Contemporary Topics in Physiotherapy and Rehabilitation: Clinical, Psychosocial, And Performance Perspectives

Editor

RECEP AKKAYA

BİDGE

BİDGE Yayınları

Contemporary Topics in Physiotherapy and Rehabilitation: Clinical, Psychosocial, And Performance Perspectives

Editor: RECEP AKKAYA

ISBN: 978-625-8567-96-0

1st Edition
Page Layout By: Gözde YÜCEL
Publication Date: 2025-12-25
BİDGE Yayınları

Certificate No: 71374

www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com
Krc Bilişim Ticaret ve Organizasyon Ltd. Şti.
Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

İÇİNDEKİLER

CHAPTER 1
Common Stress-Related Psychosocial Characteristics in Rheumatoid Arthritis: A Case-Based Synthesis

Ömer Faruk ÖZÇELEP[1]

1-Introduction

The concept of stress is complex and multifaceted, with definitions varying across physiological, psychological, and clinical contexts. Broadly, stress can be described as a state of physiological and psychological tension that arises from the dynamic interaction between an individual and their environment. From a physiological standpoint, stress is associated with the activation of the body's "fight or flight" response, primarily mediated by the hypothalamic–pituitary–adrenal (HPA) axis. The subsequent release of stress hormones, such as cortisol and adrenaline, prepares the organism for immediate action by increasing heart rate, blood pressure, and energy availability (Ji & Yeo, 2021; Levine, 1985).

From a psychological perspective, stress is commonly defined as a state of emotional distress characterized by feelings of anxiety, apprehension, or unease, often accompanied by sensations of overwhelm, frustration, or helplessness. These stress responses

[1] Öğr. Gör. Dr. (Kırşehir Ahi Evran Üniversitesi, Fizik Tedavi ve Rehabilitasyon Yüksekokulu), omer.ozcelep@ahievran.edu.tr, ORCID: 0000-0002-9232-2431.

may be triggered by a wide range of internal and external factors, including occupational demands, interpersonal relationships, and major life events (Riedl, 2022). Importantly, the subjective perception of stress and the individual's coping capacity play a critical role in determining its impact on health outcomes.

In patients with rheumatoid arthritis (RA), stress represents a particularly relevant biopsychosocial factor, as it has been implicated in disease onset, symptom exacerbation, pain perception, fatigue, and treatment response. Growing evidence suggests that chronic stress may influence immune regulation and inflammatory pathways, thereby contributing to disease activity and functional decline in RA. However, the manifestation of stress and its clinical consequences may vary considerably between individuals, underscoring the need for patient-centered and context-sensitive approaches.

Therefore, the objective of this chapter is not only to examine the impact of stress-related factors on rheumatoid arthritis and potential treatment modalities, but also to illustrate these complex interactions through clinical case examples. In addition to previously discussed cases, two new cases are introduced in this chapter to provide a more comprehensive and nuanced understanding of how stress-related mechanisms may influence disease progression, symptom presentation, and rehabilitation outcomes in RA patients (Ozcelep, 2024). By integrating theoretical perspectives with real-world clinical scenarios, this chapter aims to bridge the gap between conceptual knowledge and practical application in stress-informed rheumatological care.

2-Case example-III

Our third case involved a 49-year-old woman, who had been diagnosed with rheumatoid arthritis 25 years earlier. The patient presented with multiple comorbidities, including hypertension and asthma, and had undergone coronary angiography. During the anamnesis, we explored her emotional history and life events preceding and accompanying the onset of her disease.

The patient was married for the first time at the age of 13. She reported that her panic attacks began following a traumatic experience in childhood; at the age of eight, she witnessed a serious traffic accident, which had a significant emotional impact on her. She described the marriage environment as restrictive and oppressive. Her mother-in-law, a dominant figure, was particularly harsh toward her, and due to her young age and lack of autonomy, the patient was unable to defend herself. This created a chronic state of helplessness and emotional suppression.

As the patient described herself, she is “like a butterfly,” emphasizing gentleness, emotional transparency, and a strong inclination to care for others. She stated that she always prioritized the needs and comfort of those around her, even when she was under great strain. Such excessive altruism, paired with an inability to assert her own boundaries, formed the emotional foundation on which chronic stress gradually accumulated.

Approximately one month prior to our evaluation, the patient lost her sister-in-law, to whom she was deeply attached. This loss triggered a significant exacerbation of her pain. The pattern observed here aligns with the notion that emotional shocks, especially the loss of an attachment figure, can destabilize physiological regulatory systems and aggravate inflammatory disease activity. As Dr. Gabor Maté describes, individuals who chronically suppress emotional expression in order to maintain relational harmony may become particularly vulnerable to chronic autoimmune diseases.

Thus, this case illustrates how longstanding emotional suppression, early traumatic experiences, and the burden of caregiving obligations contribute to the systemic stress load that influences autoimmune disease progression.

3-Case example-IV

The fourth case concerned a 53-year-old woman, employed as a cook, who had been diagnosed with rheumatoid arthritis 15 years earlier. The patient had two children: a married daughter and a son struggling with severe substance addiction. Her son had been repeatedly hospitalized due to drug overdose, and in one critical episode, he remained in a coma for 18 days. The patient stated that this experience was the most terrifying period of her life.

During the interviews, it became evident that her emotional closeness to her son and the ongoing fear of losing him created a continuous state of vigilance and psychological strain. She reported that while she attempted to maintain the appearance of strength, she frequently internalized her emotional distress to avoid burdening others.

Additionally, the patient lived with her husband, who she described as largely irresponsible regarding household and familial responsibilities. The financial and emotional management of the home fell almost entirely to her. For many years, she was also the primary caretaker of her father-in-law, who had Alzheimer's disease. This caregiving role, sustained over an extended period and lacking adequate support, contributed significantly to her physical and psychological exhaustion.

In this case, we see the convergence of chronic caregiving stress, emotional suppression, and persistent worry for a vulnerable family member—factors that have been repeatedly associated with dysregulated hypothalamic–pituitary–adrenal (HPA) axis responses and increased systemic inflammation. As Gabor Maté suggests, when individuals feel compelled to maintain composure and continue functioning despite overwhelming emotional turmoil, the body may manifest this invisible struggle through chronic illness.

4-Common Characteristics Across the Four Cases

Across all four cases, a striking commonality is the presence of adverse childhood or early life experiences that appear to mark the onset of a chronic stress burden. These early stressors include significant loss, family disruption, forced separation from primary attachment figures, emotional neglect, authoritarian family dynamics, and exposure to life-threatening or destabilizing events. Such experiences seem to have impaired the development of adaptive coping mechanisms, predisposing individuals to maladaptive stress responses later in life. Rather than resolving stress through emotional processing, these individuals learned to suppress emotional expression as a means of psychological survival.

Another prominent shared characteristic among the four cases is difficulty in expressing emotions, particularly negative affect such as anger, grief, resentment, and helplessness. Instead of externalizing these emotions, patients consistently internalized them, leading to sustained psychological tension. This pattern of emotional suppression is clinically relevant, as it has been associated with dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis, altered cortisol secretion, and heightened inflammatory activity. In line with Gabor Maté's conceptualization, the inability to assert boundaries or verbalize distress may result in the body expressing what the mind cannot, through somatic and inflammatory pathways.

A further shared feature is the presence of a persistent pattern of disproportionate altruism and excessive responsibility-taking. In all four cases, patients demonstrated a longstanding tendency to prioritize the needs of others over their own, often to the detriment of their physical and emotional well-being. What initially may have functioned as an adaptive strategy in adverse environments appears to have evolved into a rigid personality trait, characterized by chronic self-neglect, internalized pressure, and emotional exhaustion. This ongoing burden contributes to psychological burnout and may negatively influence recovery trajectories and treatment responsiveness.

Social isolation and a pervasive sense of being misunderstood also emerged as common themes across all cases. Despite differing social contexts, each patient reported feelings of loneliness and the belief that their experiences were not adequately recognized or validated by others. This perceived lack of understanding and social support may further exacerbate emotional withdrawal, limit opportunities for emotional expression, and undermine self-efficacy and resilience. The resulting isolation reinforces maladaptive coping patterns and may amplify both psychological distress and physical symptomatology.

Finally, all four cases demonstrated a clear temporal association between significant life stressors and disease exacerbations or symptom flares. Episodes such as family conflict, marital separation, bereavement, prolonged caregiving stress, or acute threats to loved ones were followed by marked increases in pain, fatigue, and disease activity. This consistent pattern supports the notion that psychosocial stressors play a triggering role in inflammatory processes, highlighting the dynamic interplay between emotional stress and immune dysregulation in rheumatoid arthritis.

5-References

Davis, M. C., Zautra, A. J., Younger, J., Motivala, S. J., Attrep, J., & Irwin, M. R. (2008). Chronic stress and regulation of cellular markers of inflammation in rheumatoid arthritis: implications for fatigue. *Brain, Behavior, and Immunity*, *22*(1), 24–32. https://doi.org/10.1016/j.bbi.2007.06.013

De Cock, D., Doumen, M., Vervloesem, C., Van Breda, A., Bertrand, D., Pazmino, S., Westhovens, R., & Verschueren, P. (2022). Psychological stress in rheumatoid arthritis: a systematic scoping review. *Seminars in Arthritis and Rheumatism*, *55*, 152014. https://doi.org/10.1016/j.semarthrit.2022.152014

De Nys, L., Anderson, K., Ofosu, E. F., Ryde, G. C., Connelly, J., & Whittaker, A. C. (2022). The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis. *Psychoneuroendocrinology*, *143*, 105843. https://doi.org/10.1016/j.psyneuen.2022.105843

Direito, R., Rocha, J., Sepodes, B., & Eduardo-Figueira, M. (2021). Phenolic Compounds Impact on Rheumatoid Arthritis, Inflammatory Bowel Disease and Microbiota Modulation.

Pharmaceutics, *13*(2). https://doi.org/10.3390/pharmaceutics13020145

Evers, A. W. M., Kraaimaat, F. W., Geenen, R., Jacobs, J. W. G., & Bijlsma, J. W. J. (2002). Longterm predictors of anxiety and depressed mood in early rheumatoid arthritis: a 3 and 5 year followup. *The Journal of Rheumatology*, *29*(11), 2327–2336.

Fekete, M., Szarvas, Z., Fazekas-Pongor, V., Feher, A., Csipo, T., Forrai, J., Dosa, N., Peterfi, A., Lehoczki, A., Tarantini, S., & Varga, J. T. (2022). Nutrition Strategies Promoting Healthy Aging: From Improvement of Cardiovascular and Brain Health to Prevention of Age-Associated Diseases. *Nutrients*, *15*(1). https://doi.org/10.3390/nu15010047

Galita, G., Sarnik, J., Zając, G., Brzezińska, O., Budlewski, T., Popławska, M., Przybyłowska-Sygut, K., Joanna, M., & Popławski, T. (2023). The association between inefficient repair of oxidative DNA lesions and common polymorphisms of the key base excision repair genes as well as their expression levels in patients with Rheumatoid Arthritis. *Archives of Medical Science*. https://api.semanticscholar.org/CorpusID:258491264

Ji, L. L., & Yeo, D. (2021). Oxidative stress: an evolving definition. *Faculty Reviews*, *10*, 13. https://doi.org/10.12703/r/10-13

Levine, S. (1985). *A definition of stress*. https://api.semanticscholar.org/CorpusID:140999947

Özçelep, Ö.F.(2024). *Impact of a Stressful Life.* In Fizyoterapi ve Rehabilitayon Çalışmaları, Ed. İsmail Ceylan, Yaz Yayınları, 130-142.

Prather, A. A. (2019). *Sleep, stress, and immunity*. In M. A. Grandner (Ed.), *Sleep and Health* (pp. 319–330). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-815373-4.00024-1

Ray, A., Gulati, K., Rehman, S., Rai, N., & Anand, R. (2021). *Role of nutraceuticals as adaptogens*. *September 2022*. https://doi.org/10.1016/B978-0-12-821038-3.00016-1

Reich, J. W., & Zautra, A. J. (1995). Other-Reliance Encouragement Effects in Female Rheumatoid Arthritis Patients. *Journal of*

Social and Clinical Psychology, *14*, 119–133. https://api.semanticscholar.org/CorpusID:144683036

Riedl, R. (2022). On the stress potential of videoconferencing: definition and root causes of Zoom fatigue. *Electronic Markets*, *32*(1), 153–177. https://doi.org/10.1007/s12525-021-00501-3

Segerstrom, S. C., & Miller, G. E. (2004). Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. *Psychological Bulletin*, *130*(4), 601–630. https://doi.org/10.1037/0033-2909.130.4.601

Srour, R. A., & Keyes, D. (2024). *Lifestyle Mindfulness In Clinical Practice.*

Sturgeon, J. A., Finan, P. H., & Zautra, A. J. (2016). Affective disturbance in rheumatoid arthritis: psychological and disease-related pathways. *Nature Reviews. Rheumatology*, *12*(9), 532–542. https://doi.org/10.1038/nrrheum.2016.112

Tafet, G. E., & Nemeroff, C. B. (2020). Pharmacological Treatment of Anxiety Disorders: The Role of the HPA Axis. *Frontiers in Psychiatry*, *11*, 443. https://doi.org/10.3389/fpsyt.2020.00443

Trautmann, J. (2015). Moral Distress: Recognition, Diagnosis, and Treatment. *Journal of Infusion Nursing : The Official Publication of the Infusion Nurses Society*, *38*(4), 285–289. https://doi.org/10.1097/NAN.0000000000000111

Nordic Hamstring Exercise and Athletic Performance

CHAPTER 2

Nadir Tayfun ÖZCAN[1]

Çağlayan Pınar ÖZTÜRK[2]

[1]Asst. Prof. Dr. Süleyman Demirel University Isparta Health Services Vocational School, Department of Therapy and Rehabilitation. nadirozcan@sdu.edu.tr, ORCID ID: https://orcid.org/0000-0003-2239-2562

[2]PhD, Süleyman Demirel University Isparta Health Services Vocational School, Department of Therapy and Rehabilitation, caglayanozturk@sdu.edu.tr, ORCID ID: https://orcid.org/0000-0002-7049-9746

Introduction

Eccentric muscle contraction is a type of contraction commonly used in daily life activity such as walking, running, and descending stairs. In this type of contraction, the sarcomeres, which are the smallest units where muscle contraction occurs, lengthen, and the actin filaments within the sarcomere move away from each other. Eccentric exercises can cause strain to muscle fibers and delayed onset muscle soreness (DOMS), but when performed regularly and in a controlled manner, they strengthen the muscle and protect against injury. In this regard, eccentric exercises are one of the preferred types of exercises in preventing sports injuries, improving performance, and in the rehabilitation process (Utku & Akın, 2017).

Eccentric muscle contraction offers several advantages compared to other types of muscle contractions. For example, Eccentric training generates more force with less energy expenditure. This increases the effectiveness of training by rapidly increasing muscle volume and strength. It is also known that eccentric exercises increase muscle flexibility. During eccentric training, the physiological working length of the muscle is increased, preventing the sarcomeres from reaching critical length during contraction. Eccentric exercises may cause micro-level damage to muscles during initial applications, but when performed regularly, muscles adapt to this stress, reducing muscle damage and lowering the risk of injury (Diong et al., 2022; Nunes et al., 2024).

In recent years, exercise programs based on eccentric contractions aimed at increasing hamstring muscle strength have become a popular training method. Eccentric hamstring exercises are divided into two groups: hip-focused and knee-focused. Hip-focused exercises prioritize hip extension, while knee-focused exercises prioritize knee flexion. Exercises such as Nordic hamstring exercises (NHE), supine sliding leg curl, prone and supine leg curl, and bent knee bridge are knee-focused eccentric hamstring exercises that selectively activate the medial hamstrings more. Romanian deadlift, stiff-leg deadlift, unilateral Romanian and stiff deadlift, 45° hip extension exercise, good morning exercise, and kettleball swing exercises are hip-focused exercises that primarily activate the biceps femoris muscle (Bourne et., 2017).

Among the eccentric exercises mentioned above for increasing hamstring muscle strength, NHE is the most commonly used type of eccentric exercise. During the NHE exercise, which gained popularity following the study by Mjølsnes et al. (2004), the individual performs a forward falling motion over their knees and is asked to slow themselves down as much as possible using their hamstring muscle group during the fall. NHE programmes are known to be effective in improving eccentric muscle strength, muscle activation, performance, and reducing hamstring injury rates (Nunes et al., 2024).

This study aims to comprehensively present the effects of NHE on athletic performance and to contribute to the relevant literature.

Anatomy and biomechanics of hamstring

The hamstring muscle group consists of the biceps femoris, semitendinosus, and semimembranosus muscles, located on the back of the thigh and having important functions in both the knee and hip joints. These muscles originate from the ischial tuberosity of the pelvis and attach to the tibia and fibula bones. All hamstring muscles are primarily innervated by the tibial nerve. The hamstring muscle group crosses both the hip and knee joints, therefore it is involved in hip extension, knee flexion, and internal (semitendinosus and semimembranosus) or external knee rotation (biceps femoris) (Rodgers & Raja, 2019).

