Exercise-nutrient interactions: Timing matters for health and performance

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Circadian rhythms are ~24 h oscillations common to most biological and metabolic pathways. Many of these daily oscillations are dependent on endogenous molecular clocks that control a significant portion of the genome. The circadian clock is cell autonomous, present in most human tissues/organs, and is organised in a hierarchical manner with the hypothalamic suprachiasmatic nucleus (SCN) functioning as the 'master clock'. Light is the dominant 'zeitgeber' (time giver) for the SCN oscillator, which in turn orchestrates rhythms in peripheral tissues/organs at appropriate phases of the day. In addition to photopic cues, the timing of meals and exercise are powerful zeitgebers that can reprogram or phase-shift circadian cycles. For example, disruption of feeding/fasting rhythms is commonly found in individuals with obesity and insulin resistance. As the timing of meals profoundly affects skeletal muscle insulin sensitivity, manipulating daily meal timing is a powerful strategy to help alleviate lifestyle-related diseases. Hence, 'chrono-nutrition' refers to food administration in coordination with the body's daily rhythms, and reflects the notion that, in addition to the quality and quantity of food, meal timing is also critical for the well-being of an organism.

Exercise is a potent modulator of both whole-body and skeletal muscle metabolism, and skeletal muscle has a strong circadian profile coupled to an extensive network of clock-controlled genes. Patterns of physical activity (and inactivity) can modulate the molecular clock in skeletal muscle, affecting both the amplitude and phase. In humans, mitochondrial function peaks in the late afternoon, and most studies assessing the effects of endurance or strength training report that exercise performance is increased in the afternoon and evening compared with early morning. In individuals with overweight/obesity or type 2 diabetes, afternoon exercise training confers greater health benefits than when the same exercise is undertaken in the morning. Accordingly, synchronizing both exercise and nutrient interventions to the molecular circadian clock may be effective strategies to optimize both performance and the health benefits of exercise. While the underlying mechanisms driving the modulation of the skeletal muscle clock from regular exercise are not yet established, consistent time-of-day exercise might act as a preventive measure, serving as a daily time-cue to synchronize the skeletal muscle clock and associated metabolic pathways.