



Nutrient and Physical Activity Timing in Healthy Aging: A Conceptual Perspective [†]

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Abstract

Lifestyle behaviors such as diet and physical activity are central to healthy aging, yet their temporal organization remains underexplored in aging research. Drawing on concepts from sports science, this perspective proposes a conceptual framework examining how the timing of nutrient intake and physical activity may influence muscle maintenance, metabolic regulation, and low-grade chronic inflammation in older adults. This paper synthesizes evidence from aging physiology, chronobiology, and lifestyle research to highlight plausible mechanistic pathways and key knowledge gaps. Future observational and interventional studies are needed to determine whether optimizing the timing of lifestyle behaviors contributes meaningfully to healthier aging trajectories.

Keywords: healthy aging; nutrient timing; physical activity; sports nutrition; personalized strategies; muscle maintenance

1. Introduction

Lifestyle behaviors such as diet and physical activity promote health and functional capacity across the lifespan, with particular importance in the context of healthy aging [1,2]. Regular physical activity and appropriate nutritional intake are well-established contributors to the maintenance of metabolic health, functional ability, and overall quality of life in older adults [3]. In addition, growing evidence suggests that the interaction between diet and exercise appears to play an important role in the preservation of muscle mass and the prevention of sarcopenia in aging populations [4]. As life expectancy increases, identifying modifiable lifestyle strategies that support functional independence has become a key research priority. Within sports and exercise science, considerable attention has been given to the timing of nutrient intake and physical activity. Concepts such as nutrient timing and exercise timing have been explored in athletic and physically active populations, primarily in relation to muscle adaptation, recovery, and performance optimization [5], and are commonly applied in practice within these contexts. These approaches suggest that not only what individuals eat or how they exercise, but also when these behaviors occur, may meaningfully influence physiological outcomes.

In contrast, the temporal dimension of lifestyle behaviors remains relatively underexplored in aging research, particularly among older adults who are physically active or transitioning into later stages of adulthood. Although emerging studies have begun to examine chrononutrition-related behaviors in relation to muscle health in older adults [6], evidence remains limited and largely fragmented, with little integration of dietary and physical activity timing within a unified framework. Research in gerontology and public



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health has largely focused on diet, physical activity, or sedentary behavior, typically examining these behaviors either in isolation or in combination. While this work has generated valuable insights, it has paid limited attention to the potential interactions between dietary and physical activity behaviors across the day, or the alignment between meal timing and movement patterns. This gap is notable given that aging is accompanied by physiological changes that may increase sensitivity to the timing of lifestyle behaviors. Age-related alterations in muscle protein turnover, low-grade inflammation, insulin sensitivity, and circadian regulation suggest that the coordination of nutrient intake and physical activity could be particularly relevant for maintaining muscle health and metabolic stability in older adults. Importantly, many adults over the age of 50 remain physically active and may adopt exercise habits that resemble those of younger or athletic populations, yet evidence-based guidance on lifestyle timing in this group is limited.

Bridging concepts from sports nutrition and aging research offers a promising avenue for advancing the understanding of healthy aging. Rather than directly translating performance-oriented strategies, a conceptual adaptation of nutrient and activity timing principles may help identify approaches that support muscle maintenance, inflammation control, and long-term metabolic health. Such an approach aligns with the emerging interest in personalized and precision lifestyle strategies, while remaining grounded in modifiable daily behaviors. Therefore, the aim of this perspective paper is to propose a conceptual framework that integrates nutrient timing and physical activity timing within the context of healthy aging. By synthesizing insights from sports science and gerontological research, this paper highlights the potential relevance of lifestyle timing strategies for older adults. Emphasis is placed on identifying knowledge gaps and outlining directions for future observational and interventional studies, rather than presenting empirical findings. This perspective seeks to stimulate further research into how the temporal organization of lifestyle behaviors may contribute to the promotion of functional capacity and health across aging.