Hamstring muscles are considered double-joint muscles because they affect both the hip and knee joints. They play an active role in maintaining postural balance and during functional movements such as running, jumping, and walking. They also contribute to the healthy alignment of the pelvis and lumbar spine. During frequent trunk flexion in daily activities, the hamstring muscle group balances the forces created by the shifting center of gravity. By controlling the movements of the pelvis and trunk on the femur, they contribute to stability. During walking, the hamstring is relaxed at the initial contact. When the heel strikes the ground, it begins to contract to help stabilize the knee. During the loading phase, it contracts eccentrically to prevent excessive forward movement. Before the foot lifts-off the ground, it contracts concentrically to lift the heel and initiate forward swing of the leg. Furthermore, the tension in the non-contractile structures of the hamstring muscles helps maintain trunk stability (Gürer, 2025; Sasaki & Nepture, 2013; Zajac, 2002).

The hamstring muscle group has a strong connection with the thoracolumbar fascia via the ischial tubersity. Considering the thoracolumbar fascia's connection to the lumbar vertebrae, latissimus dorsi, transversus abdominis, internal oblique, rhomboid muscles, and cervical tendons, the hamstring muscle group's functional relationship with the lumbar-pelvic region, upper body, shoulder joint, and skull is also apparent (Hoskins & Pollard, 2005).

Effects of eccentric contraction

The sliding of actin and myosin filaments over each other during contraction forms the basic mechanism of muscle contraction. Myosin heads repeatedly bind to binding sites on actin, and each binding causes a force to be released. The magnitude of the contractile movement is determined by the number of cross-bridges formed and the amount of actin-myosin overlap (Herzog et al., 2015).

It is thought that the greater force produced during eccentric contractions compared to concentric and isometric contractions is due to differences in the number of cross-bridges and the mechanical separation of active cross-bridges. During isometric and concentric contractions, only one myosin head is bound, whereas during eccentric contraction, the increased tension in a single myosin filament triggers the activation of a second head. This mechanism causes the number of active cross-bridges to double during eccentric contraction, with an increasing number becoming active as the contraction velocity increases (Linari et al., 2000). It has been proposed that the cross-bridge cannot complete a full cycle during eccentric contraction. During an eccentric contraction, the cross-bridge remains suspended at the active site bound to actin and rapidly rebinds following forced detachment; since a full cross-bridge cycle is not completed, less ATP is consumed to maintain force Huxley, 1998; Linari et al., 2004). It is known that another reason for the sustained increase in force during eccentric contraction is the passive structural elements within the sarcomere. Titin, an important structural component of the muscle skeleton and the largest defined protein, contributes significantly to sarcomere stability and the regulation of muscle force during eccentric contraction (Herzog et al., 2015; Leonard & Herzog, 2010).

The central nervous system controls the increase in force during contraction by increasing the firing rate of motor units and recruiting additional motor units (Hedayatpour & Falla, 2015). During eccentric loading, the excessive strain on muscle tissue increases the rate of motor unit excitation. Furthermore, eccentric contraction lowers the motor unit excitation threshold and increases the number of motor units involved in the contraction (Dartnall et al., 2009). During eccentric contraction compared to concentric contraction, the concurrent modulation of the stretch reflex and Ia afferent input from the lengthening muscle results in greater cortical activity. The increased cortical activity inhibits spinal reflexes, thereby allowing the muscle fiber to lengthen (Duchateau & Enoka, 2016; Hedayatpour & Falla, 2015). Eccentric exercise is also known to induce peripheral neural adaptations. Studies have indicated that eccentric exercises can significantly enhance the electromyographic activity of muscles and lead to the recruitment of a greater number of alpha motor neurons (Gabriel et al., 2006; Lepley et al., 2015).

When examining the morphological effects of eccentric exercises, an increase in the cross-sectional area of fast-twitch type IIa and IIx muscle fibers is observed following eccentric training (Vikne et al., 2006). It has been reported that eccentric exercises performed at high velocity and resistance cause an increase in sarcomere number, which may subsequently lead to an increase in fascicle length. Increased fascicle length enhances muscle contraction velocity and extensibility. Movements performed at longer muscle lengths exhibit greater force and power production. This phenomenon not only improves muscle performance but also increases muscle flexibility, thereby creating a protective effect against muscle damage (Baroni et al., 2013; Proske & Morgan, 2001).

Eccentric exercise has different effects on the cardiovascular and pulmonary systems compared to other types of exercise. Compared to concentric exercise, oxygen consumption during eccentric exercise is lower. Eccentric exercise requires 4-5 times less oxygen than concentric exercise at similar mechanical workloads, and necessitates significantly lower cardiac output and heart rate (Billat et al., 2004; Perrey et al., 2001). Furthermore, eccentric exercise results in lower metabolic demand, blood lactate accumulation, and energy expenditure (Peñailillo, L., Blazevich, A., & Nosaka, 2014; Peñailillo et al., 2013). Due to the greater muscle force production and neurogenic stimulation during eccentric exercise, the increase in pulmonary ventilation is more pronounced. Additionally, the heat stress induced by eccentric exercise can trigger a thermoregulatory response, which may also influence oxygen dissociation kinetics (Douglas et al., 2017).

Nordic hamstring exercise

NHE, one of the eccentric exercises, is a resistance exercise designed to target the hamstring muscle group and enhance hamstring performance. Regular application of the NHE has been shown to reduce the risk of injury by increasing muscle fiber length and significantly improve muscle strength (Saleh et al., 2017). In this context, these exercises are also used as an effective strategy, particularly in the prevention of hamstring injuries (Sayers & Sayers, 2008). Furthermore, studies emphasise that eccentric strengthening should be integrated into rehabilitation from the onset of treatment following a hamstring injury (Duhig et al., 2019; Dyk et al., 2019). The basic principle is that the person stands on their knees while their ankles are immobilised with the help of a partner or apparatus, and their upper body is bent forward in a controlled manner, causing the hamstring muscles to withstand eccentric loading (Mjølsnes et al., 2004). During NHE, hamstring muscle activation in both knee joints requires greater eccentric muscle force compared to traditional hamstring exercises. Additionally, trunk and hip muscles contract largely isometrically during NHE (Narouei et al., 2018).

During the NHE, the starting position involves the individual positioned on their knees with the knee joints at 90 degrees of flexion, the hip joints slightly flexed, and the trunk upright. In the commonly used form, a partner ensures the individual's feet maintain contact with the ground and applies pressure on the ankles during the exercise to allow the individual to perform a forward lean. Subsequently, the individual begins to fall forward using the knee joint as the pivot point. The individual is instructed to resist the descent as much as possible using their hamstring muscles. NHE is advantageous because it can be performed in various conditions. Furthermore, NHE can be performed without a partner using the Nordbord Nordic hamstring machine (Ogborn et al., 2023; Saleh et al., 2017; Sayers & Sayers, 2008).

NHE is used as part of a warm-up program in many studies. However, it has also been shown that NHE can be beneficial when used as part of a cool-down program. Using NHE during the cool-down will positively affect the maintenance of eccentric hamstring strength and the preservation of functional muscle strength ratio, even in fatigue. Furthermore, using NHE during the cool-down program increases post-exercise flexibility and improves muscle performance (Mall et al., 2009; Nunes et al., 2024).

Insufficiencies in the hamstring muscle group during the transition from eccentric to concentric contraction, as well as insufficient concentric and eccentric hamstring strength, are predisposing factors for hamstring injuries (Ditroilo et al., 2013). Studies on the subject emphasize that the NHE reduces injury risk by more than 50% and should be used more frequently as an injury prevention strategy (Impellizzeri et al., 2021). A study involving professional football teams reported that the NHE is recognized as one of the two most effective strategies for preventing muscle injuries (Mccall et al., 2020). Another study analyzing two years of data demonstrated that the NHE is a more effective method for reducing the incidence of hamstring strains compared to flexibility programs (Arnason et al., 2008). A further study involving rugby players also indicated that incorporating the NHE into training programs led to a significant reduction in both the severity and incidence of hamstring injuries (Brooks et al., 2006).

Although there is much evidence regarding the effectiveness of NHE, some authors highlight the disadvantages of this exercise. A study examining muscle activation at different angles of the hamstring muscle during NHE indicated that peak electromyography activation of the hamstring muscle was observed at 65° flexion, while there was a significant decrease at 45° flexion (Ditroilo et al., 2013). Many individuals cannot reach these angles due to the difficulty of the exercise. In this context, the question have been raised as to whether NHE causes sufficient muscle activation (Saleh et al., 2017). Another significant disadvantage observed in studies is the low adherence to NHE and high dropout rates due to delayed onset muscle soreness (Hibbert et al., 2008). In individuals with high adherence rates to NHE (91%), it has been shown to be an effective method in reducing hamstring injuries (Trial et al., 2015). However, it has been reported that NHE has minimal effect on hamstring injuries when exercise adherence is poor (21%) (Engebretsen et al., 2008). Another disadvantage of NHE exercises is exercise-related pain that arises after intense NHE training. The literature reports that DOMS pain is more common in response to NHE. However, non-DOMS musculoskeletal pain (knee pain, etc.) can also occur in association with NHE (Behan et al., 2023).

The literature reveals no consensus on the optimal training intensity for the NHE. Regarding the NHE, the most common protocol involved 2–3 sets of 6–12 repetitions, with 30 seconds to 3 minutes of rest between sets, performed 1–3 times per week for a duration of 4–10 weeks (Nunes et al., 2024). In the systematic review on this topic, a protocol of 3 sets of 3 repetitions performed 3 times per week is considered the minimal effective NHE protocol (Cuthbert et al., 2020). The same study also emphasized that a total of 21-73 repetitions are required for NHE to produce significant effects (Cuthbert et al., 2020). Another study investigating the effects of NHE showed that a 10-week (700 repetitions total) NHE program resulted in a greater increase in hamstring muscle strength compared to concentric exercise (hamstring curl) (Mjølsnes et al., 2004). However, it should be noted that eccentric exercise programs performed at this intensity may be the cause of poor compliance and DOMS pain (Ullah et al., 2022). Another study on the subject emphasized that NHE performed with 6 sets of 5 repetitions per week is an extremely effective method for increasing hamstring muscle strength (Timmins et., 2016). Studies have shown that both high and low-intensity protocols are effective in increasing hamstring muscle strength and reducing injuries (Dyk et al., 2019). Presland et al. found that both high-volume (440 repetitions) and low-volume (128 repetitions) NHE had significant effects on hamstring muscle strength (Presland, 2018). The same study also highlighted that the high-volume exercise protocol had a larger effect size (Presland, 2018). Another similar study reported that both high-volume and low-volume NHE protocols caused significant changes in muscle size, strength, agility, and speed, but the high-volume protocol had a larger effect size (Ullah et al., 2022).

The Effect of Nordic Hamstring Exercises on Athletic Performance

When comparing eccentric and concentric exercises, eccentric exercises are known to be superior in both strength increase and fascicle length increase (Duclay et al., 2009). Studies in the literature show that the use of the NHE protocol, either in isolation or in combination with other exercise programs, has positive effects on some performance parameters and injury frequency in athletes.

Eccentric training leads to an increase in eccentric muscle strength by inducing changes in muscle fiber type, number, excitability, motor unit number, and synchronization (Gerard et al.,2020). In a study comparing 12 different hamstring exercises, the highest activation (>60%) in the biceps femoris muscle was shown to be caused by the NHE (Llurda-almuzara et al., 2021). There is evidence demonstrating a 15-21% increase in eccentric knee flexion strength following 4-6 weeks of NHE training (Shield & Bourne, 2018). In a study involving soccer players that examined the isolated effects of the NHE, a 10-week NHE program increased eccentric knee flexion strength by 11% at an angular velocity of 60°/s (Mjølsnes et al., 2004). The same study also showed a 7% increase in isometric hamstring strength at 90°, 60°, and 30° of knee flexion (Mjølsnes et al., 2004). Considering that hamstring injuries typically occur during the initial angles of flexion, the increase in torque values at low angles also provides a protective effect against hamstring injuries (Mjølsnes et al., 2004).

Increased muscle fiber length directly affects muscle function by affecting the force-velocity and force-length relationships. Longer muscle fibers contain a greater number of sarcomeres arranged in series. This increases muscle contraction velocity and, due to the greater extensibility, helps prevent potential muscle damage (Nunes et al., 2024). Changes in muscle architecture (fascicle shortening) occur after hamstring injury. These negative changes in muscle architecture lead to decreased performance and an increased risk of re-injury in the athlete. Eccentric exercises are known to increase muscle fascicle length. The muscle fiber elongation caused by eccentric exercises leads to a shift in peak torque towards longer fibers (Macdonald et al., 2019). A systematic review examining the effects of the NHE on eccentric strength and the fascicle length of the biceps femoris long head found the NHE to be effective in improving eccentric strength (with increases of 10-15% in isokinetic dynamometer measurements and 16-26% in measurements using the NHE device). The same review also reported that the NHE program increased the fascicle length of the biceps femoris long head by 12-22% (Medeiros et al., 2021). In a study comparing the effects of the NHE and the Stiff-Leg Deadlift on muscle architecture and eccentric strength, the NHE was found to be more effective in improving the fascicle length of the biceps femoris long head. The NHE increased the fascicle length of the biceps femoris long head by 14%, providing more than double the increase produced by the Stiff-Leg Deadlift exercise (Milanese & Eston, 2019).

Resistance exercises can lead to an increase in both muscle thickness and pennation angle. However, the increase in muscle thickness and pennation angle caused by excessive resistance exercises can limit the elongation of muscle fibers and their force-producing capacity. Similar to other resistance exercises, NHE exercise also causes an increase in muscle thickness by increasing the number of parallel sarcomeres. However, studies show that NHE exercises increase muscle thickness without causing an increase in the pennation angle (Blazevich et al., 2006; Kegawa et al., 2008; Nunes et al., 2024). A study on this subject showed that hamstring eccentric muscle training, in addition to increasing eccentric force, caused adaptations in muscle architecture, resulting in a decrease in the pennation angle and an increase in fascicle length and muscle thickness (Gerard et al., 2020).

In athletes, sprint training can be used to improve sprint performance. However, sprint training can cause fatigue in athletes. There is a reciprocal and positive relationship between muscle strength and sprint performance in athletes. In this context, a well-planned NHE protocol can be used to improve sprint performance without causing fatigue (Freeman e al., 2019). Ishøi et al. (2018) showed that a 10-week NHE protocol improved sprint acceleration performance, repeated sprint performance, and final performance sprint. In another similar study, it was found that a 6-week NHE program caused significant changes in participants' 10m sprint, 20m sprint, and vertical jump performance, and the performance increase was associated with force adaptation in the hamstring muscles (Gülü & Doğan, 2021).

Agility is a critical determinant of performance in various sports. Research has shown significant relationships between eccentric hamstring strength and agility performance (Fernandez-fernandez et al., 2022; Horníková & Zemková, 2021). Increased hamstring eccentric muscle strength with NHE balances the hamstring/quadriceps ratio and improves dynamic balance (Atçeken, 2023). Furthermore, the improvements in range of motion and knee stability observed following the NHE (Gülü & Doğan, 2021; Hosseini et al., 2025) can contribute to enhanced agility performance in athletes. In a study conducted on badminton players, it was observed that NHE caused significant changes in agility and speed performance, and that agility and speed performance times improved as leg strength increased (Karakaş et al., 2018). Hosseini et al. (2025) also found that an 8-week NHE protocol caused an increase in agility in football players.

References

Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L., & Bahr, R. (2008). Prevention of hamstring strains in elite soccer : an intervention study. *Scandinavian Journal of Medicine & Science in Sports, 18*(1), 40–48. https://doi.org/10.1111/j.1600-0838.2006.00634.x

Baroni, B. M., Geremia, J. M., Rodrigues, R., De Azevedo Franke, R., Karamanidis, K., & Vaz, M. A. (2013). Muscle architecture adaptations to knee extensor eccentric training: rectus femoris vs. vastus lateralis. *Muscle & Nerve, 48*(4), 498–506. https://doi.org/10.1002/mus.23785

Behan, F. P., Opar, D. A., Timmins, R. G., & Whiteley, R. (2023). The dose-response of pain throughout a Nordic hamstring exercise intervention. *Scandinavian Journal of Medicine & Science in Sports, 33*(4), 542–546. https://doi.org/10.1111/sms.14317

Billat, V. L., Piquard, F., & Richard, R. (2004). Eccentric Cycle Exercise: Training Application of Specific Circulatory Adjustments. *Medicine & Science in Sports & Exercise, 36*(11), 1900–1906.

Blazevich, A. J., Gill, N. D., & Zhou, S. (2006). Intra- and intermuscular variation in human quadriceps femoris architecture assessed in vivo. *Journal of Anatomy, 209*(3), 289–310. https://doi.org/10.1111/j.1469-7580.2006.00619.x

Bourne, M. N., Williams, M. D., Opar, D. A., Al Najjar, A., Kerr, G. K., & Shield, A. J. (2017). Impact of exercise selection on hamstring muscle activation. *British Journal of Sports Medicine, 51*(13), 2017.

Brooks, J. H. M., Fuller, C. W., Kemp, S. P. T., & Reddin, D. B. (2006). Incidence, Risk, and Prevention of Hamstring Muscle Injuries in Professional Rugby Union. *The American Journal of Sports Medicine, 34*(8), 1297–1306. https://doi.org/10.1177/0363546505286022

Cuthbert, M., Ripley, N., Mcmahon, J. J., Evans, M., Haff, G. G., & Comfort, P. (2020). The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations : A Systematic Review and Meta - analyses. *Sports Medicine, 50*(1), 83–99.

