EDITORIAL | Recovery from Exercise

Replace, restore, revive: the keys to recovery after exercise

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RECOVERY FROM EXERCISE (2) has emerged as a hot topic in sport and exercise science. Exercise has long been considered important to assist recovery and rehabilitation from injury (15, 20). Over the last 10 yr or so, exercise physiologists and sports scientists have also become increasingly interested in developing strategies to promote recovery between successive training sessions and competitive events (2). Enhancing recovery has a twofold benefit: it provides a competitive edge and minimizes the risk of an imbalance between training load and recovery that can potentially result in overtraining (12). Fundamental to understanding recovery from exercise is knowledge of how various physiological systems respond to different forms of exercise and when (and how) these systems return to their “normal” state after exercise. Recovery remains one of the least understood aspects of the exercise-adaptation cycle. Several reviews have described the general exercise recovery process (2, 9), specific aspects of exercise recovery for certain sports (14), and the effects of nutritional and physical interventions to promote recovery (1, 6). However, recovery from exercise is multifaceted and encompasses many different physiological systems. To gain a better understanding of the recovery process, it is necessary to consider the roles of these various systems from an integrated perspective.

We are pleased to introduce 10 reviews in this Highlighted Topic series that provide a broad but concise overview on recovery from exercise (mainly in humans). The review articles encompass many of the major physiological systems that must change their operation during exercise and that play an important role in adaptations to exercise. The articles are grouped according to themes.

The first set of articles relates to muscle regeneration and adaptation after exercise. The series begins with an article by Mackey and Kjaer (10) titled “Connective tissue regeneration in skeletal muscle after eccentric contraction-induced injury.” It addresses the evidence for injury to the extracellular matrix and the role of extracellular matrix remodeling after exercise. The next article titled “Skeletal muscle and resistance exercise training: the role of protein synthesis in recovery and remodeling” is written by McGlory, Devries, and Phillips (11). It outlines the time course of changes in the transcriptional responses in skeletal muscle and the relationship between gene expression, muscle protein synthesis, and phenotypic adaptations to exercise. The next article by Kraemer, Ratamess, and Nindl is titled “Recovery from exercise: recovery responses of testosterone, growth hormone, and IGF-1 after resistance exercise” (8). It provides a paradigm that links testosterone, growth hormone, and IGF-1 to recovery and also to adaptation to exercise training. These three articles are accompanied by another article from Peake, Neubauer, Della Gatta, and Nosaka titled “Muscle damage and inflammation during recovery from exercise” (16). This review covers the time course and factors that influence restoration of muscle function and resolution of intramuscular inflammation after exercise.

The second set of articles describes changes in cardiovascular function, thermoregulation, and hydration after exercise. The first article titled “The cardiovascular system after exercise” is by Romero, Minson, and Halliwill (19). It compares the hemodynamic changes and underlying mechanisms after endurance vs. resistance training and describes strategies to maximize cardiovascular recovery and/or minimize risks associated with postexercise hypotension. The second article has been prepared by Kenny and McGinn and is titled “Restoration of thermoregulation after exercise” (7). This review describes the mechanisms responsible for disruption of thermoregulation and the influence of nonthermal factors on restoration of thermoregulation after exercise. The third article titled “Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration” is by Evans, James, Shireffs, and Maughan (5). This paper provides an update on postexercise rehydration and practical advice on the most effective strategies to restore and maintain fluid balance in response to exercise-induced fluid losses.

The last three articles cover separate, independent themes associated with exercise recovery. The first of these is by Burke, van Loon, and Hawley and is titled “Postexercise muscle glycogen resynthesis in humans” (3). This article describes the performance benefits related to matching muscle glycogen stores to the fuel demands of exercise and the molecular signals driving glucose transport into muscle after exercise. The second article titled “Recovery of central and peripheral neuromuscular fatigue after exercise” is by Carroll, Taylor, and Gandevia (4). The authors extrapolate insights into the mechanisms of central fatigue after maximal single-joint muscle contractions to postexercise recovery and compare differences in fatigue between maximal vs. sustained submaximal muscle contractions. The third article by Peake, Neubauer, Walsh, and Simpson is titled “Recovery of immune function after exercise” (17). This review details the time course of postexercise immune changes, the effects of repeated bouts of
exercise on the same or consecutive days, the influence of sleep disturbances, and the efficacy of nutritional interventions for restoring immune function after exercise.

This Highlighted Topic series on Recovery from Exercise illustrates many of the adaptive and integrative aspects of physiology that are a key focus for the Journal of Applied Physiology. The reviews presented in this series provide readers with a broad overview of the postexercise recovery process from a systems biology perspective. The reviews reveal deficiencies in our understanding of the factors controlling recovery from exercise. They also describe and raise questions about the effect of exercise duration, intensity, and exercise type on recovery. Perhaps with the exception of cardiovascular function and thermoregulation, much of the research to date on recovery from exercise has focused on discrete biological systems. Future research in this area should aim to investigate how the various homeostatic systems interact and affect each other’s activity. Most research on promoting recovery from exercise has focused on restoring “peripheral” factors. However, as Carroll et al. (4) and others (13, 18) point out, we must not ignore how “central” factors can influence perceptions of recovery from exercise and potential strategies to manipulate these factors.

We hope that readers will be able to apply and integrate the information in these reviews and identify new areas of exploration in this exciting and burgeoning field of physiology.

**AUTHOR CONTRIBUTIONS**

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**DISCLOSURES**

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**REFERENCES**


