Skeena Journal on Otolaryngology

General Adaptation Syndrome and Mitohormesis in Dysphagia: Relevance and Clinical Applicability

Mini Review

Volume 2 Issue 1- 2025

Author Details

Guilherme Maia Zica, Leonardo Coelho Rabello de Lima,Maria Inês Rebelo Gonçalves*

Federal University of São Paulo (Unifesp) - São Paulo, Brazil

*Corresponding author

Guilherme Maia Zica, Federal University of São Paulo (Unifesp), Rua Sena Madureira Number 1500, Vila Clementino, São Paulo, SP, Brazil

Article History

Received: October 12, 2025 Accepted: October 21, 2025 Published: October 23, 2025

Abstract

Purpose: The disruption of an organism's basal state is the driving force for biological adaptation. This is the central thesis of the General Adaptation Syndrome (GAS) model, the main theoretical foundation for the athlete conditioning process. It is common for physical education and physiotherapy professionals to master and study this concept in depth. However, even though speech-language pathology involves the regular prescription of muscle exercises, professionals in this field do not typically conduct in-depth studies on exercise physiology and its theoretical and practical foundations. This paper aims to address a fundamental gap in the training of professionals working in dysphagia and inspire new reflections. Understanding exercise physiology concepts such as GAS, mitohormesis, and sarcohormesis can undoubtedly assist and provide significant gains in the rehabilitation process.

Conclusion: If the speech-language pathologist specializing in dysphagia understands the appropriate prescription, considering the muscle group, magnitude, and progression of stimuli, the system tends to increase its functional capacity and even alter its morphology. It is important to note that the magnitude of these adaptations is highly variable between individuals and specific to the load exposed, both for gain and loss. Proper stimuli associated with function are fundamental in dysphagia rehabilitation, directly impacting the quality of life of the patient and their family.

Keywords: Hormesis, General Adaptation Syndrome, Dysphagia, Rehabilitation of Speech and Language Disorders, Rehabilitation Research

Introduction

The disruption of an organism's baseline state serves as the driving force behind biological adaptation. This concept is central to the General Adaptation Syndrome (GAS) model [1], which forms a primary theoretical foundation for the athletic training process [2]. While professionals in physical education and physiotherapy are commonly trained to understand and apply this model extensively, the same is not true in the field of speech-language pathology. Despite the regular use of muscular exercises in this area, professionals often lack formal training in exercise physiology and its theoretical and practical underpinnings.

This paper aims to address a significant educational gap in the training of professionals working with dysphagia and to foster new insights. A solid understanding of exercise physiology concepts-such as General Adaptation Syndrome (GAS), mitohormesis, and sarcohormesis-can enhance the ethical, evidence-based, and effective application of muscular interventions in patients with swallowing disorders.

Equally important to knowing which exercise to prescribe and its relevance to swallowing neurophysiology is understanding its impact on the individual and how it should be administered. Variables such as stimulus intensity, number of repetitions, and fatigue recognition play a crucial role in determining both muscular and functional outcomes.

Although it has some historical limitations, the GAS model, developed by Hans Selye in 1936 [1], has been a valuable framework for understanding how training stimuli induce muscular adaptations that lead to functional improvement. Modern periodization theories are largely grounded in GAS principles, aiming to optimize adaptive responses by managing stress and fatigue [2].

General Adaptation Syndrome

The core concept of GAS is illustrated in Figure 1. A muscular stressor-such as a tongue resistance exercise-disrupts the muscle's baseline state, triggering an "alarm" phase composed of cellular processes that respond to the stressor. Physiological adjustments occur in the affected tissue. After recovery, the muscle doesn't return to its original state; instead, it adapts by increasing its resistance threshold. This progression leads to improved tolerance to future stress. However, if stress is applied continuously without adequate recovery, the organism may enter a fatigue state, reversing prior gains. This highlights the critical need for appropriate stimulus selection and sufficient recovery periods to support muscular development and functional improvement [1,2].