Dartnall, T. J., Rogasch, N. C., Nordstrom, M. A., & Semmler, J. G. (2009). Eccentric muscle damage has variable effects on motor unit recruitment thresholds and discharge patterns in elbow flexor muscles. *Journal of Neurophysiology, 102*(1), 413–423. https://doi.org/10.1152/jn.91285.2008

Diong, J., Carden, P. C., Sullivan, K. O., Sherrington, C., & Reed, D. S. (2022). Musculoskeletal Science and Practice Eccentric exercise improves joint flexibility in adults : A systematic review update and meta-analysis. *Musculoskeletal Science and Practice, 60*(March), 102556. https://doi.org/10.1016/j.msksp.2022.102556

Ditroilo, M., Vito, G. De, & Delahunt, E. (2013). Kinematic and electromyographic analysis of the Nordic Hamstring Exercise. *Journal of Electromyography and Kinesiology, 23*(5), 1111–1118.

Doğukan Hakan Atçeken. (2023). *Sporcularda Nordic Hamstring Egzersiz Modelinin, Hamstring Quadriseps Kuvvet Oranına Etkisi*. Doktora Tezi. Selçuk Üniversitesi.

Douglas, J., Pearson, S., Ross, A., Mcguigan, M., & Douglas, J. (2017). Eccentric Exercise : Physiological Characteristics and Acute Responses. *Sports Medicine*, *47*(4), 663–675. https://doi.org/10.1007/s40279-016-0624-8

Duchateau, J., & Enoka, R. M. (2016). Neural control of lengthening contractions. *Journal of Experimental Biology, 219*(2), 197–204. https://doi.org/10.1242/jeb.123158

Duclay, J., Martin, A., Duclay, A., Cometti, G., & Pousson, M. (2009). Behavior of fascicles and the myotendinous junction of human medial gastrocnemius following eccentric strength training. *Muscle and Nerve, 39*(6), 819–827. https://doi.org/10.1002/mus.21297

Duhig, S. J., Bourne, M. N., Buhmann, R. L., Williams, M. D., Minett, G. M., Roberts, L. A., Timmins, R. G., Sims, C. K. E., & Shield, A. J. (2019). Journal of Science and Medicine in Sport Effect of concentric and eccentric hamstring training on sprint recovery, strength and muscle architecture in inexperienced athletes. *Journal of Science and Medicine in Sport, 22*(7), 769–774. https://doi.org/10.1016/j.jsams.2019.01.010

Dyk, N. Van, Behan, F. P., & Whiteley, R. (2019). Including the Nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries : a systematic review and meta-analysis of 8459 athletes. *British Journal of Sports Medicine, 53*(1), 1362–1370. https://doi.org/10.1136/bjsports-2018-100045

Engebretsen, A. H., Myklebust, G., & Holme, I. (2008). Prevention of Injuries Among Male Soccer Players A Prospective, Randomized Intervention Study

Targeting Players With Previous Injuries or Reduced Function. *The American Journal of Sports Medicine, 36*(6), 1052–1060.

Fernandez-fernandez, J., Loturco, I., & Hernández-davó, J. L. (2022). On-Court Change of Direction Test : An Effective Approach to Assess COD Performance in Badminton Players by. *Journal of Human Kinetics, 82*(April), 155–164. https://doi.org/10.2478/hukin-2022-0042

Freeman, B. W., Young, W. B., Talpey, S. W., Smyth, A. M., Pane, C. L., & Carlon, T. A. (2019). The effects of sprint training and the Nordic hamstring exercise on eccentric hamstring strength. *The Journal of Sports Medicine Physical Fitness, 59*(7), 1119–1125.

Gabriel, D. A., Kamen, G., & Frost, G. (2006). Neural Adaptations to Resistive Exercise Mechanisms and Recommendations for Training Practices. *Sports Medicine, 36*(2), 133–149.

Gerard, R., Gojon, L., Decleve, P., & Van Cant, J. (2020). The effects of eccentric training on biceps femoris architecture and strength: a systematic review with meta-analysis. *Journal of Athletic Training, 55*(5), 501–514. https://doi.org/10.4085/1062-6050-194-19

Gülü, M., & Doğan, A. A. (2021). The Effect of 6 Week Nordic Hamstring Exercise on Sprint and Jumping Performance. *Spor Bilimleri Araştırmaları Dergisi, 6*(2), 421–430. https://doi.org/10.25307/jssr.978869

Gürer M. (2025). *Hamstring Germe Uygulamasının Sagital Düzlem Pelvis Postürü ve Yürümedeki Pelvis Mekaniği Üzerindeki Etkilerinin İncelenmesi*. Yüksek Lisans Tezi. İstanbul Kültür Üniversitesi.

Hedayatpour, N., & Falla, D. (2015). Physiological and Neural Adaptations to Eccentric Exercise : Mechanisms and Considerations for Training. *BioMed Research International, 1*. https://doi.org/10.1155/2015/193741

Herzog, W., Powers, K., Johnston, K., & Duvall, M. (2015). A new paradigm for muscle contraction. *Frontiers in Physiology, 6*(MAY), 1–11. https://doi.org/10.3389/fphys.2015.00174

Hibbert, O., Grant, A., & Beers, A. (2008). a systematic review of the effectiveness of eccentric strength training in the prevention of hamstring muscle strains in otherwise healthy individuals. *North American Journal of Sports Physical Therapy, 3*(2), 67–81.

Horníková, H., & Zemková, E. (2021). applied sciences Relationship between Physical Factors and Change of Direction Speed in Team Sports. *Applied Sciences*, *11*(2), 655.

Hoskins, W., & Pollard, H. (2005). The management of hamstring injury — Part 1 : Issues in diagnosis. *Manual Therapy, 10*(2), 96–107. https://doi.org/10.1016/j.math.2005.03.006

Hosseini, E., Alimoradi, M., Iranmanesh, M., Saki, F., & Konrad, A. (2025). The effects of 8 weeks of dynamic hamstring stretching or nordic hamstring exercises on balance, range of motion, agility, and muscle performance among male soccer players with hamstring shortness : a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 17, 187.

Huxley, A. F. (1998). Biological motors: Energy storage in myosin molecules. Current Biology, 8(14), 485–488. https://doi.org/10.1016/s0960-9822(98)70313-6

Impellizzeri, F. M., Mccall, A., & Smeden, M. Van. (2021). Why methods matter in a meta-analysis : a reappraisal showed inconclusive injury preventive effect of Nordic hamstring exercise. *Journal of Clinical Epidemiology, 140,* 111–124. https://doi.org/10.1016/j.jclinepi.2021.09.007

Ishøi, L., Hölmich, P., Aagaard, P., Thorborg, K., Bandholm, T., & Serner, A. (2018). Effects of the Nordic Hamstring exercise on sprint capacity in male football players : a randomized controlled trial Effects of the Nordic Hamstring exercise on sprint capacity in male football players : a randomized controlled trial. *Journal of Sports Sciences, 36*(14), 1663–1672.

Karakaş, I., Susuz, Y. E., Akarçeşme, C., Şemşek, Ö., Çemç, M. S., Demirok, K., ... & Ayılgan, E. (2018). The Correlation Between Nordic Hamstring Strength and Agility and Speed Performance in National Badminton Athletes. *Journal of Biological and Health Sciences, 27*, 1–7.

Kegawa, S. H. I., Unato, K. A. F., Sunoda, N. A. T., Anehisa, H. I. K., & Ukunaga, T. E. F. (2008). Muscle force per cross-sectional area is inversely related with pennation angle in strength trained athletes. *The Journal of Strength & Conditioning Research, 22*(1), 128–131.

Leonard, T. R., & Herzog, W. (2010). Regulation of muscle force in the absence of actin-myosin-based cross-bridge interaction. *American Journal of Physiology - Cell Physiology, 299*(1). https://doi.org/10.1152/ajpcell.00049.2010

Lepley, L. K., Wojtys, E. M., & Palmieri-smith, R. M. (2015). The Knee Combination of eccentric exercise and neuromuscular electrical stimulation to improve quadriceps function post-ACL reconstruction. *The Knee, 22*(3), 270–277. https://doi.org/10.1016/j.knee.2014.11.013

Linari, M, Lucii, L., Reconditi, M., Casoni, M. E. V., Amenitsch, H., Bernstorff, S., Piazzesi, G., & Lombardi, V. (2000). A combined mechanical and X-ray diffraction study of stretch potentiation in single frog muscle fibres. *The Journal of Physiology, 526*(3), 589–596.

Linari, Marco, Bottinelli, R., Pellegrino, M. A., Reconditi, M., Reggiani, C., & Lombardi, V. (2004). The mechanism of the force response to stretch in human skinned muscle fibres with different myosin isoforms. *Journal of Physiology, 554*(2), 335–352. https://doi.org/10.1113/jphysiol.2003.051748

Llurda-almuzara, L., Labata-lezaun, N., & Carlos, L. (2021). Biceps Femoris Activation during Hamstring Strength Exercises : A Systematic Review. *International Journal of Environmental Research and Public Health, 18*(16), 8733.

Macdonald, B., Mcaleer, S., Kelly, S., Chakraverty, R., Johnston, M., & Pollock, N. (2019). Hamstring rehabilitation in elite track and field athletes : applying the British Athletics Muscle Injury Classification in clinical practice. *British Journal of Sports Medicine, 53*(23), 1–13. https://doi.org/10.1136/bjsports-2017-098971

Mall, K., McNaughton, L., Greig, M., & Lovell, R. (2009). Effect of timing of eccentric hamstring strengthening exercises during soccer training: implications for muscle fatigability. *The Journal of Strength & Conditioning Research, 23*(4), 1077–1083.

Mccall, A., Nick, R. P., Dupont, V. D. H. G., & Impellizzeri, M. B. A. J. C. F. M. (2020). Exercise - Based Strategies to Prevent Muscle Injury in Male Elite Footballers : An Expert - Led Delphi Survey of 21 Practitioners Belonging to 18 Teams from the Big - 5 European Leagues. *Sports Medicine, 50*(9), 1667–1681. https://doi.org/10.1007/s40279-020-01315-7

Medeiros, D. M., Marchiori, C., & Baroni, B. M. (2021). Effect of Nordic Hamstring Exercise Training on Knee Flexors Eccentric Strength and Fascicle Length : A Systematic Review and Meta-Analysis. *Journal of Sport Rehabilitation, 30*(3), 482–491.

Milanese, S., & Eston, R. (2019). Hamstring injuries and Australian Rules football : over-reliance on Nordic hamstring exercises as a preventive measure ? Hamstring injuries and Australian Rules football : over-reliance on Nordic hamstring exercises as a preventive measure ? *Open Access Journal of Sports Medicine*, 99–105. https://doi.org/10.2147/OAJSM.S212008

Mjølsnes, R., Arnason, A., Østhagen, T., Raastad, T., & Bahr, R. (2004). A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scandinavian journal of medicine & science in sports*, *14*(5), 311–317.

Narouei, S., Imai, A., Akuzawa, H., Hasebe, K., & Kaneoka, K. (2018). Hip and trunk muscles activity during nordic hamstring exercise. *Journal of Exercise Rehabilitation*, *14*(2), 231–238.

Nunes, H., Martins, P. N., & Ferreira, R. M. (2024). The Effects of Nordic Hamstring Exercise on Performance and Injury in the Lower Extremities : An Umbrella Review. *In Healthcare*, *12*(5), 1–14.

Ogborn, D., Mcrae, S., Larose, G., Leiter, J., Brown, H., & Macdonald, P. (2023). Knee flexor strength and symmetry vary by device, body position and angle of assessment following ACL reconstruction with hamstring grafts at long - term follow - up. *Knee Surgery, Sports Traumatology, Arthroscopy*, *31*(5), 1658–1664. https://doi.org/10.1007/s00167-021-06712-7

Peñailillo, L., Blazevich, A., & Nosaka, K. (2014). Energy expenditure and substrate oxidation during and after eccentric cycling. *European Journal of Applied Physiology*, *114*(4), 805–814. https://doi.org/10.1007/s00421-013-2816-3

Peñailillo, L., Blazevich, A., Numazawa, H., & Nosaka, K. (2013). Metabolic and Muscle Damage Profiles of Concentric versus Repeated Eccentric Cycling ˜. *Medicine & Science in Sports & Exercise*, *45*(9), 1773–1781. https://doi.org/10.1249/MSS.0b013e31828f8a73

Perrey, S., Betik, A., Candau, R., Rouillon, J. D., & Hughson, R. L. (2001). Comparison of oxygen uptake kinetics during concentric and eccentric cycle exercise. *Journal of Applied Physiology*, *91*(5), 2135–2142.

Presland, J. D. (2018). The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation. *Scandinavian*

Journal of Medicine & Science in Sports, 28(7), 1775–1783. https://doi.org/10.1111/sms.13085

Proske, U., & Morgan, D. L. (2001). Muscle damage from eccentric exercise : mechanism, mechanical signs, adaptation and clinical applications. *Journal of Physiology, 537*(2), 333–345.

Rodgers, C. D., & Raja, A. (2019). *Anatomy, bony pelvis and lower limb, hamstring muscle*. (02.12.2025, https://europepmc.org/article/nbk/nbk546688).

Saleh, W., Attar, A. Al, Soomro, N., Sinclair, P. J., Pappas, E., & Sanders, R. H. (2017). Effect of Injury Prevention Programs that Include the Nordic Hamstring Exercise on Hamstring Injury Rates in Soccer Players : A Systematic Review and Meta-Analysis. *Sports Medicine, 47*(5), 907–916. https://doi.org/10.1007/s40279-016-0638-2

Sasaki, K., & Neptune, R. R. (2013). Differences in muscle function during walking and running at the same speed. *Journal of Biomechanics, 39*(11), 2005–2013. https://doi.org/10.1016/j.jbiomech.2005.06.019

Sayers, A., & Sayers, B. (2008). The Nordic Eccentric Hamstring Exercise for Injury Prevention in Soccer Players. *Strength & Conditioning Journal, 30*(4), 56–58.

Shield, A. J., & Bourne, M. N. (2018). Hamstring Injury Prevention Practices in Elite Sport : Evidence for Eccentric Strength vs. Lumbo-Pelvic Training. *Sports Medicine, 48*(3), 513–524. https://doi.org/10.1007/s40279-017-0819-7

Timmins, R. G., Bourne, M. N., Shield, A. J., Williams, M. D., Lorenzen, C., & Opar, D. A. (2016). Short biceps femoris fascicles and eccentric knee flexor weakness increase the risk of hamstring injury in elite football (soccer): a prospective cohort study. *British Journal of Sports Medicine, 50*(4), 1524–1535.

Trial, A. R. C., Horst, N. Van Der, Smits, D., & Petersen, J. (2015). The Preventive Effect of the Nordic Hamstring Exercise on Hamstring Injuries in Amateur Soccer Players. *The American Journal of Sports Medicine, 43*(6), 1316–1323. https://doi.org/10.1177/0363546515574057

Ullah, S., Razaq, A., Riaz, H., & Sheraz, S. (2022). Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey. *British Journal of Sports Medicine, 6*(3), 418–422.

Utku, B., Akın, Ş. (2017). Eksantrik egzersizler ve spor yaralanmalarından korunmadaki yeri. *Turkiye Klinikleri Sports Medicine, 3*(3), 233–239.

Vikne, H., Refsnes, P. E., Ekmark, M., Medbø, J. I., Gundersen, V., & Gundersen, K. (2006). Muscular Performance after Concentric and Eccentric Exercise in Trained Men. *Medicine and Science in Sports and Exercise, 38*(10), 17–19. https://doi.org/10.1249/01.mss.0000229568.17284.ab

Zajac, F. E. (2002). Understanding muscle coordination of the human leg with dynamical simulations. *Journal of Biomechanics, 35*(8), 1011–1018.

CHAPTER 3

INTEROCEPTIVE–AUTONOMIC–MOTOR DYSFUNCTION IN MENTAL DISORDERS

ÇAĞLAYAN PINAR ÖZTÜRK[1]
NADİR TAYFUN ÖZCAN[2]

Introduction

The concept of interoceptive perception was defined by Sherrington. Sherrington distinguished interoceptive perception from exteroceptive perception (perception of stimuli from the external environment) and proprioceptive perception (perception of body position) (Sherrington, 1906). According to Critchley & Garfinkel, interoceptive perception has a neural and psychological integrated structure. It is not merely the transmission of visceral afferent signals to the brain, but is divided into layers: “accuracy,” which is the capacity to correctly perceive internal signals at a subconscious level; “sensitivity,” which indicates the subjective state

[1] Süleyman Demirel University, Department of Therapy and Rehabilitation, caglayanozturk@sdu.edu.tr, ORCID ID: 0000-0002-7049-9746
[2] Süleyman Demirel University, Department of Therapy and Rehabilitation. nadirozcan@sdu.edu.tr, ORCID ID: 0000-0003-2239-2562

of the person related to this perception; and “metacognitive awareness,” which indicates the degree to which subjective evaluation is consistent with reality. The executive dimension is defined as the person's ability to shift their attention from internal sensations to the external environment and back to internal sensations. This holistic structure means that internal perception involves not only signal perception but also cognitive evaluation as part of the process (Critchley & Garfinkel, 2017).

Interoception is considered an essential element for the organism to maintain homeostatic internal balance, sustain vital processes, and perceive internal order (Critchley & Garfinkel, 2017; Khalsa et al., 2018).

