METABOLIC STRESS AND ADAPTATION TOWARDS INTERMITTENT FASTING COMBINED WITH MACRONUTRIENT INTAKE ORDER MINIREVIEW

Cvetomir Kirov
National Sport Academy "Vassil Levski", Sofia, Bulgaria

ABSTRACT
Introduction: Overweight and obesity have become major public health concerns in modern society. The widespread availability of calorie-dense foods, coupled with a decline in physical activity, has significantly contributed to the rise in nutrition-related metabolic disorders. The increasing frequency of daily meals may further exacerbate this issue. Feeding patterns have shifted dramatically from the traditional 2–3 meals per day in the 1970s to more than 10 eating occasions per day in recent years. This trend signals a worrying trajectory, with the prevalence of overweight and obesity potentially reaching alarming levels. As of 2021, 537 million people were diagnosed with diabetes, a number projected to rise to 783 million by 2045. To address this growing crisis, some nutrition experts have proposed restricting the daily feeding window, while others recommend strategies aimed at reducing insulin spikes, such as consuming macronutrients in a specific order: vegetables, then meat, followed by rice. This minireview aimed to outline the most used weight loss strategies, the scientific knowledge that supports them, and the assumptions made by logic.
Methodology: For the sake of our investigation, we have reviewed twenty-six scientific studies, national database reports, expert panel reports, dietary guidelines, and meta-analyses. The literature was categorized to address the various dimensions of the topic systematically.
Results: Intermittent fasting (IF) when combined with a strict order of macronutrient ingestion within the feeding window appears to first reduce the time frame for alimentation. This temporal restriction is associated with a decrease in meal frequency and total caloric consumption across the day. Moreover, the consequent reduction allows a reduction in insulin levels, which in turn assists in lipolysis to occur and provide glucose for normoglycemia.
Conclusion: IF, combined with structured macronutrient intake, contributes to reduced insulin secretion and offers a promising approach for modulating postprandial glucose and insulin responses.

ORCID
Cvetomir Kirov
https://orcid.org/0009-0009-4596-2979
Cite this article as:
Kirov, C. (2025). Metabolic stress and adaptation towards intermittent fasting combined with macronutrient intake order minireview. *Proceeding book of the 4th International Scientifi c Congress "Applied Sports Sciences", 2025, Sofia.* pp. 313 - 318. https://doi.org/10.37393/ICASS2025/49

Keywords: *Weight loss, time-restricted eating, obesity prevention, macronutrient consumption sequence*

INTRODUCTION

In this minireview, we aim to shed light on the importance of IF for overall well-being and physical health. Additionally, we investigate whether the order of macronutrient consumption can influence the trajectory of the blood glucose curve in isocaloric meals.

Since ancient times, people have practiced fasting for various reasons, such as religious, spiritual, self-discipline, and others (Grajower & Horne, 2019). However, with the advent of the industrial revolution and the year-round availability of food, modern society has significantly increased the frequency of eating and snacking. The number of daily meals has shifted drastically from the widely accepted 2–3 meals per day in the 1970s to more than 10 eating occasions per day today (Gill & Panda, 2015).

Modern society has tended to reduce the complex issue of fat accumulation to a simple equation: calories in versus calories out. This view is rooted in the first law of thermodynamics, which states that energy within a system is conserved, meaning the energy input must equal the energy output plus any change in internal energy ("C." 2015). This belief has become widely adopted and forms the basis of one of the most commonly recommended weight-loss strategies: to lose weight, one must simply consume fewer calories and increase energy expenditure through physical activity (Expert Panel Report: Guidelines for the Management of Overweight and Obesity in Adults, 2013; Schwartz

et al., 2017).

Ludwig et al. (2021) describe two of the most prominent models that have shaped nutritional science over the past century. The first is the Energy Balance Model (EBM), which posits that reducing caloric intake (eating less) and increasing physical activity should inevitably lead to weight loss. This model, however, largely overlooks the complexity of human biological systems, focusing narrowly on the arithmetic of calorie intake versus expenditure. In contrast, the Carbohydrate-Insulin Model (CIM) offers an alternative explanation. CIM attributes fat accumulation to the overconsumption of highly processed, high-glycemic-load foods, which disrupt hormonal regulation, particularly insulin, and promote a positive energy balance (Ludwig et al., 2021).