2. Methods

2.1. Study Design

This study adopts a conceptual and integrative approach and does not employ an empirical research design. No original data were collected, and no experimental or observational analyses were conducted. Instead, the proposed framework was developed through the synthesis and integration of existing theoretical and empirical evidence from sports nutrition, exercise science, and gerontology, with a specific focus on the temporal dimension of lifestyle behaviors.

2.2. Conceptual Framework Development

The conceptual approach centers on older adults, with particular relevance to physically active and community-dwelling individuals. This population was selected because it represents a critical transition phase in the aging process, during which declines in muscle mass, metabolic regulation, and recovery capacity begin to accelerate, while lifestyle behaviors remain modifiable and responsive to intervention.

The framework specifically examines the alignment of meal timing and physical activity patterns across the day, rather than treating these behaviors as isolated exposures. Drawing from established principles in sports nutrition—such as nutrient timing around exercise, protein distribution, and nutrient–exercise interactions—the model explores how these concepts might be conceptually adapted to aging populations when the primary outcome shifts from performance optimization to the preservation of functional capacity and metabolic health.

In addition to structured exercise, the framework also considers broader daily movement patterns, including sedentary behavior and light-intensity physical activity, recognizing that these behaviors may interact with both dietary timing and circadian regulation. Accordingly, the temporal organization of eating, movement, and rest is conceptualized as a dynamic and interrelated system with potential implications for key physiological domains relevant to healthy aging.

Finally, this conceptual approach is intended to inform the design of future observational and interventional studies. By outlining plausible mechanistic pathways linking nutrient and activity timing with muscle maintenance, metabolic regulation, and low-grade inflammation, the framework provides a structured basis for hypothesis generation and cross-disciplinary research in aging populations.

2.3. Literature Search and Selection Strategy

To ensure transparency in the conceptual synthesis, a structured non-systematic literature search was conducted in major scientific databases, including PubMed and Google Scholar. The search was not intended to be exhaustive, but rather to ensure coverage of key theoretical and empirical contributions relevant to the development of the conceptual framework. The search strategy combined keywords related to physical activity timing, nutrient timing, chronobiology, chrononutrition, sedentary behavior, and healthy aging. Additional relevant publications were identified through backward and forward citation tracking of key review articles and seminal studies.

Priority was given to peer-reviewed systematic reviews, meta-analyses, position stands, and high-quality empirical studies in the fields of sports nutrition, exercise physiology, and gerontology. No formal inclusion or exclusion criteria or systematic review protocol were applied, as the aim of this work was to develop a conceptual integration rather than to produce a comprehensive evidence synthesis.

This literature base was used to identify recurring mechanistic themes and to support the integration of temporal aspects of nutrition and physical activity into a unified framework for healthy aging.

3. Results and Discussion

3.1. Muscle Maintenance

Age-related loss of skeletal muscle mass and function is a central feature of the aging process and a major determinant of reduced functional capacity and metabolic health. This condition, commonly referred to as sarcopenia, reflects adverse changes in muscle strength, quantity, and quality that accrue across the lifespan and are influenced by age-related alterations in nutritional status, physical activity patterns, and muscle responsiveness to anabolic stimuli [4,7]. Within this context, the timing of nutrient intake relative to physical activity may represent a modifiable factor with relevance for muscle maintenance in older adults.

Evidence from sports nutrition indicates that the temporal distribution of protein intake, particularly in proximity to exercise, can support anabolic processes underlying muscle protein synthesis and muscle adaptation [8–10]. While these findings are well-established in athletic populations, their direct translation to older adults remains limited. However, the underlying physiological mechanisms—such as amino acid availability, muscle anabolic signaling, and exercise-induced sensitivity to nutrients—are not exclusive to athletes and may retain relevance in aging populations. From a conceptual standpoint, aligning protein-containing meals with periods of physical activity may help counteract age-related anabolic resistance, as physical activity—particularly resistance or mixed-mode exercise—may transiently enhance muscle responsiveness to amino acids and thereby

amplify the anabolic response to protein intake [11]. This suggests that nutrient–activity alignment could support muscle preservation even in the absence of the high training volumes or intensities, typically required for hypertrophic adaptations. This perspective shifts the focus from maximizing hypertrophy to sustaining muscle mass and function over time.