In a study evaluating the fundamental characteristics of interoception, Khalsa et al. defined interoception as a structure with a broad function encompassing signal transmission, reflexes, impulses, emotions, drives, adaptive responses, and cognitive and emotional experiences (Khalsa et al., 2018). Craig drew attention to the function of the Insula and Anterior Cingulate Cortex (ACC), stating that the Insula is a center for perception and evaluation and that the information transmitted to the ACC establishes a connection with the motor system and the Autonomic Nervous System (ANS). Therefore, they used the term “emotional motor cortex” for the ACC due to its function. They also reported that all bodily sensations, including itching and visceral sensations, as well as exteroceptive sensations such as pain and temperature, can actually be evaluated within the scope of interoception, and that this information is transmitted via a special nerve pathway (Lamina I Spinothalamocortical system) that starts in the spinal cord and reaches the Insular cortex deep within the brain. According to this theory, Insular maps the body's current state, and other areas that use this information determine emotional responses and behavioral motivations. Specifically, the right anterior Insula serves subjective awareness. It enables the person to perceive “how they feel,” which forms the neuroanatomical basis of self-awareness and emotions (Craig, 2002). Thayer's “neurovisceral integration model” adds a higher-level autonomic regulation dimension to this system; the healthy functioning of the Prefrontal Cortex–Insula–ACC–ASS loop enables the maintenance of parasympathetic tone, the appropriate filtering of bodily signals, and the balanced production of motor-autonomic responses. According to Thayer, when this regulatory network weakens, parasympathetic activity decreases, and bodily signals are perceived more intensely, fragmentarily, or threateningly (Thayer & Lane, 2000). Barrett and Simmons proposed that the interoception system is not a passive system that merely detects sensations from the body, but rather an active system that utilizes past experiences. According to this claim, regions such as the ACC, ventromedial PFK, orbitofrontal cortex, and anterior Insula (agranular visceromotor regions) regulate autonomic and hormonal responses by generating visceromotor commands, while predicting the interoceptive sensations that these commands will create. These predictions are sent to the middle and posterior İnsula, where they are compared with actual internal body signals arriving via the vagus and lamina I pathways. Although the resulting difference is reported upward as a "prediction error," the structural characteristics of the agranular visceromotor regions (thin upper layers and a distinct lack of layer IV) make these regions less sensitive to the error signal. This leads to slower updating of interoceptive predictions, making them more resistant and persistent. As a result, a person's bodily experience often reflects the brain's built-in predictions rather than actual signals. Dysfunctions in this prediction system may play a significant role in the development of anxiety, depression, and stress-related physical disorders (Barrett & Simmons 2015).

The Relationship Between Emotional State and Autonomic Nervous System

There are studies in the literature on the relationship between emotions and the autonomic nervous system. These studies report that in psychiatric disorders, the autonomic nervous system, particularly the activation of the vagus nerve, is weakened (Göçen & Özden, 2024). In these studies, heart rate variability (HRV) is used rather than heart rate (HR). HR and HRV are two distinct concepts. HR refers to the average number of beats per minute, while HRV refers to a capacity for variability and, unlike HR, increases with increased parasympathetic system influence. Therefore, when HRV is high, the system responds more flexibly and quickly to environmental demands, while when it is low, the system's adaptability decreases. Thayer and Lane “Neurovisceral Integration Model” to explain the reduction in HRV observed in psychiatric conditions and the connections between the heart, brain, and behavior. According to this model, HRV decreases through parasympathetic inhibition when the Amygdala perceives a threat in the relationship between the ventromedial Prefrontal Cortex (vmPFC) and the Amygdala (Thayer and Lane 2000). The vmPFC, as a higher-order center, exerts an inhibitory effect on the amygdala and tends to interpret situations in a rationalized manner. HRV demonstrates the vmPFC's control capacity over the amygdala. A decrease in this capacity may result in excessive sensitivity to threats, inability to adapt to safety signals, and constant vigilance, reflecting the amygdala's dominant activity (Thayer et al., 2012). Sgoifo et al., indicated that HRV measurement can be used to detect depression and monitor prognosis (Sgoifo et al., 2015). Pole reported that individuals with Post-Traumatic Stress Disorder (PTSD) exhibit higher than normal cardiovascular reactivity and skin conductance during rest and in response to stimuli, indicating that the “fight or flight” mode is active in these individuals (Pole, 2007). Alvares and colleagues reported that HRV decreases as an autonomic response in different psychiatric conditions (mood, anxiety, psychosis, and addiction). They interpreted that this condition occurs in patients not taking medication, suggesting that the decrease in HRV stems from its own nature, independent of the effects of medication (Alvares et al., 2016).

The Polyvagal Theory, developed by Stephen W. Porges, explains that vagal tone influences social behavior, emotion regulation, and stress response. The Polyvagal Theory describes a hierarchical response selection within the autonomic nervous system and explains how this physiological state determines emotional and social behavior. This approach, which envisions a three-stage response system, suggests that the most developed stage supports communication (Unmyelinated Vagus / VVC (Ventral Vagal Complex)), the second system supports the fight or flight response (Sympathetic Nervous System), and the most primitive system supports the freeze/collapse response (Unmyelinated Vagus / DVC (Dorsal Vagal Complex)) (Porges 2001).

According to this model, if the first system is active, the individual behaves in a social, engaged, and orderly manner. In the second system, the individual exhibits fight-or-flight behaviors. When the third system is dominant, responses such as freezing, withdrawal, and depression are observed. Therefore, according to this theory, the ASS shapes not only peripheral outputs such as heart rate but also the individual's attention, emotional responses, cognitive processes, and motor behaviors (Porges 2001).

Table 1. Characteristics of Interoception

Features	Description
Attention	Observing the body's internal sensations
Detection	Whether an internal sensation is consciously perceived or not
Magnitude	The subjective intensity of the perceived sensation
Discrimination	Localization of sensations originating from a specific channel or organ system and distinguishing them from other sensations
Accuracy/ Sensitivity	Accurate and precise monitoring of internal body signals
Insight	Metacognitive assessment of experience or performance (e.g., confidence–accuracy fit)
Sensibility	The individual's subjective perception of their tendency to focus on interoceptive stimuli (trait level)
Self-report Scales	Psychometric assessment (state/trait measurement) conducted through surveys
Khalsa et al. 2018	

The Relationship Between Emotional State and Motor System

The interoception system is a system that produces outputs to both the autonomic and motor systems (Critchley & Garfinkel, 2017; Khalsa et al. 2018, Craig, 2002 Thayer, & Lane, 2002). Reviews of publications on interoception at the peak of interoception have reported that, in addition to the formation mechanisms and functions described above, dysfunction in this system is associated with psychopathological problems. In other words, there is a consensus that in psychopathological conditions, the perception and interpretation of signals from the body are impaired. Regarding treatment methods, it has been reported that they should not only aim to suppress symptoms but also target the perception, interpretation, integration, and regulation of interoceptive signals (Khalsa et al., 2018). Roxendal (1985) linked motor disorders observed in psychiatric conditions to interoceptive impairment much earlier and defined them as an expression of the disruption of psychosomatic integrity. According to this approach, some of these are psychological and some are due to deterioration in the motor system; muscle tension, lack of coordinated movement, slowness of movement, closed body posture, impaired body image, internal tension, anxiety, neglect of hygiene, reluctance to move, avoidance of eye contact and one's own mirror image, extrapyramidal side effects, and a general feeling of illness (Roxendal, 1985). Bunse et al. reported that motor problems seen in psychiatric disorders are not solely due to muscle strength or primary motor cortex issues; rather, they are due to impairments in interoceptive processing, emotional regulation, and cognitive control networks, and that the common feature of psychiatric disorders is cortical disinhibition and weak cognitive-motor integration. Therefore, motor symptoms were defined not as secondary consequences of mental disorders but as a direct reflection of the neurophysiological integrity of the disorder (Bunse et al. 2014). Northoff et al. have expanded psychomotor symptoms beyond merely impaired dopamine release and motor cortex involvement to include impaired serotonin release and disorders modulated by non-motor cognitive networks (Northoff et al. 2021). According to Wüthrich et al., brain activation areas vary across different diseases and even different forms of the same disease. It has also been suggested that excessive activation in the brains of individuals with psychiatric disorders (excessive communication on the brain surface) compensates for this dysfunction (Wüthrich et al. 2024).

Table 2. Symptoms and clinical findings indicating impairment of the interoception system in some psychiatric disorders

Psychiatric Disorders	Symptoms	Clinical Findings
Panic Disorder	Palpitations, chest pain, dyspnea, feeling of suffocation, nausea, dizziness, flushing,	Increased heart rate and/or blood pressure, exaggerated

	depersonalization/derealization	startle, flight, and freezing responses
Depression	Increased or decreased appetite, fatigue, weakness	Weight gain or weight loss, psychomotor slowing
Eating Disorders	Hunger insensitivity, eating anxiety, gastrointestinal complaints	Extreme food restriction, significant weight loss, vomiting, compulsive exercise
Somatic Symptom Disorders	Multiple and persistent physical and nociceptive symptoms	Medical findings inconsistent with reported symptoms
Substance Use Disorders	Physical symptoms associated with craving, intoxication, and/or withdrawal	Increased/decreased heart rate, respiratory rate, and/or blood pressure; pupil dilation or constriction
Post-Traumatic Stress Disorder (PTSD)	Autonomic hypervigilance,	Startle, flight responses, increased heart rate

	depersonalization/derealization	and/or blood pressure
Generalized Anxiety Disorder (GAD)	Muscle tension, headache, fatigue, gastrointestinal complaints, pain	Trembling, twitching, shaking, sweating, nausea, exaggerated startling
Depersonalization/Derealization Disorder	Alienation from the body, primarily a feeling of fullness, tingling, dizziness	Physiological overreaction to emotional stimuli
Autism Spectrum Disorders	Skin hypersensitivity	Selective clothing preferences (related to tactile sensitivity)
Khalsa et al. 2018		

When examining studies measuring the impact of psychiatric problems on the motor system, a study examining the motor functions of individuals with anxiety (48 people) and healthy individuals (45 people) found that those in the anxiety group walked slower and had shorter stride lengths. Additionally, this study reported that individuals with anxiety had balance deficits and muscle strength loss (Feldman et al. 2009). A study investigating whether walking speed could be a predictor of depression risk reported that slow walking was associated with a significant increase in the risk of future depression. Meta-regression analyses showed that this relationship remained consistent regardless of age, gender, or follow-up duration (Guimarães et al. 2025). Shoryabi et al. investigated whether the depression and anxiety states of participants whose gait was analyzed using machine learning could be predicted from their gait data. The results showed that gait data had a high success rate (86.53%) in identifying depression, but a lower accuracy rate (61.67%) in classifying anxiety. These results suggest that the combination of gait analysis and machine learning could serve as a non-invasive and promising biomarker for the early detection and real-time assessment of mental health disorders in the future (Shoryabi et al. 2025). In a systematic review of motor system impairment in depression, the concept of Psychomotor Retardation (PMR) is highlighted. According to this, depression causes a retardation in cognition, speech, and the motor system. Furthermore, since the severity of this condition is related to the level of symptoms in depression, it has been reported that its monitoring can be used as part of the diagnostic and treatment processes. Activity inhibition has been attributed primarily to functional deficits in the Prefrontal Cortex and abnormalities in dopamine neurotransmission. As a result, physical activities are weakened, decision-making processes become difficult, and speech is affected (Bennabi et al. 2013).

Improving the underlying interoceptive issues in my psychopathological disorders appears to be important. Khalsa et al. proposed treatments that could be effective in these disorders at the interoception summit, approaches that aim not only to suppress symptoms but also to target the perception and integration of interoceptive signals and the reorganization of autonomic-motor responses to these signals (Khalsa et al. 2018). Body-centered therapies are recommended as methods that aim to improve body-mind-movement integration. These methods improve emotional and motor organization by restructuring interoception. Body Awareness Therapy (BAT) and earlier Reich-based approaches, the Alexander Technique, the Feldenkrais Method, and Concentrative Movement Therapy are methods that reorganize the individual's relationship with the body. BBAT supports the reestablishment of psychosomatic integrity through techniques such as safe place contact, center line organization, body control, breath-movement integration, and awareness of individual walking patterns (Roxendal, 1985).

In addition to body-centered treatment concepts, mind-body exercises (tai chi, yoga, qigong, etc.) are also considered methods that can improve the brain's functional structure affected by psychiatric disorders (Han et al. 2023; Zhang et al. 2021). Roxendal also mentions Tai Chi, one of the mind-body exercises, in her book, as she drew inspiration from it (Roxendal, 1985).

Conclusion

In literature, interoception is the process of perceiving and interpreting the body's physiological signals; this process is accepted to play a role in the emergence of autonomic and motor responses. In psychopathological conditions, not only cognitive and emotional functions are impaired, but also the regulation of the autonomic nervous system and the integrity of bodily functions. Current studies show that psychiatric problems are not limited to the level of thought and behavior; they also affect physical areas such as movement, posture, breathing, and motor control. In this context, it is considered insufficient for treatment approaches to focus solely on symptom reduction; the importance of therapeutic interventions that aim to reorganize disrupted interoceptive processes and address motor-autonomic functions in a holistic manner is emphasized.

References

Alvares, G. A., Quintana, D. S., Hickie, I. B., & Guastella, A. J. (2016). Autonomic nervous system dysfunction in psychiatric disorders and the impact of psychotropic medications: A systematic review and meta-analysis. *Journal of Psychiatry and Neuroscience, 41*(2), 89–104. https://doi.org/10.1503/jpn.140217

Barrett, L. F., & Simmons, W. K. (2015). Interoceptive predictions in the brain. *Nature Reviews Neuroscience, 16*(7), 419–429. https://doi.org/10.1038/nrn3950

Bennabi, D., Vandel, P., Papaxanthis, C., Pozzo, T., & Haffen, E. (2013). Psychomotor retardation in depression: A systematic review of diagnostic, pathophysiologic, and therapeutic implications. *BioMed Research International, 2013*, 158746. https://doi.org/10.1155/2013/158746

Bunse, T., Wobrock, T., Strube, W., Padberg, F., Palm, U., Falkai, P. et al. (2014). Motor cortical excitability assessed by transcranial magnetic stimulation in psychiatric disorders: A systematic review. *Brain Stimulation, 7*(2), 158–169. https://doi.org/10.1016/j.brs.2013.08.009

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews Neuroscience, 3*(8), 655–666. https://doi.org/10.1038/nrn894

Critchley, H. D., & Garfinkel, S. N. (2017). Interoception and emotion. *Current Opinion in Psychology, 17*, 7–14. https://doi.org/10.1016/j.copsyc.2017.04.020

Feldman, R., Schreiber, S., Pick, C. G., & Been, E. (2019). Gait, balance, mobility and muscle strength in people with anxiety compared to healthy individuals. *Human Movement Science, 67*, 102513. https://doi.org/10.1016/j.humov.2019.102513

Göçen, H. B., & Özden, A. V. (2024). Autonomic dysfunction in psychiatric disorders. *Psikiyatride Güncel Yaklaşımlar / Current Approaches in Psychiatry, 16*(3), 401–409. https://doi.org/10.18863/pgy.1329118

Guimarães, M. E. A., da Silva, M. G., Machado, R., Oliveira, G., Balsan, L., Viera, H. L. S. et al. (2025). Gait speed and incident depression: A systematic review and meta-analysis. *Journal of Affective Disorders, 370*, 120516. https://doi.org/10.1016/j.jad.2025.120516

Han, Y. M. Y., Chan, M. M. Y., Choi, C. X. T., Law, M. C. H., Ahorsu, D. K., & Tsang, H. W. H. (2023). The neurobiological effects of mind-body exercise: A systematic review and meta-analysis of neuroimaging studies. Scientific Reports, 13(1), 10948. https://doi.org/10.1038/s41598-023-37309-4

Khalsa, S. S., Adolphs, R., Cameron, O. G., Davenport, P. W., Feinstein, J. S., Feusner, J. D. et al. (2018). Interoception and mental health: A roadmap. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 3*(6), 501–513. https://doi.org/10.1016/j.bpsc.2017.12.004

Northoff, G., Hirjak, D., Wolf, R. C., Magioncalda, P., & Martino, M. (2021). All roads lead to the motor cortex: Psychomotor mechanisms and their biochemical modulation in psychiatric disorders. *Molecular Psychiatry, 26*, 92–102. https://doi.org/10.1038/s41380-020-0814-5

Pole, N. (2007). The psychophysiology of posttraumatic stress disorder: A meta-analysis. *Psychological Bulletin, 133*(5), 725–746. https://doi.org/10.1037/0033-2909.133.5.725

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42*, 123–146.

Roxendal, G. (1985). Body awareness therapy and the body awareness scale: Treatment and evaluation in psychiatric physiotherapy. Gothenburg, Sweden: University of Gothenburg. ISBN 91-7222-853-9

Sgoifo, A., Carnevali, L., de los Angeles Pico Alfonso, M., & Amore, M. (2015). Autonomic dysfunction and heart rate variability in depression. *Stress, 18*(3), 343–352. https://doi.org/10.3109/10253890.2015.1045868

Sherrington, C. S. (1906). *The integrative action of the nervous system*. Yale University Press.