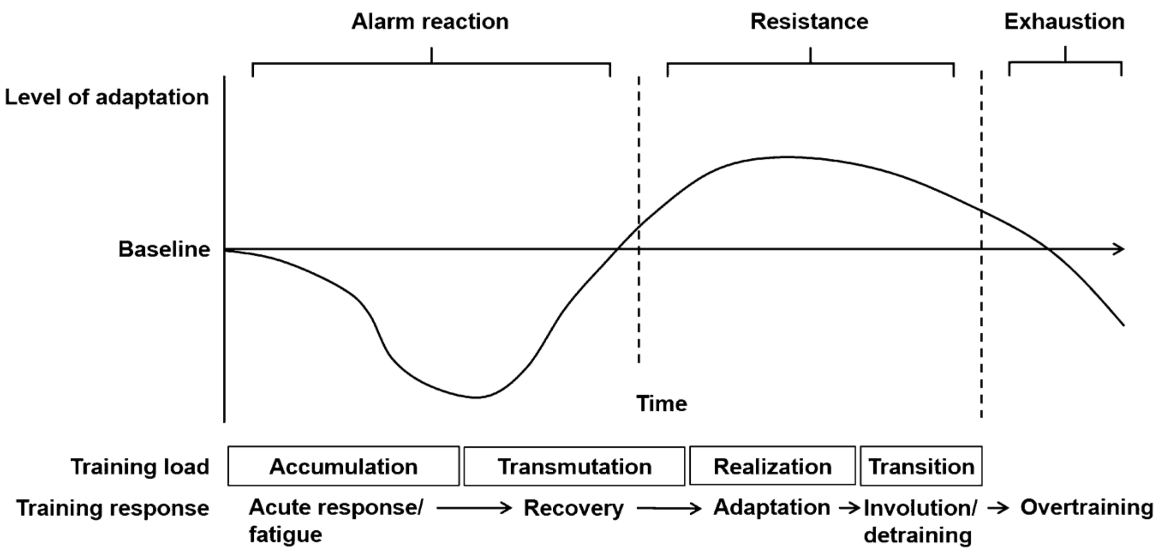

Figure 1: Representation of the General Adaptation Syndrome (GAS): The organism's response to a stressor begins with a temporary reduction in adaptive capacity, followed by a recovery phase that leads to supercompensation-an enhanced functional state beyond the initial baseline. However, prolonged exposure to the stressor or the application of an excessive training load can push the organism into a state of exhaustion, impairing performance and adaptation. The relationship between training load and physiological response is effectively explained by the GAS model, which emphasizes that overtraining typically results from poorly structured training programs and insufficient management of fatigue and recovery [2].

Mitohormesis

In subsequent developments within biomedical sciences, the concept of hormesis was introduced, further expanding the principles of GAS [3,4]. Hormesis refers to a phenomenon where controlled exposure to a potentially harmful stressor induces beneficial adaptive responses at the cellular level [3,5].

When applied to mitochondria, this concept is known as mitohormesis. It suggests that mitochondrial stress can initiate a signaling cascade to the nucleus, resulting in transcriptional responses that restore or enhance cellular homeostasis. Mitohormesis plays a central role in mediating exercise-induced adaptations [3].

Physical activity increases mitochondrial metabolism and reactive oxygen species (ROS) production, triggering adaptations that not only boost stress resistance (e.g., antioxidant defenses) but also promote broader physiological benefits that may contribute to lifespan extension [4,5]. In essence, controlled mitochondrial stress promotes resilience and metabolic optimization.

Mild disturbances in mitochondrial homeostasis activate cytosolic and nuclear responses that make the entire cell more resistant to subsequent stress. These adaptations are not only acute and protective but can also involve long-term metabolic and structural remodeling. As exercise increases mitochondrial activity to meet energy demands, the ability of mitochondria to coordinate both local and systemic cellular responses through mitohormesis becomes crucial to training adaptations [3].

From a macro perspective, sarcohormesis describes similar adaptive processes at the skeletal muscle level. It encompasses the tissue-level consequences of the cellular signaling events described above, further reinforcing the central role of hormetic principles in physical exercise.

Fundamental Contemporary Bases of Physical Exercise

Physical exercise can subject skeletal muscles to various types of stress: thermal, metabolic, oxidative, hypoxic, or mechanical [6]. The nature of stress depends on exercise type, volume, intensity, duration, and contraction type (concentric, eccentric, or isometric). These stresses activate biochemical signaling pathways beyond mitochondrial ROS.

