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A Mixed-Integer Nonlinear Program to Optimally Pace and Fuel Ultramarathons

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Abstract : The purpose of this research is to determine the pacing and nutrition strategies which minimize completion time and carbohydrate intake for athletes competing in ultramarathon races. The model formulation consists of a two-phase optimization. The first-phase mixed-integer nonlinear program (MINLP) determines the minimum completion time subject to the altitude, terrain, and distance of the race, as well as the mass and cardiovascular fitness of the athlete. The second-phase MINLP determines the minimum total carbohydrate intake required for the athlete to achieve the completion time prescribed by the first phase, subject to the flow of carbohydrates through the stomach, liver, and muscles. Consequently, the second phase model provides the optimal pacing and nutrition strategies for a particular athlete for each kilometer of a particular race. Validation of the model results over a wide range of athlete parameters against completion times for real competitive events suggests strong agreement. Additionally, the kilometer-by-kilometer pacing and nutrition strategies, the model prescribes for a particular athlete suggest unconventional approaches could result in lower completion times. Thus, the MINLP provides prescriptive guidance that athletes can leverage when developing pacing and nutrition strategies prior to competing in ultramarathon races. Given the highly-variable topographical characteristics common to many ultramarathon courses and the potential inexperience of many athletes with such courses, the model provides valuable insight to competitors who might otherwise fail to complete the event due to exhaustion or carbohydrate depletion.

Keywords : nutrition, optimization, pacing, ultramarathons
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