Shoryabi, M., Hajipour, A., Shoeibi, A., & Foroutannia, A. (2025). Recognition of anxiety and depression using gait data recorded by the Kinect sensor: A machine learning approach with data augmentation. *Scientific Reports, 15*, Article 22489. https://doi.org/10.1038/s41598-025-06535-3

Thayer, J. F., Åhs, F., Fredrikson, M., Sollers, J. J., III, & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: Implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews, 36*(2), 747–756. https://doi.org/10.1016/j.neubiorev.2011.11.009

Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in emotion regulation and dysregulation. *Journal of Affective Disorders, 61*(3), 201–216. https://doi.org/10.1016/S0165-0327(00)00338-4

Wüthrich, F., Lefebvre, S., Mittal, V. A., Shankman, S. A., Alexander, N., Brosch, K. et al. (2024). The neural signature of psychomotor disturbance in depression. *Molecular Psychiatry, 29*(2), 317–326. https://doi.org/10.1038/s41380-023-02327-1

Zhang, X., Zong, B., Zhao, W., & Li, L. (2021). Effects of mind–body exercise on brain structure and function: A systematic review on MRI studies. Brain Sciences, 11(2), 205. https://doi.org/10.3390/brainsci11020205

CHAPTER 4

Locomotive Syndrome Definition and Management

1.ÜMRAN ARICAN CAN [1]
2. MESUT ERGAN [2]

---

[1] Arş.Gör., Afyonkarahisar Sağlık Bilimleri Üniversitesi,Fizyoterapi ve Rehabilitasyon Bölümü, Orcid: 0009-0009-6220-917X
[2] Dr.Öğr.Üyesi, Süleyman Demirel Üniversitesi , Fizyoterapi ve Rehabilitasyon Bölümü, Orcid: 0000-0002-9712-5154

Introduction

Locomotive syndrome is a condition characterized by decreased mobility due to disorders originating in the locomotor system (bones, joints, muscles, intervertebral discs, and associated nerve structures). It was first introduced by the Japanese Orthopedic Association in 2007 to describe the limitations in basic movements such as standing and walking, and the resulting increase in care costs. Symptoms such as pain, decreased range of motion, balance disorders, postural malalignment, and walking difficulties limit activities of daily living; they increase the risk of falls and fractures, leading to increased dependency and caregiving needs. The prevalence of conditions such as sedentary lifestyles, obesity, osteoarthritis, osteoporosis, and sarcopenia in younger age groups makes locomotive syndrome a significant public health problem not limited to older individuals.

Early diagnosis of locomotor syndrome is crucial for detecting early declines in functional performance, preventing mobility loss, and extending a healthy lifespan. The short test battery recommended by the Japanese Orthopedic Association (stand-up test, two-step test, and GLFS-25) allows for the determination of an individual's risk level for locomotor syndrome and the monitoring of functional capacity.

Lifestyle modifications and structured exercise programs are the primary approaches to treatment and prevention. Regular physical activity, supporting muscle strength and balance, maintaining appropriate body weight, and environmental adjustments to reduce the risk of falls are at the forefront. Locomotion training (Locotra), recommended by the Japanese Orthopedic Association, is a program that aims to improve lower extremity muscle strength and balance, consisting of exercises such as one-legged standing, squatting, heel raises, and forward lunges.

In this section, a general framework will be drawn for the scientific and practical consideration of the basic characteristics of locomotive syndrome, factors associated with locomotive syndrome in different age groups, locomotive syndrome assessment methods and physiotherapy approaches, especially the place of Locotra exercises in clinical practice.

Locomotive Syndrome

Human lifespans are increasing thanks to advances in healthcare and the opportunities offered by the technological age. The care challenges that come with a longer lifespan are also essential. The Japanese Orthopedic Association (JOA) coined the term "Locomotive Syndrome" in 2007 to draw attention to rising care costs. Locomotive syndrome is a movement and function disorder that affects individuals' behaviors and is related to the components of one or more of the locomotive organs responsible for movement (Yoshimura et al., 2022a).

Bones, joints, discs, muscles, and nerves, which are locomotive organs, are the structures responsible for human movement. Common musculoskeletal problems such as osteoporosis, sarcopenia, and lumbar disc herniation affect the locomotive system, increasing the risk of locomotive syndrome (Yoshimura et al., 2009). Although it was introduced to highlight the increasing costs of care in the elderly, Locomotive Syndrome is a condition that affects all age groups (A. Nishimura et al., 2020).

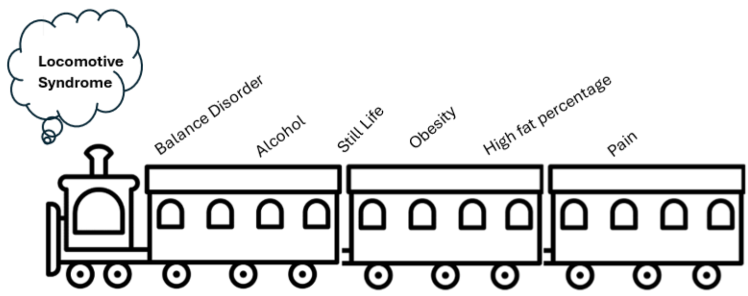
Obesity, bone mineral density, balance, poor posture, and decreased physical activity are problems that can be seen in all age groups, from children to the elderly. These problems contribute to locomotive syndrome. Musculoskeletal problems are among the leading causes of hospitalization in children. Disruptions in the musculoskeletal system are suggestive of locomotive syndrome. The risk of locomotive syndrome is particularly high in obese children who experience foot, knee, and back pain and have poor grip strength. Furthermore, a high body mass index, increased body fat percentage, and prolonged video game play increase the risk of locomotive syndrome in children (Gu et al., 2021).

Similarly, in middle-aged and young adults, balance disorders, prolonged sedentary work, alcohol and tobacco use, and irregular eating habits increase the risk of locomotive syndrome (Muramoto et al., 2016; M. Nakamura et al., 2015; A. Nishimura et al., 2020; Watanabe et al., 2024a).

Factors associated with locomotive syndrome in the elderly include low income, low physical activity levels, the presence of comorbid chronic diseases, cardiovascular problems, and balance disorders (Hirano et al., 2012; Miyashita et al., 2022; Muramoto et al., 2016; Seichi et al., 2012, 2014).

When examining the factors associated with locomotive syndrome, factors that affect a person's daily life, lead to a sedentary lifestyle, and can lead to systemic diseases stand out (Watanabe et al., 2024).

Figure 1. Locomotive Syndrome



(K. Nakamura, 2008)

Risk Factors for Locomotive Syndrome

Risk factors should be considered in the diagnosis and treatment of locomotive syndrome. Decreased single-leg standing time, decreased back strength and grip strength values, decreased maximum step length, and increased Timed Up and Go Test (TUG) time have been identified as risk factors for the development or progression of locomotive syndrome. A study of community-dwelling older adults found that high Geriatric Locomotive Function Scale scores were associated with decreased single-leg standing time and weak back strength (Kobayashi et al., 2022). In a 10-year follow-up study, the prevalence of locomotive syndrome was closely associated with weak grip strength (Yoshimura et al., 2011). Participants who were able to climb tall stairs and had shorter TUG times were found to have a lower risk of developing locomotive syndrome (Metsios & Kitas, 2018). High disease activity score 28-C-reactive protein (DAS28-CRP), which is encountered in rheumatic diseases, is an important risk factor for the development and progression of locomotive syndrome (Sobue et al., 2022).

Evaluation in Locomotive Syndrome

Performance-based tests such as the single-leg balance test, the handgrip test, and the 6-minute walk test have been recommended for the evaluation of locomotive syndrome. However, none of these tests alone are sufficient to diagnose locomotive syndrome. Ogata and colleagues used a three-item test battery known as the Geriatric Locomotive Syndrome Scale (GLFS-25), the 2-stage test, and the Standing Test to assess locomotive syndrome (Ogata et al., 2015).

Geriatric Locomotive Syndrome Scale: The scale developed by Seichi and colleagues consists of 25 questions, with each question scoring between 0 and 4. Locomotive syndrome is graded using the scores obtained from this scale. A score of 7 or higher is sufficient to diagnose locomotive syndrome. The higher the score, the higher the locomotive syndrome stage (Seichi et al., 2012). The Turkish validity and reliability study was conducted by Sadıkoğlu et al.(Sadıkoğlu, 2021).

Two-stage test: The two-stage test is related to lower extremity flexibility, walking speed, and balance performance. The subject performs the test by taking as many steps as possible without losing their balance. The two-step test score is calculated by dividing the two-step distance by the height.

This ratio is sufficient to diagnose locomotive syndrome if it is greater than or equal to 1.1 and less than 1.3 (Demura & Yamada, 2011).

Standing Test: This test, which is related to lower extremity muscle strength and balance, measures the ability to stand up on one or both feet from various heights. If a person cannot stand on one leg with their hands crossed over their body from a height of 40 cm, but can stand on both legs from a height of 20 cm, this is sufficient to diagnose locomotive syndrome. A person without locomotive syndrome must stand up on one leg from a height of 40 cm and maintain their balance for 3 seconds (Ikemoto & Arai, 2018)

If a diagnosis of locomotive syndrome is made in all or any of these three tests, the person is recorded as having locomotive syndrome. This three-test battery is safely used in all age groups (Yamada et al., 2020)

Staging in Locomotive Syndrome

Locomotive Syndrome is staged using a three-test battery.

An individual without locomotive syndrome must receive a maximum score of 6 on the GLSF-25 scale.

The two-stage test ratio must be greater than 1.3.

The individual must be able to stand on one leg from a height of 40 cm, with their hands crossed on their body, and maintain their balance for 3 seconds.

To avoid being diagnosed with locomotive syndrome, the individual must successfully pass all three tests.

For Locomotive Syndrome Stage 1:

A score of more than 6 and less than 16 on the GLSF-25 scale must be obtained.

The two-stage test ratio must be less than 1.3 and equal to or greater than 1.1.

The patient must be unable to stand up on one leg from a height of 40 cm with their hands crossed on the body, but must be able to stand up on both legs from a height of 20 cm with their hands crossed on the body.

For Locomotive Syndrome Stage 2:

A score of 16 or more on the GLSF-25 scale must be obtained, but must be less than 24.

The two-stage test ratio must be less than 1.1 but equal to or greater than 0.9.

The patient must be unable to stand up on two legs from a height of 20 cm with their hands crossed on the body, but must be able to stand up on both legs from a height of 30 cm with their hands crossed on the body.

For Locomotive Syndrome Stage 3:

A score of 24 or more on the GLSF-25 scale must be obtained. The two-stage test ratio should be less than 0.9.

The patient should not be able to stand up from a height of 30 cm on both legs with their hands crossed on the body (Ogata et al., 2015; Yamada et al., 2020).

The worst result from the three-test battery is used for staging locomotive syndrome. For example, someone with LS stage 3 on the GLSA, LS stage 1 on the Two-Step Test, and LS stage 2 on the Stand Test is designated as LS stage 3 (Kadono et al., 2010; K. Nakamura & Ogata, 2016; Ogata et al., 2015; Yoshimura et al., 2017).

Locomotive Syndrome in Children

Although the term "Locomotive Syndrome" was coined to reduce care costs in the elderly and draw attention to musculoskeletal problems, it is also a concept that concerns children. A musculoskeletal health checkup assessment form, revised in 2016 by the Japan Clinical Orthopaedic Association, is used in children to diagnose locomotive syndrome (Gu et al., 2021).

The assessment form questions the presence of scoliosis, trunk flexion flexibility, pain during trunk extension, ability to stand on one leg for 5 seconds, ability to squat while maintaining balance with arms extended forward, ability to flex and extend elbows with palms touching shoulders, ability to raise arms to ear level, accidents within the last year, and any musculoskeletal pain.

A deficiency in any of the assessments on this form is sufficient to diagnose locomotive syndrome in children (Gu et al., 2021).

Locomotive Syndrome in Young and Middle-Aged People

Locomotive syndrome affects all age groups. Factors affecting the locomotor system constitute risk factors for locomotive syndrome. Even a minor functional decline in the musculoskeletal system, including in young individuals, is initially identified as LS and can become increasingly severe, leading to weakness in older adults. Therefore, early diagnosis and treatment of LS is crucial. The incidence of locomotive syndrome in young individuals ranges from 21.7% to 25.0% (Yoshimura et al., 2022a). Studies on locomotive syndrome in young individuals have shown that the prevalence of LS is higher in women than in men, that musculoskeletal pain increases the risk of LS in women, and that there is a significant association between balance problems and LS in men (Ma et al., 2023; Sawaya et al., 2024). Furthermore, another study conducted on young and middle-aged individuals indicated that conditions affecting the musculoskeletal system, such as continuous work hours and lack of physical activity, also increase the risk of LS (Tsuruta et al., 2018).

Locomotive Syndrome in Elderly Individuals

LS, aims to reduce care costs in the elderly and facilitate early diagnosis of the negative effects of frailty and sarcopenia. The deterioration of the locomotor system that occurs with aging also increases the prevalence of LS. Factors associated with LS in older adults include gender (Yoshimura et al., 2022a), body mass index (BMI) (Ono et al., 2021) body fat percentage (Ito et al., 2022), pain, muscle strength, physical activity, nutrition (A. Nishimura et al., 2020; T. Nishimura et al., n.d.; Ohtsuki et al., 2022), and posture (Nishizawa et al., 2022).

The Relationship Between Locomotive Syndrome and Musculoskeletal Problems

LS is associated with musculoskeletal problems. A deterioration in the musculoskeletal system, including pathology of the bones, joints, muscles, and nervous system, can impair quality of life and lead to dependence (K. Nakamura & Ogata, 2016). Undesirable conditions such as deterioration, pain, weakness, and fragility in the musculoskeletal system suggest the risk of locomotive syndrome (Tsuruta et al., 2018). Aging, osteoporosis and low back pain, knee osteoarthritis, and lumbar spinal stenosis have been found to increase the risk of locomotive syndrome (Akahane et al., 2019). A study investigating the risk of locomotive syndrome in individuals performing trunk sway in balance tests found that individuals with increased postural sway, particularly in the Y-balance test, which measures the physical function and muscle strength of the lower extremity, also had locomotive syndrome (Tanaka et al., 2019). Individuals with locomotive syndrome may also have decreased back muscle strength. Decreased back muscle strength is significantly associated with thoracic and lumbar kyphosis, leading to increased spinal curvature (Briggs et al., 2007).

Locomotive Syndrome and Nutrition

Factors such as visceral diseases and genetic factors, a sedentary lifestyle, and malnutrition predispose to LS (Ishibashi, 2018)

In addition to reduced mobility, especially in the elderly, malnutrition is a common condition and is closely associated with morbidity, mortality, and decreased quality of life (Saka et al., 2010). Malnutrition negatively impacts musculoskeletal health and has been associated with chronic musculoskeletal pain in older adults (Ramsey et al., 2020). Muscle strength is closely linked to impaired mobility and malnutrition. Decreased muscle strength has been reported to be an indicator of impaired mobility, and reduced muscle mass has been reported to be a consequence of malnutrition (Jensen et al., 2019). Excessive salt intake and hypertension have been associated with locomotive syndrome. Therefore, it is thought that limiting salt intake may be effective in preventing LS (Ito et al., 2022) A link has also been found between inadequate vitamin K intake and LS. Foods rich in vitamin K, such as seaweed, vegetables, beans, meat, milk, and eggs, are recommended (Ohtsuki et al., 2022).

A systematic review of treatments for locomotive syndrome found that oral glucosamine, electrical stimulation, and exercise were effective in improving locomotive syndrome.

Physical Interventions in Locomotive Syndrome

LS, which is defined as a condition characterized by a decrease in mobility due to impairments in one or more locomotor organs. Since the concept of locomotive syndrome originated in Japan, preventive measures against LS have become crucial not only in Japan but also in other countries with rapidly aging societies (Yasuda, 2021). To prevent the progression of locomotive syndrome, it is important to recognize the decline in mobility and to establish a balanced diet along with a daily exercise routine. Therefore, various strategies have been developed to prevent the progression of locomotive syndrome (Shibata & Kon, 2024).

Physical interventions are known to be effective in controlling mobility, strength, balance, and gait impairments and functional decline (Dodds & Sayer, 2015). However, while physical interventions are effective in individuals with mild to moderate disabilities, their benefits are limited in individuals with severe disabilities (Faber et al., 2006). This highlights the importance of early detection and intervention for locomotive syndrome (K. Nakamura & Ogata, 2016). Furthermore, it remains unclear which physical interventions are most effective in locomotive syndrome (Ishigaki et al., 2014). Certain principles should be considered in physical interventions based on exercise principles. For example, the principle of specificity involves targeting and developing specific body components involved in a specific exercise. Another principle, the principle of overload, requires a load for any functional improvement. With the principle of progression, it is important to gradually increase the amount of exercise, taking safety into account, in the middle-aged and elderly populations, who are among the groups most affected by locomotive syndrome. Taking all these principles into account, Locotra movement training was developed for locomotive syndrome (K. Nakamura & Ogata, 2016). These exercises are recommended for locomotive syndrome because they are directly related to standing, are safe for walking functions, and can be implemented for self-management at home (Hashimoto et al., 2012). Walking, forward lunge, and heel raise exercises are recommended for individuals with locomotive syndrome stage 1 (Smith et al., 2016). Activities that build skeletal muscle mass, such as resistance training, are recommended for preventing locomotive syndrome in young people (Yasuda, 2021).

Locotra Movement Training

This movement training, designed to improve balance and standing functions, emphasizes single-leg stance and squat exercises.

Single-Legged Stance Training

This training, aimed at improving balance, involves subjects standing on one leg for 1 minute with their eyes open. It is recommended that individuals perform this exercise standing next to a stable chair or table with arm support to prevent falls. It is performed on both legs, forming one set. It is recommended to perform 3 sets, 3 times a day (K. Nakamura & Ogata, 2016)

Squat Training

Squat training has been found to be effective in improving independence in activities of daily living, in addition to improving lower extremity strength and body balance (Seitz et al., 2014)

During the squat movement, the trunk is moved downward from a standing position. To prevent overloading the knee, the knee should be maintained over the toes. The knee flexion angle should not exceed 90°. One set consists of 5-6 squats, and approximately three sets should be performed daily (K. Nakamura & Ogata, 2016)

After interrupting the 2-3 months of locomotor training, there were persistent improvements in knee postures, waist range, single-leg stance time, knee extension torque, and maximum walking speed (Hashimoto et al. 2012; Kana Aoki a＊ 2015).