In a complementary perspective, Pontzer et al. (2016) describe two models of energy expenditure that account for total energy expenditure (TEE). The first, the additive model, is more widely recognized, likely due to its simplicity. It conceptualizes TEE as the sum of the energy expended on physical activity and the basal metabolic rate (BMR), assuming the latter remains constant. The second, the constrained model, considers the adaptive nature of biological systems. It posits that increases in physical activity or decreases in caloric intake are met with compensatory reductions in other metabolic processes. In this view, total energy expenditure does not increase proportionally with physical activity but is instead regulated by a reduction in BMR to maintain energy balance (Bautista et al., 1998; Pontzer, 2015).

IF has been shown to enhance metabolic rate and increase the secretion of norepinephrine, thereby promoting fat metabolism over glucose oxidation, reducing insulin secretion, and contributing to body weight reduction (Zauner et al., 2000; Natalucci et al., 2005). Prolonged fasting periods, such as the 18:6 protocol, may suppress appetite, naturally leading to reduced caloric intake and subsequently lowering both glucose and insulin levels. This metabolic shift favors fat oxidation to meet the body's energy demands (Cienfuegos et al., 2020).

Complementary to fasting, the macronutrient order of meals may also influence glycemic control. Specifically, consuming food in the sequence of vegetables, proteins, and carbohydrates has been shown to attenuate postprandial glucose spikes (Imai et al., 2011; Shukla et al., 2015; Nesti et al., 2019; Sun et al., 2020). By blunting insulin peaks, this strategy supports more stable blood glucose levels, reduces the risks of both hypo- and hyperglycemia, and minimizes the long-term complications associated with poor glycemic control (Nathan et al., 1993; UKPDS 33 & 34, 1998; Nathan et al., 2005; Holman et al., 2008).

In summary, an effective dietary strategy should consider not only caloric intake but also hormonal regulation. Fasting appears to integrate both factors through a relatively simple protocol involving extended periods of food deprivation followed by a defined feeding window.

In this study, we aimed to evaluate whether IF combined with sequential food consumption (vegetables first, followed by proteins and then carbohydrates) would result in a synergistic effect greater than either strategy alone. To investigate this, we compiled data from twenty-six peer-reviewed scientific studies relevant to the topic and analyzed them to determine the validity of this approach.

METHODOLOGY

To identify relevant studies, we utilized several academic databases, including PubMed, Google Scholar, Scopus, and Web of Science. The inclusion criteria were defined to encompass clinical trials focused on overweight, obesity, insulin resistance, diabetes, nutrition, dieting, IF, and the regulation of blood glucose and insulin. Additionally, some database-generated recommendations were considered for review. Complementary data, such as country-specific and global incidence trends, were also included, sourced from expert panel reports, national health databases, and best practice guidelines. A total of twenty-six scientific studies were evaluated against alternative approaches, forming the foundation of this minireview article.

RESULTS

Caloric restriction (CR) has been shown to result in a decline in resting metabolic rate (RMR), an indicator of reduced energy expenditure for basal physiological processes (Leibel et al., 1984). This reduction is accompanied by decreased levels of several appetite- and metabolism-regulating hormones, including leptin, cholecystokinin (CCK), ghrelin, and reported subjective hunger. Following weight loss, the body appears to engage in homeostatic compensation through significant reductions in leptin, peptide YY (PYY), CCK, and insulin ($p < .001$ for all comparisons), amylin ($p = .002$), and pancreatic polypeptide ($p = .008$). Conversely, average levels of ghrelin and gastric inhibitory polypeptide (GIP) increase significantly ($p < .001$), contributing to enhanced appetite (Sumithran et al., 2011).

In contrast to traditional CR, IF operates through distinct physiological and hormonal mechanisms. IF not only influences the quantity and type of food consumed but also emphasizes meal timing and the fasting-feeding cycle. It has been shown to lower insulin levels, reduce overall caloric intake, improve insulin sensitivity, and enhance fat oxidation In terms of energy expenditure, Zauner et al. (2000) reported a significant increase in resting energy expenditure (REE), measured via indirect calorimetry, during a four-day fasting protocol involving 11 lean, fit participants. REE rose from 3.97 ± 0.9 kJ/min at baseline to 4.53 ± 0.9 kJ/min by day 3 ($p < .05$), accompanied by a substantial increase in serum norepinephrine levels from 1716 ± 574 to 3728 ± 1636 pmol/L. Patel et al. (2002) reported comparable trends, with REE increasing from 4.89 ± 0.3 kJ/min on day 1 to 5.02 ± 0.4 kJ/min on day 3

Evidence from multiple studies suggests that the sequence in which macronutrients are consumed, specifically, consuming carbohydrates after proteins and/or fats, can significantly influence glycemic control. This pattern promotes glucagon-like peptide-1 (GLP-1) secretion from the intestine, enhances insulin and glucagon release, and delays gastric emptying, collectively resulting in a flatter postprandial glucose curve (Nesti et al., 2019).