Beyond single exercise sessions, daily patterns of activity and eating may also play a role. Irregular meal timing, prolonged fasting periods, or long intervals of sedentary behavior may reduce opportunities for muscle protein synthesis across the day. In contrast, a more evenly distributed intake of protein, temporally aligned with habitual movement or planned exercise, could promote a more favorable anabolic environment in older adults. Importantly, muscle maintenance in aging is not an isolated outcome but is closely intertwined with metabolic health and inflammatory regulation. Loss of muscle mass can exacerbate insulin resistance and impair glucose disposal, while chronic low-grade inflammation may further compromise anabolic signaling [12]. Thus, strategies that support muscle preservation through optimized timing may have broader implications for overall health and functional independence.

Taken together, this conceptual framework suggests that nutrient and activity timing may represent an underexplored pathway for supporting muscle maintenance in older adults. While direct evidence remains limited, the convergence of mechanistic insights from sports nutrition and aging physiology underscores the need for targeted observational and interventional studies to examine whether temporal alignment of diet and physical activity can meaningfully attenuate age-related muscle loss.

3.2. Metabolic Regulation

Age-related changes in metabolic regulation represent a major challenge to healthy aging. Reduced insulin sensitivity, impaired glucose handling, and diminished metabolic flexibility commonly emerge with advancing age and are closely linked to both sedentary behavior and alterations in body composition. Within this framework, the temporal organization of dietary intake and physical activity may play a meaningful role in shaping daily metabolic responses in older adults. Research from sports and exercise science demonstrates that the timing of exercise and nutrient intake can influence substrate utilization, insulin sensitivity, and glycemic control [13]. Exercise performed in proximity to meals has been shown to enhance glucose uptake and improve postprandial metabolic responses, while nutrient timing can modulate the availability and utilization of carbohydrates and fats [14]. Although the existing evidence may vary in terms of study populations and design, the underlying physiological mechanisms are likely relevant to aging physiology.

From a conceptual perspective, aligning physical activity with periods of nutrient intake across the day may help mitigate age-related declines in metabolic flexibility. Older adults often experience prolonged sedentary periods and irregular eating patterns, both of which may exacerbate postprandial hyperglycemia and lipid dysregulation. Introducing structured or habitual movement around meal times could support more efficient substrate handling and improve daily metabolic stability. However, circadian rhythms introduce an additional layer of complexity to metabolic regulation, as aging is associated with alterations in circadian amplitude and timing, which may affect glucose tolerance and insulin sensitivity across the day [15,16]. Consequently, the timing of meals and physical activity relative to endogenous circadian rhythms may influence metabolic outcomes. Misalignment between behavioral timing and internal biological clocks could contribute to metabolic disturbances [17,18], whereas improved alignment may support healthier metabolic profiles.

Importantly, metabolic regulation is closely interconnected with muscle mass and function. Skeletal muscle serves as a major site for glucose disposal, and declines in muscle quantity or quality can amplify metabolic impairments. Therefore, strategies that support muscle maintenance through optimized nutrient–activity timing may simultaneously contribute to improved metabolic health, reinforcing the interdependence of these physiological domains. Overall, metabolic regulation is likely a plausible target through which nutrient and activity timing may influence healthy aging. While direct empirical evidence in older adults remains limited, integrating insights from sports nutrition, chronobiology, and aging research underscores the potential value of examining daily temporal patterns of eating and movement. Future studies are needed to determine whether timing strategies offer benefits beyond total diet quality and physical activity levels in supporting metabolic health across aging populations.