Conclusion

Locomotive syndrome is a musculoskeletal disorder that is becoming increasingly prevalent with aging societies, but can also affect young and middle-aged individuals. Decreased mobility results in an increased risk of falls and fractures, dependence on activities of daily living, a decreased quality of life, and an economic burden on the healthcare system. Therefore, locomotive syndrome should be addressed not only as an orthopedic problem but as a holistic public health issue. Physiotherapy plays a central role in both the early diagnosis and management of locomotive syndrome. Detailed assessment of posture, gait, balance, muscle strength, range of motion, and functional capacity allows for the identification of at-risk individuals and the development of personalized intervention programs. Combining structured exercise programs such as Locotra, which focus on improving muscle strength and balance, with appropriate nutritional recommendations and lifestyle modifications, appears effective in slowing the progression of locomotive syndrome and maintaining independence.

In conclusion, early detection of locomotive syndrome, expansion of physiotherapy-based interventions, and interdisciplinary collaboration will both support functional independence at the individual level and contribute to reducing healthcare costs and the burden of care at the societal level. In this context, physiotherapists are positioned as key healthcare professionals in the assessment, education, exercise prescription, and long-term follow-up processes.

References

Akahane, M., Maeyashiki, A., Tanaka, Y., & Imamura, T. (2019). The impact of musculoskeletal diseases on the presence of locomotive syndrome. *Modern Rheumatology*, *29*(1), 151–156. https://doi.org/10.1080/14397595.2018.1452173

Briggs, A. M., van Dieën, J. H., Wrigley, T. V, Greig, A. M., Phillips, B., Lo, S. K., & Bennell, K. L. (2007). Thoracic Kyphosis Affects Spinal Loads and Trunk Muscle Force. *Physical Therapy*, *87*(5), 595–607. https://doi.org/10.2522/ptj.20060119

Demura, S., & Yamada, T. (2011). The maximal double step length test can evaluate more adequately the decrease of physical function with age, than the maximal single step length test. *Archives of Gerontology and Geriatrics*, *53*(1), e21–e24. https://doi.org/10.1016/j.archger.2010.09.009

Dodds, R., & Sayer, A. A. (2015). Sarcopenia and frailty: new challenges for clinical practice. *Clinical Medicine*, *15*(6), s88–s91. https://doi.org/10.7861/clinmedicine.15-6-s88

Faber, M. J., Bosscher, R. J., Chin A Paw, M. J., & van Wieringen, P. C. (2006). Effects of Exercise Programs on Falls and Mobility in Frail and Pre-Frail Older Adults: A Multicenter Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation*, *87*(7), 885–896. https://doi.org/10.1016/j.apmr.2006.04.005

Gu, Y., Ito, T., Ito, Y., Noritake, K., Ochi, N., Matsunaga, N., Takahashi, D., & Sugiura, H. (2021). Factors Related to Locomotive Syndrome in School-Aged Children in Okazaki: A Cross-Sectional Study. *Healthcare*, *9*(11), 1595. https://doi.org/10.3390/healthcare9111595

Hashimoto, M., Yasumura, S., Nakano, K., Kimura, M., Nakamura, K., Fujino, K., & Ito, H. (2012). Feasibility study of locomotion training in a home-visit preventive care program. *Nippon Ronen Igakkai Zasshi. Japanese Journal of Geriatrics*, *49*(4), 476–482. https://doi.org/10.3143/geriatrics.49.476

Hirano, K., Imagama, S., Hasegawa, Y., Wakao, N., Muramoto, A., & Ishiguro, N. (2012). Impact of spinal imbalance and back muscle strength on locomotive syndrome in community-living elderly people. *Journal of Orthopaedic Science*, *17*(5), 532–537. https://doi.org/10.1007/s00776-012-0266-0

Ikemoto, T., & Arai, Y.-C. (2018). Locomotive syndrome: clinical perspectives. *Clinical Interventions in Aging*, *Volume 13*, 819–827. https://doi.org/10.2147/CIA.S148683

Ishibashi, H. (2018). Locomotive syndrome in Japan. *Osteoporosis and Sarcopenia*, *4*(3), 86–94. https://doi.org/10.1016/j.afos.2018.09.004

Ishigaki, E. Y., Ramos, L. G., Carvalho, E. S., & Lunardi, A. C. (2014). Effectiveness of muscle strengthening and description of protocols for preventing falls in the elderly: a systematic review. *Brazilian Journal of Physical Therapy*, *18*(2), 111–118. https://doi.org/10.1590/S1413-35552012005000148

Ito, S., Nakashima, H., Ando, K., Machino, M., Seki, T., Ishizuka, S., Takegami, Y., Wakai, K., Hasegawa, Y., & Imagama, S. (2022). Nutritional Influences on Locomotive Syndrome. *Journal of Clinical Medicine*, *11*(3), 610. https://doi.org/10.3390/jcm11030610

Jensen, G. L., Cederholm, T., Correia, M. I. T. D., Gonzalez, M. C., Fukushima, R., Higashiguchi, T., de Baptista, G. A., Barazzoni, R., Blaauw, R., Coats, A. J. S., Crivelli, A., Evans, D. C., Gramlich, L., Fuchs-Tarlovsky, V., Keller, H., Llido, L., Malone, A., Mogensen, K. M., Morley, J. E., … Van Gossum, A. (2019). GLIM Criteria for the Diagnosis of Malnutrition: A Consensus Report From the Global Clinical Nutrition Community. *Journal of Parenteral and Enteral Nutrition*, *43*(1), 32–40. https://doi.org/10.1002/jpen.1440

Kadono, Y., Yasunaga, H., Horiguchi, H., Hashimoto, H., Matsuda, S., Tanaka, S., & Nakamura, K. (2010). Statistics for orthopedic surgery 2006–2007: data from the Japanese Diagnosis Procedure Combination database. *Journal of Orthopaedic Science*, *15*(2), 162–170. https://doi.org/10.1007/s00776-009-1448-2

Kana Aoki a＊, M. S. N. O. K. N. E. C. and N. E. (2015). The Effects of Self-directed Home Exercise with Serial Telephone Contacts on Physical Functions and Quality of Life in Elderly People at High Risk of Locomotor Dysfunction. *Acta Medica Okayama*, *69*(4), 245–253.

Kobayashi, T., Morimoto, T., Otani, K., & Mawatari, M. (2022). Locomotive Syndrome and Lumbar Spine Disease: A Systematic Review. *Journal of Clinical Medicine*, *11*(5), 1304. https://doi.org/10.3390/jcm11051304

Ma, Y., Wu, X., Shen, S., Hong, W., Qin, Y., Sun, M., Luan, Y., Zhou, X., & Zhang, B. (2023). Relationship between Locomotive Syndrome and Musculoskeletal Pain and Generalized Joint Laxity in Young Chinese Adults. *Healthcare*, *11*(4), 532. https://doi.org/10.3390/healthcare11040532

Metsios, G. S., & Kitas, G. D. (2018). Physical activity, exercise and rheumatoid arthritis: Effectiveness, mechanisms and implementation. *Best Practice & Research Clinical Rheumatology*, *32*(5), 669–682. https://doi.org/10.1016/j.berh.2019.03.013

Miyashita, N., Ishida, T., Ikemoto, T., Hirasawa, A., Arai, Y.-C., & Deie, M. (2022). Smartphone Use Is Associated with Low Prevalence of Locomotive Syndrome among Elderly Individuals with Musculoskeletal Disorders. *International Journal of Environmental Research and Public Health*, *19*(23), 16213. https://doi.org/10.3390/ijerph192316213

Muramoto, A., Imagama, S., Ito, Z., Hirano, K., Ishiguro, N., & Hasegawa, Y. (2016). Spinal sagittal balance substantially influences locomotive syndrome and physical performance in community-living middle-aged and elderly women. *Journal of Orthopaedic Science*, *21*(2), 216–221. https://doi.org/10.1016/j.jos.2015.12.016

Nakamura, K. (2008). A "super-aged" society and the "locomotive syndrome." *Journal of Orthopaedic Science*, *13*(1), 1–2. https://doi.org/10.1007/s00776-007-1202-6

Nakamura, K., & Ogata, T. (2016). Locomotive Syndrome: Definition and Management. *Clinical Reviews in Bone and Mineral Metabolism*, *14*(2), 56–67. https://doi.org/10.1007/s12018-016-9208-2

Nakamura, M., Hashizume, H., Oka, H., Okada, M., Takakura, R., Hisari, A., Yoshida, M., & Utsunomiya, H. (2015). Physical Performance Measures Associated With Locomotive Syndrome in Middle-Aged and Older Japanese Women. *Journal of Geriatric Physical Therapy*, *38*(4), 202–207. https://doi.org/10.1519/JPT.0000000000000033

Nishimura, A., Ohtsuki, M., Kato, T., Nagao, R., Ito, N., Kato, K., Ogura, T., & Sudo, A. (2020). Locomotive syndrome testing in young and middle adulthood. *Modern Rheumatology*, *30*(1), 178–183. https://doi.org/10.1080/14397595.2018.1551176

Nishimura, T., Fujimoto, M., Kurihara, T., & Nagata, T. (n.d.). *Adverse effects of the coexistence of locomotive syndrome and sarcopenia on the walking ability and performance of activities of daily living in Japanese elderly females: a cross-sectional study*.

Nishizawa, A., Katsuhira, J., Watanabe, M., Fujii, T., Yoshimoto, T., Oka, H., & Matsudaira, K. (2022). Relationship between the locomotive syndrome and kinetic and kinematic parameters during static standing and level walking. *Gait & Posture*, *93*, 146–152. https://doi.org/10.1016/j.gaitpost.2022.01.017

Ogata, T., Muranaga, S., Ishibashi, H., Ohe, T., Izumida, R., Yoshimura, N., Iwaya, T., & Nakamura, K. (2015). Development of a screening program to assess motor function in the adult population: a cross-sectional observational study. *Journal of Orthopaedic Science*, *20*(5), 888–895. https://doi.org/10.1007/s00776-015-0737-1

Ohtsuki, M., Nishimura, A., Kato, T., Wakasugi, Y., Nagao-Nishiwaki, R., Komada, A., & Sudos, A. (2022). Locomotive syndrome is associated with insufficient nutrient intake in young and middle-aged adults: a cross-sectional survey. *Nutrition & Food Science*, *52*(3), 569–580. https://doi.org/10.1108/NFS-07-2021-0224

Ono, R., Murata, S., Uchida, K., Endo, T., & Otani, K. (2021). Reciprocal relationship between locomotive syndrome and social frailty in older adults. *Geriatrics & Gerontology International*, *21*(11), 981–984. https://doi.org/10.1111/ggi.14273

Ramsey, K. A., Meskers, C. G. M., Trappenburg, M. C., Verlaan, S., Reijnierse, E. M., Whittaker, A. C., & Maier, A. B. (2020). Malnutrition is associated with dynamic physical performance.

Aging Clinical and Experimental Research, *32*(6), 1085–1092. https://doi.org/10.1007/s40520-019-01295-3

Sadıkoğlu, M. (2021). *Geriatrik lokomotif fonksiyon ölçeği'nin Türkçe geçerlilik ve güvenilirlik çalışması* [Yüksek Lisans Tezi]. İstanbul Aydın Üniversitesi.

Saka, B., Kaya, O., Ozturk, G. B., Erten, N., & Karan, M. A. (2010). Malnutrition in the elderly and its relationship with other geriatric syndromes. *Clinical Nutrition*, *29*(6), 745–748. https://doi.org/10.1016/j.clnu.2010.04.006

Sawaya, Y., Hirose, T., Onuma, S., Nakajima, R., Fujita, S., Muroi, S., Sato, R., Yin, L., Shiba, T., Kobayashi, K., & Urano, T. (2024). Prevalence and associated factors of locomotive syndrome in young Japanese adults: a cross-sectional study. *BMC Musculoskeletal Disorders*, *25*(1), 366. https://doi.org/10.1186/s12891-024-07493-z

Seichi, A., Hoshino, Y., Doi, T., Akai, M., Tobimatsu, Y., & Iwaya, T. (2012). Development of a screening tool for risk of locomotive syndrome in the elderly: the 25-question Geriatric Locomotive Function Scale. *Journal of Orthopaedic Science*, *17*(2), 163–172. https://doi.org/10.1007/s00776-011-0193-5

Seichi, A., Hoshino, Y., Doi, T., Akai, M., Tobimatsu, Y., Kita, K., & Iwaya, T. (2014). Determination of the optimal cutoff time to use when screening elderly people for locomotive syndrome using the one-leg standing test (with eyes open). *Journal of Orthopaedic Science*, *19*(4), 620–626. https://doi.org/10.1007/s00776-014-0581-8

Seitz, L. B., Reyes, A., Tran, T. T., de Villarreal, E. S., & Haff, G. G. (2014). Increases in Lower-Body Strength Transfer Positively to Sprint Performance: A Systematic Review with Meta-

Analysis. *Sports Medicine*, *44*(12), 1693–1702. https://doi.org/10.1007/s40279-014-0227-1

Shibata, S., & Kon, S. (2024). Functional Ingredients Associated with the Prevention and Suppression of Locomotive Syndrome: A Review. *Biological and Pharmaceutical Bulletin*, *47*(12), b24-00443. https://doi.org/10.1248/bpb.b24-00443

Smith, A. R., Chen, C., Clarke, P., & Gallagher, N. A. (2016). Trajectories of Outdoor Mobility in Vulnerable Community-Dwelling Elderly. *Journal of Aging and Health*, *28*(5), 796–811. https://doi.org/10.1177/0898264315611665

Sobue, Y., Suzuki, M., Ohashi, Y., Koshima, H., Okui, N., Funahashi, K., Ishikawa, H., Asai, S., Terabe, K., Yokota, Y., Kishimoto, K., Takahashi, N., Imagama, S., & Kojima, T. (2022). Relationship between locomotive syndrome and frailty in rheumatoid arthritis patients by locomotive syndrome stage. *Modern Rheumatology*, *32*(3), 546–553. https://doi.org/10.1093/mr/roab024

Tanaka, S., Ando, K., Kobayashi, K., Hida, T., Seki, T., Hamada, T., Ito, K., Tsushima, M., Morozumi, M., Machino, M., Ota, K., Ishiguro, N., Hasegawa, Y., & Imagama, S. (2019). Increasing postural sway in balance test is related to locomotive syndrome risk: A cross-sectional study. *Journal of Orthopaedic Science*, *24*(5), 912–917. https://doi.org/10.1016/j.jos.2019.01.011

Tsuruta, K., Yoshinaga, S., Shiomitsu, T., Tamura, H., Fujii, Y., & Chosa, E. (2018). Quantitative assessment of locomotive syndrome in Japanese office workers. *The Journal of Physical Fitness and Sports Medicine*, *7*(2), 143–149. https://doi.org/10.7600/jpfsm.7.143

Watanabe, K., Lu, X., Masuda, S., Miyamoto, T., & Katoh, T. (2024). Relationship between physical activity and locomotive syndrome among young and middle-aged Japanese workers. *Journal of Occupational Health*, *66*(1). https://doi.org/10.1093/joccuh/uiae001

Yamada, K., Ito, Y. M., Akagi, M., Chosa, E., Fuji, T., Hirano, K., Ikeda, S., Ishibashi, H., Ishibashi, Y., Ishijima, M., Itoi, E., Iwasaki, N., Izumida, R., Kadoya, K., Kamimura, M., Kanaji, A., Kato, H., Kishida, S., Mashima, N., … Takashi Ohe. (2020). Reference values for the locomotive syndrome risk test quantifying mobility of 8681 adults aged 20–89 years: A cross-sectional nationwide study in Japan. *Journal of Orthopaedic Science*, *25*(6), 1084–1092. https://doi.org/10.1016/j.jos.2020.01.011

Yasuda, T. (2021). Identifying preventative measures against frailty, locomotive syndrome, and sarcopenia in young adults: a pilot study. *Journal of Physical Therapy Science*, *33*(11), 2021–2095. https://doi.org/10.1589/jpts.33.823

Yoshimura, N., Iidaka, T., Horii, C., Mure, K., Muraki, S., Oka, H., Kawaguchi, H., Akune, T., Ishibashi, H., Ohe, T., Hashizume, H., Yamada, H., Yoshida, M., Nakamura, K., & Tanaka, S. (2022). Epidemiology of locomotive syndrome using updated clinical decision limits: 6-year follow-ups of the ROAD study. *Journal of Bone and Mineral Metabolism*, *40*(4), 623–635. https://doi.org/10.1007/s00774-022-01324-8

Yoshimura, N., Muraki, S., Nakamura, K., & Tanaka, S. (2017). Epidemiology of the locomotive syndrome: The research on osteoarthritis/osteoporosis against disability study 2005–2015. *Modern Rheumatology*, *27*(1), 1–7. https://doi.org/10.1080/14397595.2016.1226471

Yoshimura, N., Muraki, S., Oka, H., Mabuchi, A., En-Yo, Y., Yoshida, M., Saika, A., Yoshida, H., Suzuki, T., Yamamoto, S., Ishibashi, H., Kawaguchi, H., Nakamura, K., & Akune, T. (2009). Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: The research on osteoarthritis/osteoporosis against disability study. *Journal of Bone and Mineral Metabolism*, *27*(5), 620–628. https://doi.org/10.1007/s00774-009-0080-8

Yoshimura, N., Oka, H., Muraki, S., Akune, T., Hirabayashi, N., Matsuda, S., Nojiri, T., Hatanaka, K., Ishimoto, Y., Nagata, K., Yoshida, M., Tokimura, F., Kawaguchi, H., & Nakamura, K. (2011). Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: the second survey of the ROAD study. *Journal of Orthopaedic Science*, *16*(6), 768–777. https://doi.org/10.1007/s00776-011-0160-1

CHAPTER 5

EVALUATION OF OBSTRUCTIVE SLEEP APNEA WITHIN THE FRAMEWORK OF THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY AND HEALTH (ICF)

Engin RAMAZANOGLU[1]

Introduction

Sleep refers to the complex set of processes fundamentally regulated by neurobiological mechanisms and influencing multiple physiological systems (Grandner, 2017). As an essential component of human life, sleep constitutes approximately one-third of an individual's lifespan and represents an indispensable process for physical and mental restoration (Work & Patient, 2023). Robust studies have demonstrated that insufficient sleep is associated with numerous medical and psychological dysfunctions. Globally, sleep deprivation is prevalent across different age groups and is often unrecognized, underreported, and considered a major public health issue that imposes a significant economic burden (Chattu & et al., 2018).