A study by Shukla et al. (2015) demonstrated that the order of macronutrient consumption can produce glycemic effects comparable to those of pharmacological agents aimed at lowering postprandial glucose. Similarly, Imai et al. (2011) conducted a study involving groups of diabetic participants divided into two dietary intervention methodologies. The Exchange-Based Meal Plan (EXB) group ($n = 32$) received guidance on food exchanges using standardized nutritional values, while the other Vegetables Before Carbohydrates (VBC) group ($n = 69$) was instructed to consume vegetables prior to carbohydrate intake at each meal. Both groups showed significant improvements in HbA1c over 24 months, but the VBC group demonstrated superior outcomes at 6, 9, 12, and 24 months.

Sun et al. (2020) further confirmed the impact of macronutrient sequencing. In their study, postprandial glucose levels peaked when rice was consumed first, followed by vegetables and meat. The researchers concluded that beginning a meal with vegetables, followed by protein and ending with carbohydrates, significantly improves glycemic, insulinemic, and incretin responses.

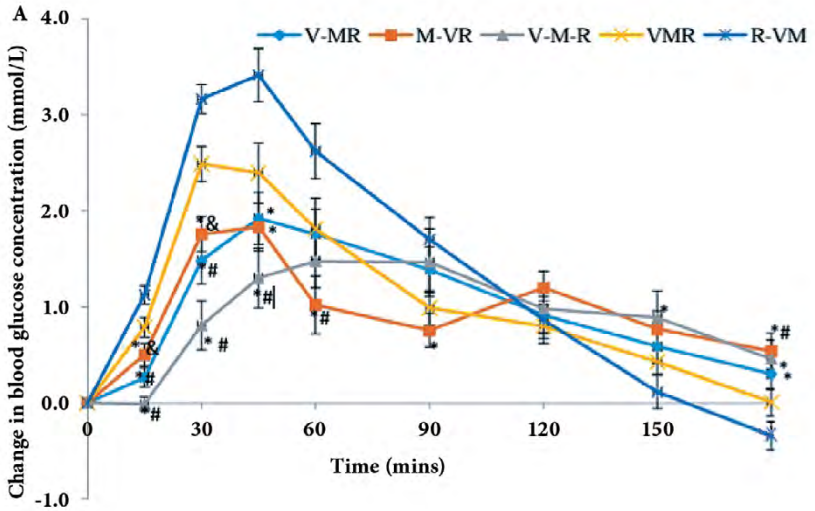

Figure 1. *Given five different food intake sequences, each respective postprandial glucose response over a 180-minute timeframe. Reproduced from Sun et al. (2020) with permission from Elsevier.*

Since IF reduces insulin levels and low insulin permits lipolysis, the increase in physical activity during IF is likely to promote fat oxidation. Utilizing fat as a primary energy source contributes to the reduction of adipose tissue and supports weight loss. This mechanism aligns with the (CIM), which posits that low insulin levels are essential for mobilizing fat as a metabolic fuel during periods of energy demand, such as exercise. Furthermore, combining IF with strategic macronutrient sequencing, specifically consuming vegetables first, followed by protein, and carbohydrates last, may help sustain lower postprandial insulin levels. This dietary pattern enhances the conditions necessary for continuous fat oxidation and may optimize body composition over time.

DISCUSSION

IF consists of a fasting period followed by a defined eating window. As insulin and glucose levels fall after the last meal, glucagon rises, stimulating glycogen breakdown and fat oxidation. Once glycogen stores are depleted, triglycerides become the primary energy source, a shift sustained only under low insulin. IF also increases norepinephrine and growth hormone, enhancing fat oxidation, preserving lean mass, and maintaining metabolic rate.

The findings of this minireview support the conclusions of Ludwig et al. (2021) regarding the CIM. Hormones are an integral component of human physiology, enabling adaptation to dynamic environmental and metabolic demands. This adaptive hormonal responsiveness has played a vital role in the evolution and survival of the human species. Hormones act as chemical messengers synthesized by the endocrine system; they travel through the bloodstream to specific organs or tissues, triggering targeted physiological responses.