For instance, high or repetitive mechanical loads disrupt the sarcolemma, basement membrane, and myofibrillar proteins, leading to exercise-induced muscle damage (EIMD)a well-documented phenomenon [5,7]. EIMD initiates an inflammatory response mediated by neutrophils, which secrete substances that facilitate repair and regeneration [7]. Notably, ROS released during this immune response also contribute to adaptive signaling in muscle tissue [5].

Additional anabolic agents, such as myokines (e.g., IL-6, IL-10), are secreted by skeletal muscle and play roles in muscle hypertrophy and adaptation. Mechanical stimuli can also trigger anabolic pathways, including cell swelling, satellite cell proliferation, and increased levels of insulin-like growth factor 1 (IGF-1), a key extracellular mediator of muscle growth [3,4,6,7].

However, from a clinical standpoint-especially in dysphagia management-hypertrophy is not the primary goal. Dysphagia rehabilitation typically avoids exercises that induce muscle damage, which are often associated with high intensities, large volumes, and eccentric contractions.

Muscle adaptation depends directly on the characteristics of applied stimulus. Inadequate load results in no improvement, whereas excessive load may cause tissue damage. Thus, exercise prescription must strike the right balance. To effectively manage this balance, foundational principles of physical training should be observed when prescribing swallowing exercises:

a.Biological Individuality: Consider that each individual has a set of unique characteristics that make them more or less susceptible to adaptations induced by the practice of exercises [3,4,8].

b.Specificity: Understanding that the adaptations suffered by the body are specific to the exercises performed with regard to factors such as type of exercise, muscle focus, speed and duration of muscle contraction. It is only possible to improve the target of the correct intervention [7,9].

c.Progressive Overload: Exposure to progressively greater exercise loads distributed throughout the sessions is necessary to achieve a higher level of physical fitness than the baseline. The exercise load must be increased progressively and respect fatigue [5,6,7].

d.Reversibility: Morphological and functional adaptations induced by conditioning tend to be reversed when it is interrupted. It can be applied to the concept of use it or lose it in dysphagia. Adaptations decline when training is discontinued [4,5].

Clinical Relevance and Applicability in Dysphagia

A wide range of swallowing exercises is available, including the Masako maneuver, various tongue exercises such as resistance-based and lingual vestibular rotation tasks , the isotonic/isometric Shaker exercise, and interventions using expiratory muscle strength training devices [10]. It is reasonable to expect that muscles subjected to repetitive and progressively challenging stimuli will become stronger, more resilient, and more mobile, thereby enhancing functional performance.

In the context of dysphagia, for example, a patient who requires increased tongue propulsion strength-based on speech-language pathology assessment-would be expected to show improved muscular and functional outcomes following systematic stress-based tongue exercises [10]. However, it is essential to align these exercises with the functional act of swallowing, taking into account the patient's broader clinical context and reported symptoms. Therefore, integrating muscle conditioning with motor learning, tailored to individual needs, is fundamental.

It is essential to select exercises correctly and on an individualized basis, as well as to perform them at the appropriate intensity and frequency, with progression whenever possible. Understanding the patient and identifying moments of fatigue are crucial to optimizing the outcomes of oromyofunctional therapy.

The baseline functional capacity of skeletal muscle is determined by the demands placed upon it, whether promoting gains or mitigating losses. In dysphagia rehabilitation, appropriate stimuli associated with swallowing function are crucial and have a direct impact on the patient's and their family's quality of life.

Conclusion

Human physiological systems adapt to external stressors both acutely and chronically. When a speech-language pathologist specializing in dysphagia understands how to prescribe exercises appropriately considering the targeted muscle group, stimulus magnitude, and progression-the system tends to improve its functional capacity and may even undergo morphological changes. It is important to note that the extent of these adaptations varies significantly among individuals and is specific to the type and intensity of the stimulus applied.

Acknowledgement

None.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

This study was not supported by any sponsor or funder.

Author Contributions

GMZ conceptualization of the study, analysis and interpretation of data and writing of the article; LCRL writing and review of the article; MIRG writing and review of the article.

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