Obstructive Sleep Apnea Syndrome (OSAS) is among the most common and serious sleep disorders leading to adverse health

Assistant Professor
Mardin Artuklu University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Mardin, Türkiye
ORCID: 0000-0002-2765-0121

outcomes. It occurs due to recurrent narrowing or collapse of the upper airway during sleep. Worldwide, it is reported that 936 million adults aged 30–69 years are affected (Iannella & et al., 2025; Benjafield & et al., 2019). In patients with OSAS, prominent symptoms such as loud snoring, breathing pauses during sleep, and excessive daytime sleepiness are commonly observed. In addition, nocturia, night sweats, morning headaches, difficulties in attention and concentration, and depressive mood are frequently reported. OSAS not only impairs sleep quality but also negatively affects daily functioning, leading to metabolic disorders, an increased risk of cardiovascular diseases, traffic accidents, and even higher mortality rates. Undiagnosed or untreated OSAS cases cause serious health problems at the individual level while also imposing significant economic and social burdens on healthcare systems (Pihtili, & et al., 2025).

The evaluation and management of OSAS are mostly based on physiological indicators such as the Apnea–Hypopnea Index (AHI) (Wang, & et al., 2025). However, this approach tends to overlook the multidimensional effects of the disease on an individual’s functioning, participation level, and environmental interactions. A person with sleep apnea is not merely a “patient who struggles to breathe during sleep,” but rather an individual experiencing fatigue, distractibility, decreased work performance, social isolation, and psychological exhaustion. Therefore, OSAS should be addressed not only from a biomedical perspective but also from functional, behavioral, and social dimensions (Tanellari, & et al., 2025; Emsellem, & et al., 2025).

At this point, the World Health Organization's International Classification of Functioning, Disability and Health (ICF) model (Jaiswal, & et al., 2024) provides a robust framework for comprehensively assessing the impact of OSAS on individuals. The ICF defines health conditions not merely on the basis of "disease" but through the interactions between body functions and structures, activity and participation, as well as environmental and personal factors (Schneidert, & et al., 2003). Thus, OSAS can be understood not only as a respiratory disorder but as a condition that affects an individual's functional capacity, social roles, and overall quality of life.

The aim of this book chapter is to address OSAS from the perspective of the ICF framework, systematically revealing the relationships between the physiological, functional, and environmental components of the disease. This approach seeks to establish a common language for rehabilitation professionals and multidisciplinary healthcare teams, while also promoting an ICF-based paradigm shift in clinical assessment and treatment planning.

Epidemiology and Clinical Effects of Obstructive Sleep Apnea

Due to its increasing global prevalence, OSAS is now considered not only a sleep disorder but also an important public health problem (Iannella & et al., 2025). In a study conducted in the United States, the prevalence of OSAS in the adult population was reported as 15–30% in men and 10–15% in women (McNicholas, 2017). In Türkiye, based on a questionnaire-based study titled “Sleep Epidemiology in the Turkish Adult Population,” which included 5021 participants, the prevalence of OSAS was estimated to be approximately 14% according to the Berlin Questionnaire results (Demir, & et al., 2015). In the Turkish Sleep Apnea Database study conducted this year across 34 centers in Türkiye, a total of 7130 patients were included, of whom 70.2% were male and 29.8% were female (Pihtili, & et al., 2025). Advanced age, obesity, fat accumulation around the neck, and anatomical airway narrowings are among the main risk factors. However, the high rate of undiagnosed cases suggests that the true prevalence may be considerably higher (McNicholas, 2017; Demir, & et al., 2015; Pihtili, & et al., 2025).

The pathophysiology of OSAS is primarily explained by the interaction between decreased upper airway muscle tone, a tendency toward pharyngeal collapse, neuromuscular control disturbances, and anatomical obstructions. During apnea and hypopnea episodes, oxygen desaturation, hypercapnia, and arousals trigger autonomic nervous system activation, which creates long-term adverse effects on cardiovascular and metabolic systems. Particularly, strong associations have been established with clinical conditions such as hypertension, coronary artery disease, arrhythmia, stroke, and insulin resistance (McNicholas & Pevernagie, 2022; Deegan & McNicholas, 1995).

The clinical implications of OSAS are not limited to physiological dysfunctions but also lead to significant restrictions in individuals' daily living activities and social participation. Symptoms such as excessive daytime sleepiness, difficulty concentrating, irritability, headaches, and cognitive slowing reduce performance in work and social life. These impairments can result in serious consequences such as occupational and traffic accidents and loss of productivity. Neurobehavioral effects resulting from sleep fragmentation and insufficient oxygenation cause a marked decrease in patients' quality of life (Chu & Zinchuk, 2024).

The psychosocial consequences of OSAS are also noteworthy. Depression, anxiety, and sexual dysfunction are among the common comorbidities (Jehan & et al., 2017). Moreover, partners who witness snoring or apnea episodes during sleep may develop anxiety and sleep disturbances, leading to stress within family relationships. Therefore, OSAS is not only an individual health issue but also a multidimensional disorder that causes loss of functioning at the family and societal levels (Luyster, 2017).

Although polysomnography (PSG) remains the gold standard in diagnostic evaluation (Sanchez Gomez & et al., 2024), portable home-based devices and screening tools such as the STOP-BANG (Yılmaz & Küpçü, 2025) and the Berlin Questionnaire (Li & et al., 2025) are widely used in clinical practice. However, most of these methods focus solely on the AHI and fail to adequately reflect the relationship between the disease, functional status, participation, and environmental factors (Sanchez Gomez & et al., 2024; Yılmaz & Küpçü, 2025; Li & et al., 2025). Therefore, comprehensive frameworks such as the ICF allow OSAS to be assessed not only physiologically but also functionally and socially in a systematic manner.

International Classification of Functioning, Disability and Health (ICF)

The ICF model, developed by the World Health Organization in 2001, was designed to evaluate and conceptualize health-related structures as a whole, providing a framework that assesses not only the pathophysiological mechanisms of diseases but also their effects on daily living activities, social participation, and environmental dimensions (Stojic & et al., 2025). This model offers a multidimensional and holistic understanding by integrating biological, individual, and social dimensions.

The health condition comprises six fundamental components: body structures and functions, activities, participation, environmental factors, and personal characteristics**.** There are dynamic bidirectional relationships among these components, represented by double arrows. These relationships demonstrate that environmental factors continuously influence body functions, daily activities, and participation, while all these components mutually affect one another (Kim & et al., 2025).

ICF Coding Examples in OSAS

b440: Respiratory functions

The anatomical and physiological alterations that predispose individuals to OSAS negatively affect respiratory functions (Salepçi & et al., 2016). In individuals with OSAS, narrowing of the pharyngeal lumen, increased resistance in the upper airway, and reduced airflow are observed (Stauffer & et al., 1990). This condition results in the inspiratory muscles operating under a continuously increasing workload. Intermittent hypoxemia and frequent arousals lead to fatigue of the diaphragm and accessory respiratory muscles, consequently reducing inspiratory muscle strength (Owens & et al., 2008). Furthermore, during obstructive apnea episodes, the increase in negative intrathoracic pressure can impair chest wall mechanics, thereby reducing the efficiency of respiratory muscles (Patel, Chong & Baydur, 2008). In the long term, these alterations result in decreased lung volumes, reduced respiratory muscle endurance, and imbalances in ventilatory control mechanisms (DiCaro & et al., 2024).

b130: Energy and Drive Functions

Metabolic and hormonal alterations occurring in patients with OSAS adversely affect energy mechanisms. Recurrent hypoxemia during sleep, oxidative stress, and increased sympathetic system activation can lead to disturbances in energy metabolism, impaired glucose tolerance, and increased insulin resistance (Shechter, 2017).

Energy balance is a multifactorial process, and physical activity level, sleep quality, hormonal regulation, and metabolic stability are key determinants of this process. Because this regulation is disrupted in OSAS, patients frequently experience daytime fatigue, low energy, and lack of motivation (Shechter, 2017). The frequent occurrence of daytime sleepiness, fatigue, and lack of energy in individuals with OSAS demonstrates the association between these symptoms and imbalances in energy regulation systems (Chotinaiwattarakul & et al., 2009). Therefore, OSAS should be considered not only as a disorder of respiratory function but also as a systemic disease that affects the body's capacity for energy production, conservation, and maintenance.

d240: Activities Involving Initiating and Maintaining Sleep

It has been reported that patients with OSAS experience difficulties in initiating and maintaining sleep compared with healthy individuals. Fragmented sleep leads to reductions in both REM and non-REM sleep durations and negatively affects sleep architecture (Fogel & Malhotra, 2004).

Changes occurring in the upper airway adversely affect synchronized respiratory function, resulting in sleep fragmentation, reduced total sleep time, and prolonged sleep onset latency (White & Younes, 2012; Fogel & Malhotra, White, 2004).

Recent studies have shown that even treated OSAS patients continue to experience sleepiness and difficulties in maintaining sleep (Tankéré & et al., 2024).

d850: Participation in Work Life

OSAS negatively affects not only an individual's personal health system but also their participation in work life (Mulgrew & et al., 2007). Limitations in selective attention, time management, and social interaction adversely influence work participation (Mulgrew & et al., 2007). Guglielmi et al. demonstrated that depressive symptoms and increased anxiety in patients with OSAS lead to reduced work motivation (Guglielmi & et al., 2015).

Population-based studies have shown that employment rates among individuals with OSAS are lower compared to the general population (Fisker & et al., 2023).

e310/e355: Support from Family and Health Professionals

Evaluating the psychosocial effects of OSAS is among the factors that enhance treatment success. Therefore, in addition to individual interventions, the support of family members and healthcare professionals plays an important role. The literature indicates that patients with higher levels of family support demonstrate greater self-efficacy and more positive attitudes toward treatment (Xu & et al., 2015). Furthermore, the attitudes and support provided by healthcare professionals have been shown to help prevent increases in the severity of sleep apnea (Zhang & et al., 2015).

Support and guidance from family and health professionals provide a foundation for patients to take a more active role both in psychosocial aspects and in managing their health (Xu & et al., 2015; Zhang & et al., 2015).

Functional Assessment Approaches

Measures of Fatigue and Energy Levels

In patients with OSAS, symptoms such as excessive daytime sleepiness, fatigue, and low energy levels can negatively affect daily living activities (Sauter & et al., 2000). Both subjective and objective methods are used to assess these symptoms.
The Epworth Sleepiness Scale and the Stanford Sleepiness Scale evaluate individuals' levels of sleepiness and selective attention performance, whereas the Fatigue Severity Scale and the Fatigue Impact Scale are used to measure the impact of fatigue on daily life (Çalışkan & et al., 2019).
A review of the literature indicates that different scales are also used to assess fatigue. The Multidimensional Fatigue Inventory is a comprehensive questionnaire that evaluates fatigue across five subdimensions: general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity (Pajediene, Bileviciute-Ljungar, & Friberg, 2018). In addition, the Visual Analog Scale for Fatigue is a practical and commonly used tool for evaluating individuals' subjective perception of fatigue (Ilhanli Guder & Celik, 2016).

For assessing energy levels, the Profile of Mood States (POMS) scale is frequently used. This scale holistically evaluates mood, energy, and fatigue states, revealing the relationship between psychological condition and energy levels in patients with OSAS (Alemohammad & et al., 2017).

Assessment of Attention and Cognitive Functions

Cognitive dysfunctions are among the most frequently observed neuropsychological consequences in OSAS. In particular, attention, executive functions, motor skills, and memory processes are significantly affected in these patients (Gagnon & et al., 2014). For the evaluation of sustained attention, measurement tools such as the Four Choice Reaction Time Test**,** Cancellation Task (Weaver & et al., 1997), Continuous Performance Test, Driving Simulation (Beebe & Gozal, 2002), Psychomotor Vigilance Task (Mazza & et al., 2005), Trail Making Test A (Be'dard & et al., 1991), and the Simon and Flanker Task (Sforza & et al., 2004) are commonly used (Gagnon & et al., 2014).

For assessing executive functions, which include subcomponents such as behavioral inhibition, planning, and cognitive flexibility, tests such as the Stroop Test**,** Maze Test**,** Wisconsin Card Sorting Test**,** Trail Making Test B**,** Zimmerman-Fimm Tests Battery for Attentional Performance**,** Verbal Fluency**,** Digit Span (Backward)**,** and Tower of Toronto Test are utilized (Kilpinen, Saunamäki & Jehkonen, 2014; Aloia & et al., 2003; Gagnon & et al., 2014).

In the domain of memory particularly for the assessment of episodic memory tests such as the Rey Auditory-Verbal Learning Test**,** Wechsler Memory Scale Logical Stories**,** California Verbal Learning Test**,** Buschke Selective Reminding Test**,** WMS Figural Recall, and

Brief Visuospatial Memory Test – Revised (BVMT-R) are employed (Gagnon & et al., 2014; Saunamäki & Jehkonen, 2007).

Measures of Physical Performance and Exercise Capacity

Assessing exercise capacity in patients with OSAS is of great importance for understanding the systemic effects of the disease and determining the effectiveness of rehabilitation approaches. The Cardiopulmonary Exercise Test (CPET) is considered the gold standard method for measuring exercise capacity (Shengrui & et al., 2025). CPET provides a detailed evaluation of cardiorespiratory performance through parameters such as maximal oxygen consumption, ventilatory threshold, and oxygen pulse (Shengrui & et al., 2025). In the evaluation of functional capacity, lower extremity endurance and overall physical performance measurements are prioritized. For this purpose, the 6-Minute Walk Test (6MWT) (Lin & et al., 2024), Incremental Shuttle Walk Test (ISWT) (Carvalho & et al., 2018), and 30-Second Chair Stand Test (Sit-to-Stand Test) (Saldıran & et al., 2021) are frequently used. These tests provide submaximal physical performance assessments that reflect daily living activities and are important for identifying exercise intolerance in OSAS patients.

In assessing muscle function, both respiratory and skeletal muscles are examined. The Handgrip Strength Test is used to evaluate upper extremity muscle strength (Aksu & et al., 2023); Quadriceps Isokinetic Power Measurement is applied for lower extremity strength (Silva & et al., 2015); and Respiratory Muscle Strength Tests are employed to assess respiratory muscle function (Kuo & et al., 2017). These assessments reveal the relationship between reduced muscle performance, OSAS severity, and hypoxemic load. Self-report questionnaires also play an important role in determining the level of physical activity in both clinical and research applications. For evaluating daily living activities, the International Physical Activity Questionnaire (IPAQ) is commonly used (Fridgeirsdottir & et al., 2024); for measuring physical activity in older adults, the Physical Activity Scale for the Elderly (PASE) is preferred (Morelhão & et al., 2024); and for examining the physical activity subdimensions of quality of life, the Nottingham Health Profile (NHP) is utilized (Baycheva & et al., 2024).

The combined evaluation of these tests and scales enables a holistic analysis in patients with OSAS, encompassing not only exercise capacity but also muscle functions, physical activity levels, and overall quality of life.

Quality of Life Scales and Level of Participation

OSAS is a multidimensional clinical condition that affects not only physiological functions but also daily living activities, emotional well-being, and social participation. Therefore, quality of life assessments serve as an important indicator for understanding both the clinical burden of the disease and the response to treatment. In patients with OSAS, both generic and disease-specific instruments are used to assess quality of life (Moyer & et al., 2001).

Among the general quality of life scales, the Short Form-36 Health Survey (SF-36) is one of the most widely used tools. It evaluates eight subdimensions and has been found reliable in OSAS populations (Ware, 1996). The Nottingham Health Profile (NHP) is also frequently preferred in OSAS due to its subdimensions of energy, sleep, social isolation, and physical mobility (Hunt & et al., 1981). Scales such as the Sickness Impact Profile (SIP) and the Functional Limitations Profile (FLP) provide detailed assessments of mobility, self-care, social interaction, and recreation (Bergner & et al., 1981; Patrick & Peach, 1989). In addition, brief assessment tools such as the EuroQol EQ-5D and the Munich Life Quality Dimension List have been validated for OSAS patients, showing strong correlations with energy and psychological well-being (EuroQol Group, 1996; Heinisch & et al., 1991).