In contrast, the EBM largely disregards hormonal dynamics. It assumes that the only factors influencing weight regulation are the caloric content of consumed foods, measured in kilocalories per gram, and total energy intake. According to this model, if energy intake is lower than energy expenditure, the resulting deficit is compensated by mobilizing stored adipose tissue (Ludwig et al., 2021).

Ludwig et al. (2021) argue that CIM more effectively captures the hormonal and metabolic processes that regulate energy balance. By contrast, the EBM assumes all calories are equivalent, summarized in the phrase "a calorie is a calorie," and overlooks macronutrient-specific hormonal effects. Ludwig and colleagues call for a paradigm shift toward dietary quality, emphasizing low-glycemic-load foods and carbohydrate restriction as more effective strategies for managing obesity.

The EBM holds that combining caloric restriction with exercise promotes weight loss, with the additional energy for muscular work drawn from fat stores (Ludwig et al., 2021). Pontzer et al. (2016) challenge this view, however, with the constrained model, which proposes that the body adapts by downregulating other processes, thereby keeping total energy expenditure within a limited range.

This constrained response reflects hormonal regulation, particularly insulin's inhibition of fat mobilization, as well as evolutionary adaptations to energy scarcity. Pontzer et al. (2016) found that caloric deficits reduced non-exercise activity thermogenesis (NEAT) and, by week 40, lowered basal metabolic rate (BMR), ovarian activity, and estrogen in women. Such adaptations underscore the limits of the "eat less, move more" approach and the need for a more nuanced understanding of weight regulation.

Adherence to severe caloric restriction is strongly affected by hunger. Leibel et al. (1995) showed that prolonged restriction produces a hormonal profile that intensifies appetite and impedes fat loss: ghrelin and gastric inhibitory polypeptide (GIP) increase, stimulating hunger and insulin secretion, while leptin, peptide YY (PYY), cholecystokinin (CCK), insulin, amylin, and pancreatic polypeptide decline, reducing satiety (Sumithran et al., 2011).

Leptin, which regulates long-term energy balance by signaling satiety and modulating expenditure, declines with adipose loss, signaling deficiency, and promoting intake. Reductions in PYY and CCK further weaken short-term satiety. Amylin, secreted with insulin at ~1:100, slows gastric emptying and enhances satiety while stabilizing postprandial glucose; its decline undermines both glycemic control and fullness.

In a study by Sumithran et al. (2011), participants who had successfully completed a weight loss program were followed for one year. From which researchers found that levels of leptin, PYY, CCK, insulin, ghrelin, GIP, and subjective hunger remained significantly altered long after initial weight loss. These findings suggest that the human body engages multiple homeostatic mechanisms to defend fat mass.

The elevation in blood glucose due to food consumption stimulates the pancreas to secrete insulin. However, elevated insulin levels also inhibit lipolysis, primarily by inducing the inactivation of hormone-sensitive lipase (HSL) and dephosphorylation (Enoksson et al., 1998).

Collectively, these findings suggest that norepinephrine not only promotes fat mobilization at the tissue level but also contributes to maintaining or even increasing overall energy expenditure during periods of caloric restriction or fasting.

Limitations

To the authors' knowledge, there are currently no long-term studies specifically focused on IF that track hormonal changes over extended periods of fasting. This lack of longitudinal data limits our understanding of the long-term efficacy, safety, and sustainability of IF.

This minireview was designed to explore the combined effects of two independently supported weight management strategies, IF and macronutrient sequencing. However, several limitations must

be acknowledged:

- Small sample sizes in many of the included studies, which result in low statistical power and make it difficult to detect small but potentially meaningful effects or to generalize findings to broader populations.
- Protocol inconsistencies across studies, including potential methodological errors or deviations, may introduce bias and affect the accuracy of the pooled results.
- Lack of standardization in intervention designs (e.g., fasting duration, meal composition, macronutrient proportions) may contribute to heterogeneity and reduce the comparability of outcomes across studies.

These limitations underscore the need for well-controlled, large-scale, long-term studies to confirm the proposed benefits of combining IF with strategic macronutrient intake and to establish robust, evidence-based guidelines for clinical and public health applications.