3.3. Inflammation and Low-Grade Chronic Inflammatory Processes

Low-grade chronic inflammation is so frequently observed in older adults that the term inflammaging was introduced to describe this condition [19,20]. This chronic inflammatory state is closely linked to metabolic dysfunction, sarcopenia, and an increased risk of age-related chronic diseases [21]. Importantly, lifestyle behaviors such as diet, physical activity, and sedentary behavior are recognized modulators of inflammatory processes [22–24], suggesting that not only their quantity but also their temporal organization may play a role in inflammatory regulation in older adults. Nevertheless, the temporal alignment of these behaviors and its relevance to aging physiology and chronic low-grade inflammatory states remains insufficiently explored, highlighting an important gap in the current literature.

From a conceptual standpoint, aligning nutrient intake with physical activity may help attenuate inflammatory responses associated with prolonged sedentary behavior and postprandial metabolic stress [22,24]. Older adults often experience extended periods of sedentary behavior combined with clustered or irregular eating patterns, conditions that may promote transient elevations in inflammatory markers [24]. Strategic timing of movement and meals across the day could therefore theoretically reduce cumulative inflammatory exposure by improving metabolic handling and limiting inflammatory activation.

In addition, circadian regulation plays a critical role in inflammatory processes. Inflammatory mediators exhibit pronounced diurnal variation [15], and aging is associated with disruptions in circadian rhythmicity that may further exacerbate inflammatory dysregulation [16]. Behavioral misalignment—such as late eating, irregular meal timing, or physical inactivity during biologically optimal periods—may amplify low-grade inflammation [18], whereas improved alignment between eating, activity, and circadian rhythms could support more favorable inflammatory profiles.

Inflammation is also tightly linked to muscle and metabolic health. Chronic low-grade inflammation contributes to anabolic resistance, impaired muscle protein synthesis, and reduced insulin sensitivity, reinforcing a cycle of functional decline. Within this interconnected framework, nutrient–activity timing may indirectly influence inflammatory burden by supporting muscle maintenance and metabolic regulation across the aging trajectory.

Overall, inflammation represents a key mechanistic pathway through which nutrient and activity timing may influence healthy aging trajectories. Although direct empirical evidence in older populations remains limited, the convergence of findings from exercise science, nutrition, and chronobiology highlights inflammation as a plausible and biologically meaningful target. Future observational and interventional studies are needed to determine whether optimizing the temporal distribution of lifestyle behaviors can meaningfully modulate inflammatory processes and contribute to healthier aging outcomes.

4. Conclusions

This conceptual perspective highlights nutrient and physical activity timing as an underexplored yet biologically plausible dimension of healthy aging. While diet and physical activity are well-established determinants of muscle health, metabolic regulation, and inflammation, their temporal organization across the day has received limited attention in aging research, particularly when examined in an integrated manner. Drawing on principles from sports nutrition and exercise science, this framework suggests that aligning meal timing with physical activity patterns may influence key physiological processes relevant to aging, including muscle maintenance, metabolic flexibility, and low-grade chronic inflammation. Importantly, these effects are not viewed in isolation but rather as interconnected mechanisms that may jointly shape functional capacity and long-term health trajectories in older adults. Rather than proposing specific interventions or prescriptive guidelines, this work emphasizes the need for observational and interventional studies that simultaneously assess diet, physical activity, sedentary behavior, and their timing. Such integrative approaches are essential to determine whether timing adds meaningful value beyond the behaviors themselves and to clarify the contexts in which temporal alignment may be most relevant.

In conclusion, adapting timing-related concepts from athletic populations to aging research offers a promising avenue for advancing our understanding of lifestyle-related mechanisms in later life. By bridging sports nutrition, exercise science, and gerontology, future research can move toward more nuanced, evidence-based strategies that support healthier aging while acknowledging the inherent complexity and individual variability of daily behavioral patterns.

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