability.The proposed biological explanation is plausible. Smaller portions of carbohydrates can reduce the glycemic load of each individual eating occasion. Vegetables

and proteins consumed before carbohydrates can delay the availability of carbohydrates in the intestine and modify the response of gut hormones called incretins, including GLP-1 and GIP, which participate in the regulation of glycemia and insulin. The so-called second-meal effect, on the other hand, indicates that a previous meal or snack can favorably influence the response to the subsequent meal.These mechanisms were not measured directly: the study did not assay insulin, GLP-1, GIP, free fatty acids, or gastric emptying. Furthermore, the comparison combined three interventions: carbohydrate fractionation, number of meals, and food sequencing. For this reason, the results demonstrate the effect of the complete protocol, not the share attributable with certainty to each individual step.

6. INDEPENDENT CONFIRMING EVIDENCE

A systematic review of 11 acute experiments with isocaloric meals, i.e., with equal energy intake, evaluated the order of food intake. In all studies measuring glucose and insulin, consuming carbohydrates last tended to reduce at least some postprandial excursions; the most consistent certainty, judged as moderate by the authors, concerned the acute reduction of glucose and insulin excursions. This evidence confirms the narrative regarding the sequence of vegetables and/or proteins before carbohydrates, but does not specifically verify the five-meal model [1].In the PATTERN study, 16 healthy Chinese adults completed a randomized crossover with five different sequences of the same foods: vegetables, chicken, and rice. Compared to rice consumed first, the overall glycemic response was significantly attenuated when vegetables and proteins preceded the rice. The sequence of vegetables meat rice also produced greater GLP-1 secretion without an increased demand for insulin in the first 60 minutes. This experiment directly supports both the direction of the effect on glucose and the plausibility of the link with incretins, although it remains a short study on a small group of healthy people [2].The possible effect of the previous meal is supported by a small crossover experiment on 10 adults with type 2 diabetes treated with diet and/or metformin. A protein-rich soy and yogurt snack before breakfast reduced the incremental area under the glucose curve after breakfast from 699 ± 99 to 450 ± 55 mmol·min/L. The result is compatible with the so-called second-meal effect, but it concerns a population with diabetes and a protein snack before breakfast; it does not prove that the same mechanism explains the effect observed in the young healthy women in the analyzed study [3].

7. CONFLICTING EVIDENCE

A 2026 meta-analysis included 18 randomized trials on the consumption of vegetables before carbohydrates. It found a reduction in postprandial glycemia at 30 minutes, equal to −1.21 mmol/L, and at 60 minutes, equal to −0.52 mmol/L. However, at 120 minutes, glycemia was 0.24 mmol/L higher compared to controls. This trend suggests that the initial benefit may also reflect a delayed shift in the glycemic response, rather than necessarily a uniform reduction in total glucose exposure [4].The authors rated the certainty of the estimates as very low and identified a moderate risk of bias in ten studies and a high risk in eight. This evidence does not contradict the attenuation of early peaks observed in the analyzed study, but it cautions against automatically interpreting a lower peak as an improvement in all glycemic indicators or as a long-term clinical benefit. No sufficiently relevant directly conflicting evidence was identified regarding the combined scheme of five meals with fractionated carbohydrates; this does not prove the absence of contrary results.

8. QUADRO COMPARATIVO E SINTESI DELLE EVIDENZE

The table distinguishes the study that is the subject of the Evidence Review from independent publications that confirm or define the scope of the paragraph's narrative.

Quadro comparativo

Reference	Study type	Population or model	Main result	Direction of evidence	Strength of evidence
Original study	Open-label crossover RCT	18 healthy young Japanese women	Five meals with fractionated carbohydrates and a vegetable → protein → carbohydrate sequence reduced MAGE, peaks, and time above 7.8 mmol/L compared to three mixed meals.	direct confirmation	moderate
[1]	Systematic review	11 acute experiments, mixed populations	Consuming carbohydrates last tended to reduce postprandial glucose and insulin excursions.	direct confirmation	moderate
[2]	Crossover RCT	16 healthy Chinese adults	Vegetables and protein before rice attenuated the glycemic response; the vegetable → meat → rice sequence increased GLP-1 without higher early insulin demand.	direct confirmation	moderate
[3]	Crossover study	10 adults with type 2 diabetes	A protein snack before breakfast reduced the incremental post-breakfast glucose area.	indirect confirmation	preliminary
[4]	Systematic review and meta-analysis	18 RCTs in adults with and without clinical conditions	Reduction in glycemia at 30 and 60 minutes, but higher value at 120 minutes; very low certainty.	discordant evidence	moderate

9. SINTESI EDITORIALE E CONCLUSIONI

CONCLUSIONS

The analyzed study shows that, in the healthy young women examined, five eating occasions with carbohydrates portioned and consumed after vegetables and proteins reduced postprandial spikes and glycemic variability compared to three mixed meals with identical nutritional value. The result is moderately supported by independent literature regarding food sequencing. The specific role of meal portioning, incretins, gastric emptying, and the second-meal effect requires targeted validation. It has not been proven that this strategy prevents diabetes or replaces individualized clinical interventions.

Aggiornato al 17/11/2026. Questo contenuto riflette una sintesi divulgativa delle evidenze scientifiche al momento della pubblicazione e non sostituisce il parere medico.

10. TRANSPARENCY AND SCIENTIFIC RESPONSIBILITY

Artificial Intelligence was used solely as a tool for editorial and documentary support. All content, interpretations, bibliographic citations and conclusions have been verified, reviewed and approved by the author, who assumes full scientific responsibility for them.

The manuscript was also subjected to independent peer review prior to publication.

To ensure the greatest transparency, the complete history of the article, including the dates of submission, revision, acceptance and publication, as well as information on the peer review process, is available on the dedicated Article History page.

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