CONCLUSION

There is a substantial amount of scientific literature regarding IF alone that attributes benefits like reduced insulin levels, improved insulin resistance, reduced adipose tissue, etc. to IF. A growing pool of studies using the order of macronutrient intake consisting of vegetables, protein, and carbohydrates, lastly, suggests that this sequence of macronutrient ingestion reduces insulin spikes to a degree resembling pharmaceutical drugs. The synergy of IF with such macronutrient order in the feeding window offers a promising approach for modulating postprandial glucose excursions and insulin response. Further experimental research combining those two strategies must be conducted in order to see if the presumable net effect will elicit the expected results.

REFERENCES

Bautista, L. M., Tinbergen, J., Wiersma, P., & Kacelnik, A. (1998). Optimal foraging and beyond: How starlings cope with changes in food availability. *The American Naturalist*, *152*(4), 543–561. https://doi.org/10.1086/286189

C. (2015). *Dictionary of Energy*, 82–145. https://doi.org/10.1016/b978-0-08-096811-7.50003-2

Cienfuegos, S., Gabel, K., Kalam, F., Ezpeleta, M., Wiseman, E., Pavlou, V., Lin, S., Oliveira, M. L., & Varady, K. A. (2020). Effects of 4- and 6-h time-restricted feeding on weight and cardiometabolic health: A randomized controlled trial in adults with obesity. *Cell Metabolism*, *32*(3), 366-378.e3. https://doi.org/10.1016/j.cmet.2020.06.018

Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34). UK Prospective Diabetes Study (UKPDS) Group. (1998). *Lancet (London, England)*, *352*(9131), 854–865. https://pubmed.ncbi.nlm.nih.gov/9742977

Enoksson, S., Degerman, E., Hagström-Toft, E., Large, V., & Arner, P. (1998). Various phosphodiesterase subtypes mediate the in vivo antilipolytic effect of insulin on adipose tissue and skeletal muscle in man. *Diabetologia*, *41*(5), 560–568. https://doi.org/10.1007/s001250050947

Expert panel report: Guidelines (2013) for the management of overweight and obesity in adults. (2013). *Obesity*, *22*(S2), S41–S410. https://doi.org/10.1002/oby.20660

Gill, S., & Panda, S. (2015). A Smartphone app reveals erratic diurnal eating patterns in humans that can be modulated for health benefits. *Cell Metabolism*, *22*(5), 789–798. https://doi.org/10.1016/j.cmet.2015.09.005

Grajower, M. M., & Horne, B. D. (2019). Clinical management of intermittent fasting in patients with diabetes mellitus. *Nutrients*, *11*(4), 873. https://doi.org/10.3390/nu11040873

Holman, R. R., Paul, S. K., Bethel, M. A., Matthews, D. R., & Neil, H. A. W. (2008). 10-year follow-up of intensive glucose control in type 2 diabetes. *The New England Journal of Medicine*, *359*(15), 1577–1589. https://doi.org/10.1056/NEJMoa0806470

Imai, S., Matsuda, M., Hasegawa, G., Fukui, M., Obayashi, H., Ozasa, N., & Kajiyama, S. (2011). A simple meal plan of "eating vegetables before carbohydrate" was more effective for achieving glycemic control than an exchange-based meal plan in Japanese patients with type 2 diabetes. *Asia Pacific Journal of Clinical Nutrition*, *20*(2), 161–168. https://pubmed.ncbi.nlm.nih.gov/21669583/

Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. (2025). *Lancet (London, England)*, *352*(9131). https://pubmed.ncbi.nlm.nih.gov/9742976

Leibel, R. L. & Hirsch, J. (1984). Diminished energy requirements in reduced-obese patients. *Metabolism*, *33*(2), 164–170. https://doi.org/10.1016/0026-0495(84)90130-6

Leibel, R. L., Rosenbaum, M., & Hirsch, J. (1995). Changes in energy expenditure re-

sulting from altered body weight. *New England Journal of Medicine*, *332*(10), 621–628. https://doi.org/10.1056/nejm199503093321001

Ludwig, D. S., Aronne, L. J., Astrup, A., de Cabo, R., Cantley, L. C., Friedman, M. I., Heymsfield, S. B., Johnson, J. D., King, J. C., Krauss, R. M., Lieberman, D. E., Taubes, G., Volek, J. S., Westman, E. C., Willett, W. C., Yancy, W. S., & Ebbeling, C. B. (2021). The carbohydrate-insulin model: a physiological perspective on the obesity pandemic. *The American Journal of Clinical Nutrition*, *114*(6). https://doi.org/10.1093/ajcn/nqab270

Natalucci, G., Riedl, S., Gleiss, A., Zidek, T., & Frisch, H. (2005). Spontaneous 24-h ghrelin secretion pattern in fasting subjects: maintenance of a meal-related pattern. *European Journal of Endocrinology*, *152*(6), 845–850. https://doi.org/10.1530/eje.1.01919

Nathan, D. M., Genuth, S., Lachin, J., Cleary, P., Crofford, O., Davis, M., Rand, L., & Siebert, C. (1993). The effect of intensive treatment of diabetes on the development and progression of Long-Term complications in Insulin-Dependent diabetes mellitus. *New England Journal of Medicine*, *329*(14), 977–986. https://doi.org/10.1056/nejm199309303291401

Nathan, D. M. (2005). Intensive diabetes treatment and cardiovascular disease in patients with type 1 diabetes. *New England Journal of Medicine*, *353*(25), 2643–2653. https://doi.org/10.1056/nejmoa052187

Nesti, L., Mengozzi, A., & Tricò, D. (2019). Impact of nutrient type and sequence on glucose tolerance: Physiological insights and therapeutic implications. *Frontiers in Endocrinology*, *10*(10). https://doi.org/10.3389/fendo.2019.00144

Patel, J. N., Coppack, S. W., Goldstein, D. S., Miles, J. M., & Eisenhofer, G. (2002). Norepinephrine Spillover from Human Adipose Tissue before and after a 72-Hour Fast. *The Journal of Clinical Endocrinology & Metabolism*, *87*(7), 3373–3377. https://doi.org/10.1210/jcem.87.7.8695

Pontzer, H. (2015). Constrained total energy expenditure and the evolutionary biology of energy balance. *Exercise and Sport Sciences Reviews*, *43*(3), 110–116. https://doi.org/10.1249/jes.0000000000000048

Pontzer, H., Durazo-Arvizu, R., Dugas, Lara R., Plange-Rhule, J., Bovet, P., Forrester, Terrence E., Lambert, Estelle V., Cooper, Richard S., Schoeller, Dale A., & Luke, A. (2016). Constrained total energy expenditure and metabolic adaptation to physical activity in adult humans. *Current Biology*, *26*(3), 410–417. https://doi.org/10.1016/j.cub.2015.12.046

Schwartz, M. W., Seeley, R. J., Zeltser, L. M., Drewnowski, A., Ravussin, E., Redman, L. M., & Leibel, R. L. (2017). Obesity pathogenesis: An endocrine society scientific statement. *Endocrine Reviews*, *38*(4), 267–296. https://doi.org/10.1210/er.2017-00111

Shukla, A. P., Iliescu, R. G., Thomas, C. E., & Aronne, L. J. (2015). Food order has a significant impact on postprandial glucose and insulin levels: *Diabetes Care*, *38*(7), e98–e99. https://doi.org/10.2337/dc15-0429

Sumithran, P., Prendergast, L. A., Delbridge, E., Purcell, K., Shulkes, A., Kriketos, A., & Proietto, J. (2011). Long-Term Persistence of Hormonal Adaptations to Weight Loss. *New England Journal of Medicine*, *365*(17), 1597–1604. https://doi.org/10.1056/nejmoa1105816

Sun, L., Goh, H. J., Govindharajulu, P., Leow, M. K.-S., & Henry, C. J. (2020). Postprandial glucose, insulin and incretin responses differ by test meal macronutrient ingestion sequence (PATTERN study). *Clinical Nutrition*, *39*(3), 950–957. https://doi.org/10.1016/j.clnu.2019.04.001

Zauner, C., Schneeweiss, B., Kranz, A., Madl, C., Ratheiser, K., Kramer, L., Roth, E., Schneider, B., & Lenz, K. (2000). Resting energy expenditure in short-term starvation is increased as a result of an increase in serum norepinephrine. *The American Journal of Clinical Nutrition*, *71*(6), 1511–1515. https://doi.org/10.1093/ajcn/71.6.1511

Corresponding author:
Cvetomir Kirov
Faculty of Sport, Physiology and Biochemistry department,
National Sport Academy "Vassil Levski" Sofia
21, Acad. Stefan Mladenov, str.
Sofia, Bulgaria
E-mail: ck110hurdles@gmail.com

IV International Scientific Congress "Applied Sports Sciences"

PROCEEDING BOOK

Peer-Review Statement

All full-text papers included in this conference proceedings volume have undergone a rigorous peer-review process. Each submission was evaluated by at least two independent reviewers with academic expertise relevant to the topic of the paper. Reviews were conducted in accordance with established scholarly standards, ensuring the quality, validity, and originality of the published contributions. Only papers that met the required scientific and ethical criteria were accepted for publication.

Publication Ethics and Malpractice Statement

The editors of this conference proceedings volume are committed to upholding the highest standards of publication ethics, following the principles outlined by the Committee on Publication Ethics (COPE).

By submitting their manuscripts, all authors confirm that:

- their work is original and has not been previously published or submitted elsewhere;
- the research presented is conducted in accordance with accepted ethical standards;
- all sources used are properly cited;
- there is no plagiarism, data fabrication, or falsification;
- all authors have contributed substantially to the manuscript and approve its final version;
- any conflicts of interest have been disclosed.

The editors maintain responsibility for the integrity of the publication process, ensuring fair and unbiased review, confidentiality of submissions, and immediate action in cases of suspected misconduct. Any breaches of ethical standards will lead to correction, retraction, or other appropriate measures.

21–22 November 2025

Sofia, Bulgaria

IV International Scientific Congress "Applied Sports Sciences"

21–22 November 2025
Sofia, Bulgaria

PROCEEDING BOOK

EDITORS OF THE PROCEEDING BOOK:

Prof. Ognyan Miladinov, DSc
Assoc. Prof. Milena Kuleva, PhD
Assoc. Prof. Stefka Djobova, PhD

SCIENTIFIC COMMITTEE

INTERNATIONAL MEMBERS OF THE SCIENTIFIC COMMITTEE

Prof. Suzanne Lundvall – University of Gothenburg, Sweden
Prof. Nenad Stojiljkovic – University of Nish, Serbia
Prof. Monica Stanescu – National University of Physical Education and Sport, Bucharest, Romania
Prof. Jean-Paul Belgrado – Free University of Brussels, Belgium
Prof. Thierry Zintz – Catholic University of Louvain, Belgium
Prof. Cevdet Cengiz – Canakkale Onsekiz Mart University, Turkiye
Prof. Alejandro García Mas – University of the Balearic Islands, Spain
Prof. Lana Ružić Švegl – University of Zagreb, Croatia
Prof. Javier Pérez-Tejero – Polytechnic University of Madrid, Spain
Prof. Biljana Popeska – Goce Delchev University, North Macedonia
Assoc. Prof. Branislav Antala – FIEP World Vice-president, Comenius University in Bratislava, Slovakia
Assoc. Prof. Dario Novak – FIEPS Europe President, University of Zagreb, Croatia
Assoc. Prof. Simone Digennaro – University of Cassino and Southern Lazio, Italy
Assoc. Prof. Jirí Balas – University of Prague, Czech Republic
Assoc. Prof. Gülşah Şahin – Canakkale Onsekiz Mart University, Turkiye

MEMBERS OF THE SCIENTIFIC COMMITTEE FROM THE NATIONAL SPORTS ACADEMY "VASSIL LEVSKI"

Prof. Krasimir Petkov
Prof. Ognyan Miladinov
Prof. Daniela Lyubenova
Prof. Nikolay Popov
Prof. Nikolay Izov
Prof. Ivan Maznev
Prof. Tatiana Iancheva
Prof. Valentin Panayotov
Prof. Mihail Konchev
Prof. Mihail Mihailov
Prof. Eleonora Mileva
Prof. Daniela Dasheva
Prof. Albena Alexandrova
Prof. Antonio Antonov
Assoc. Prof. Hristo Andonov
Assoc. Prof. Ivan Slavchev
Assoc. Prof. Milena Kuleva
Assoc. Prof. Stefka Djobova
Assoc. Prof. Korneliya Naydenova
Assoc. Prof. Petar Peev
Assoc. Prof. Nina Atanasova
Assoc. Prof. Marina Petrova
Assoc. Prof. Ivan Ivanov
Assoc. Prof. Antoaneta Dimitrova
Assoc. Prof. Ina Vladova

Design: Slavka Asenova, Svetla Kostova
Publisher: Scientific Publishing House NSA Press
ISBN (Online): 978-954-718-803-7