Disease-specific scales provide more sensitive measurements of the unique effects of OSAS on daily life. The Calgary Sleep Apnea Quality of Life Instrument (SAQLI) (Flemons & Reimer, 1998) consists of subdimensions assessing daily functioning, emotional state, social interaction, and symptoms. The Functional Outcomes of Sleep Questionnaire (FOSQ) (Weaver & et al., 1997) covers areas such as activity level, wakefulness, relationships, and productivity, evaluating functional losses associated with sleep disorders. Tools such as the OSA Patient Oriented Severity Index

(Piccirillo & et al., 1998) and Franco's Pediatric OSA Instrument (OSA-18) (Franco & et al., 2000) are used in adult and pediatric populations, respectively, focusing on emotional stress, daytime functioning, and caregiver anxiety. In pediatric cases, Cohen's Pediatric OSA Surgery QOL Questionnaire was developed to monitor postoperative changes in health, sleep, and parental burden (Cohen & et al., 2000).

Physiotherapy and Rehabilitation Perspective

OSAS is a complex syndrome that requires a multidisciplinary approach in its diagnosis and treatment processes (Khode & et al., 2025). Physiotherapists play not only a supportive but also a directly therapeutic role in the management of OSAS (Khode & et al., 2024). Through respiratory muscle training (Silva de Sousa & et al., 2024), oropharyngeal exercises (Arslan & Şevgin, 2024), aerobic (Arslan & Şevgin, 2024) and resistance exercise programs (Lin & et al., 2024), postural regulation (Battaglia & et al., 2025), as well as fascial mobilization and relaxation techniques (Park & Kim, 2024), physiotherapists improve both upper airway stability and overall cardiorespiratory endurance. Furthermore, they facilitate adherence to CPAP therapy, enhance exercise capacity, and significantly improve quality of life. Recent literature demonstrates that physiotherapists in OSAS treatment not only reduce symptoms but also achieve lasting improvements in autonomic nervous system balance, muscle function, and functional capacity. Thus, physiotherapy in sleep apnea rehabilitation has evolved from being a merely "complementary" intervention to becoming a core component of treatment**.**

A recent systematic review and meta-analysis examined the efficacy and safety of respiratory muscle training in patients with OSAS (Silva de Sousa & et al., 2024). The study combined the results of 13 randomized controlled trials and reported that inspiratory muscle training, compared to sham interventions, may improve systolic blood pressure and daytime sleepiness. However, no significant differences were observed in AHI, sleep quality, respiratory functions, or overall quality of life.

Additionally, it was noted that when inspiratory muscle training was combined with physical exercise or cardiac rehabilitation, additional benefits were observed in certain respiratory parameters, although its impact on general quality of life remained limited. These findings indicate that respiratory muscle training is a supportive and safe approach in OSAS rehabilitation and may provide clinical benefits, particularly when integrated with exercise-based interventions (Silva de Sousa & et al., 2024).

A recent randomized controlled clinical trial investigated the effects of combined oropharyngeal and aerobic exercises on daytime sleepiness, sleep quality, fatigue level, and quality of life in patients with OSAS (Arslan & Şevgin, 2024). Individuals aged 18–65 were divided into three groups: oropharyngeal exercise, combined oropharyngeal and aerobic exercise, and control. After an eight-week intervention, both exercise approaches resulted in improvements in sleep quality, daytime sleepiness, and quality of life. However, only the group that performed oropharyngeal exercises alone showed a more pronounced decrease in Epworth Sleepiness Scale and Fatigue Severity Scale scores. These findings suggest that specific exercises targeting oropharyngeal muscles may be more effective on their own in reducing daytime sleepiness and alleviating fatigue in patients with moderate to severe OSAS (Arslan & Şevgin, 2024).

A recent large-scale meta-analysis examined the therapeutic effects of exercise interventions in patients with OSAS and explored which patient subgroups benefited the most (Lin & et al., 2024). Analysis of data from twelve randomized controlled trials revealed that exercise training produced significant reductions in AHI, Epworth Sleepiness Scale scores, and body mass index, while markedly increasing maximal oxygen consumption. The effects of exercise were observed regardless of obesity status or OSAS severity. It was also noted that combining aerobic and resistance exercises further enhanced reductions in AHI and improvements in cardiorespiratory capacity (Lin & et al., 2024).

A recently published comprehensive review evaluated the role of positional therapy in OSAS management (Battaglia & et al., 2025). The study addressed the clinical effectiveness and long-term feasibility of physiotherapy in cases of "positional OSAS," where apneas predominantly occur in the supine position. Findings indicated that modern approaches such as vibrotactile devices were found to be more comfortable, easier to use, and associated with higher compliance rates compared to the traditional tennis ball technique. Although positional therapy did not produce AHI reductions as substantial as CPAP, physiotherapeutic interventions demonstrated favorable outcomes in terms of average disease alleviation rates and sleep continuity (Battaglia & et al., 2025).

Conclusion

OSAS is not merely a sleep disorder confined to episodic upper airway obstruction and the Apnea–Hypopnea Index (AHI); rather, it is a multidimensional, function-based health condition shaped by the dynamic interaction among body functions and structures (b440, b130), activities (d240), participation (d850), and environmental/personal factors (e310/e355). Intermittent hypoxemia, autonomic nervous system imbalance, and disruption of sleep architecture trigger daytime sleepiness, fatigue, and cognitive slowing, thereby reducing participation in work and social life. This condition leads to losses and economic burden not only at the individual level but also within the family, workplace, and broader society.

The ICF framework provides a common language for the holistic evaluation and management of OSAS.

- **b440** Impairments in respiratory functions and structural/neuromuscular components,
- **b130** Decrease along the fatigue–motivation axis through impairments in energy and drive functions,

- **d240** Difficulties in initiating and maintaining sleep,
- **d850** Limitations in participation in work life,
- **e310/e355** The determining role of environmental facilitators, including support from family and health professionals,

It shifts the clinical management of OSAS from an AHI-centered perspective to a functionality-oriented rehabilitation paradigm. This approach elevates the role of physiotherapy from a "complementary" intervention to a core component of treatment. In conclusion, the successful management of OSAS significantly improves through a multilayered, interdisciplinary approach that integrates physiological indicators, functionality, participation, and environmental support.

References

Aksu, S., Çaman, T., Özdemir, İ., Bek, S., & Kutlu, G. (2023). Lower handgrip strength in short-sleeper individuals with obstructive sleep apnea. *Sleep Medicine, 112*, 352–358. https://doi.org/10.1016/j.sleep.2023.07.010

Alemohammad, Z. B., Aminian, O., Noorani, A., Sadeghniiat-Haghighi, K., & Eftekhari, S. (2017). Mood and psychological state in patients with obstructive sleep apnea (OSA) referring to a sleep laboratory. *Journal of Sleep Sciences, 2*(3–4), 71–74. https://doi.org/10.18502/jss.v2i3-4.1048

Aloia, M. S., Ilniczky, N., Di Dio, P., Perlis, M. L., Greenblatt, D. W., & Giles, D. E. (2003). Neuropsychological changes and treatment compliance in older adults with sleep apnea. *Journal of Psychosomatic Research, 54*(1), 71–76. https://doi.org/10.1016/S0022-3999(02)00571-9

Arslan, E., & Şevgin, Ö. (2024). The effects of aerobic and oropharyngeal exercises on sleep quality of patients with obstructive sleep apnoea syndrome: A randomized controlled study. *Sleep and Breathing, 28*(6), 2729–2736. https://doi.org/10.1007/s11325-024-03157-3

Bardwell, W. A., Ancoli-Israel, S., Berry, C. C., & Dimsdale, J. E. (2001). Neuropsychological effects of one-week continuous positive airway pressure treatment in patients with obstructive sleep apnea: A placebo-controlled study. *Psychosomatic Medicine, 63*(4), 579–584. https://doi.org/10.1097/00006842-200107000-00008

Battaglia, E., Poletti, V., Volpato, E., & Banfi, P. (2025). Positional therapy: A real opportunity in the treatment of obstructive sleep apnea? An update from the literature. *Life, 15*(8), 1175. https://doi.org/10.3390/life15081175

Baycheva, S., Georgieva, G., Stoykov, M., Milkov, M., & Enchev, M. (2024). Impact of obstructive sleep apnea on patients' quality of life. *Romanian Journal of Rhinology, 14*(53), 45–50. https://doi.org/10.2478/rjr-2024-0053

Bédard, M. A., Montplaisir, J., Richer, F., & Malo, J. (1991). Nocturnal hypoxemia as a determinant of vigilance impairment in sleep apnea syndrome. *Chest, 100*(2), 367–370. https://doi.org/10.1378/chest.100.2.367

Beebe, D. W., & Gozal, D. (2002). Obstructive sleep apnea and the prefrontal cortex: Towards a comprehensive model linking nocturnal upper airway obstruction to daytime cognitive and behavioral deficits. *Journal of Sleep Research*, *11*(1), 1–16. https://doi.org/10.1046/j.1365-2869.2002.00289.x
https://doi.org/10.1016/S2213-2600(19)30198-5

Bergner, M., Bobbitt, R. A., Carter, W. B., & Gilson, B. S. (1981). The Sickness Impact Profile: Development and final revision of a health status measure. *Medical Care, 19*(8), 787–805. https://doi.org/10.1097/00005650-198108000-00001

Carvalho, T. M. D. C. S., Soares, A. F., Climaco, D. C. S., Secundo, I. V., & Lima, A. M. J. D. (2018). Correlation of lung function and respiratory muscle strength with functional exercise capacity in obese individuals with obstructive sleep apnea syndrome. *Jornal Brasileiro de Pneumologia*, *44*(4), 279–284. https://doi.org/10.1590/S1806-37562017000000324

Chattu, V. K., Manzar, M. D., Kumary, S., Burman, D., Spence, D. W., & Pandi-Perumal, S. R. (2018). The global problem of insufficient sleep and its serious public health implications. *Healthcare (Basel)*, 7(1), 1. https://doi.org/10.3390/healthcare7010001

Chotinaiwattarakul, W., O'Brien, L. M., Fan, L., & Chervin, R. D. (2009). Fatigue, tiredness, and lack of energy improve with treatment for OSA. *Journal of Clinical Sleep Medicine*, *5*(3), 222–227. https://doi.org/10.5664/jcsm.27497

Chu, Y., & Zinchuk, A. (2024). The present and future of the clinical use of physiological traits for the treatment of patients with OSA: A narrative review. *Journal of Clinical Medicine*, 13(6), 1636. https://doi.org/10.3390/jcm13061636

Cohen, S. R., Suzman, K., Simms, C., Burstein, F. D., Riski, J., & Montgomery, G. (1998). Sleep apnea surgery vs tracheostomy in children: An exploratory study of the comparative effects on quality of life. *Plastic and Reconstructive Surgery*, *102*(6), 1855–1864. https://doi.org/10.1097/00006534-199811000-00004

Çalışkan, H., Ertürk, N., Kütükçü, E. Ç., Arıkan, H., Yağlı, N. V., Sağlam, M., İnce, D. İ., & Ege, M. Y. (2019). The relationship between the physical activity level and fatigue perception, quality of life, and psychological status in patients with obstructive sleep apnea syndrome. *Journal of Turkish Sleep Medicine, 6*(1), 1–6.* https://doi.org/10.4274/jtsm.galenos.2019.28247

Deegan, P. C., & McNicholas, W. T. (1995). Pathophysiology of obstructive sleep apnoea. *European Respiratory Journal*, 7, 1161–1178. https://doi.org/10.1183/09031936.95.08071161

Demir, A. U., Ardic, S., Firat, H., Karadeniz, D., Aksu, M., Uçar, Z. Z., et al. (2015). Prevalence of sleep disorders in the Turkish adult population: Epidemiology of sleep study. *Sleep and Biological Rhythms, 13*(4), 298–308.

DiCaro, M. V., Lei, K., Yee, B., & Tak, T. (2024). The effects of obstructive sleep apnea on the cardiovascular system: A comprehensive review. *Journal of Clinical Medicine*, *13*(11), 3223. https://doi.org/10.3390/jcm13113223

Emsellem, H. A., Colwell, H. H., Cronin, J., Farkas, R. H., & Mathias, S. D. (2025). Fatigue is distinct from sleepiness and negatively impacts individuals living with obstructive sleep apnea (OSA): Results from qualitative research of individuals with OSA. *Health and Quality of Life Outcomes*, 23(1), 26. https://doi.org/10.1186/s12955-025-02526-7

EuroQol Group. (1996). The EuroQol quality of life scale (Revised 1993). In I. McDowell & C. Newell (Eds.), *Measuring health: A guide to rating scales and questionnaires* (2nd ed., pp. xxx–xxx). Oxford, UK: Oxford University Press.

Fisker, F. Y., Udholm, N., Fuglsang, M., Lundbye-Christensen, S., Marshall, N. S., Bille, J., Nyboe, C., & Udholm, S. (2023). Risk of permanent social security benefits and overview of work participation among patients with obstructive sleep apnea. *Sleep Medicine*, *108*, 16–21. https://doi.org/10.1016/j.sleep.2023.05.011

Flemons WW, Reimer MA. Development of a disease-specific health-related quality of life questionnaire for sleep apnea. Am J Respir Crit Care Med 1998;158:494–503.

Fogel, R. B., Malhotra, A., & White, D. P. (2004). Sleep 2: Pathophysiology of obstructive sleep apnoea/hypopnoea syndrome. *Thorax*, *59*(2), 159–163. https://doi.org/10.1136/thx.2003.015859

Franco, R. A., Jr., Rosenfeld, R. M., & Rao, M. (2000). Quality of life for children with obstructive sleep apnea. *Otolaryngology–Head and Neck Surgery*, *123*(1), 9–16. https://doi.org/10.1067/mhn.2000.105254

Fridgeirsdottir, K. Y., Ólafsdóttir, K. A., Islind, A. S., Leppänen, T., Arnardottir, E. S., & Saavedra, J. M. (2024). The role of physical activity on obstructive sleep apnea severity and hypoxic load, and the mismatch between subjective and objective physical activity assessments. *Journal of Sleep Research*, *33*(6), e14195. https://doi.org/10.1111/jsr.14195

Gagnon, K., Baril, A. A., Gagnon, J. F., Fortin, M., Décary, A., Lafond, C., Desautels, A., Montplaisir, J., & Gosselin, N. (2014). Cognitive impairment in obstructive sleep apnea. *Pathologie Biologie*, *62*(5), 233–240. https://doi.org/10.1016/j.patbio.2014.05.015

Grandner, M. A. (2017). Sleep, health, and society. *Sleep Medicine Clinics*, 12(1), 1–22. https://doi.org/10.1016/j.jsmc.2016.10.012

Guglielmi, O., Jurado-Gámez, B., Gude, F., & Buela-Casal, G. (2015). Occupational health of patients with obstructive sleep apnea syndrome: A systematic review. *Sleep and Breathing*, *19*(1), 35–44. https://doi.org/10.1007/s11325-014-0985-3

Heinisch, M., Ludwig, M., & Bullinger, M. (1991). Psychometrische Testung der Münchner Lebensqualitätsfragenbogen. In M. Bullinger, M. Ludwig, & N. von Steinbüchel (Eds.), *Lebensqualität bei kardiovaskulären Erkrankungen: Grundlagen, Messverfahren, Ergebnisse, Dimensionen Liste (MLDL)* (pp. 73–90). Göttingen, Germany: Hogrefe.

Hunt, S. M., McKenna, S. P., McEwen, J., Williams, J., & Papp, E. (1981). The Nottingham Health Profile: Subjective health status and medical consultations. *Social Science & Medicine A*, *15*(3, Part 1), 221–229. https://doi.org/10.1016/0271-7123(81)90005-5

Iannella, G., Pace, A., Bellizzi, M. G., Magliulo, G., Greco, A., De Virgilio, A., … Maniaci, A. (2025). The global burden of obstructive sleep apnea. *Diagnostics*, 15(9), 1088. https://doi.org/10.3390/diagnostics15091088

Ilhanli, I., Guder, N., & Celik, C. (2016). STOP-Bang test results of a randomly selected group of fibromyalgia patients. *American Journal of Clinical and Experimental Medicine*, *4*(1), 1–6. https://doi.org/10.11648/j.ajcem.20160401.11

Jaiswal, A., Paramasivam, A., Budhiraja, S., Santhakumaran, P., Gravel, C., Martin, J., … Wittich, W. (2024). The International Classification of Functioning, Disability and Health (ICF) core sets for deafblindness, part II of the systematic review: Linking data to the ICF categories. *European Journal of Physical and Rehabilitation Medicine*, 60(5), 893. https://doi.org/10.23736/S1973-9087.24.08339-7

Jehan, S., Auguste, E., Pandi-Perumal, S. R., Kalinowski, J., Myers, A. K., Zizi, F., Rajanna, M. G., Jean-Louis, G., & McFarlane, S. I. (2017). Depression, obstructive sleep apnea and psychosocial health. *Sleep Medicine and Disorders*, 1(3), 00012.

Johannesen, G., Damlund, A. R. S., Grundtvig Vinter, S., Spuur, H. S., Sarkez-Knudsen, M., & Thomsen, T. G. (2024). First step to empowering change: Enhancing self-efficacy, energy management, and physical activity in patients with sleep apnea. *Frontiers in Rehabilitation Sciences, 5*, 1359371. https://doi.org/10.3389/fresc.2024.1359371

Khode, S., Khare, M., Talwekar, A., Jacobowitz, O., Moffa, A., Casale, M., & Vicini, C. (2025). "An interdisciplinary collaboration": A holistic approach in the management of obstructive sleep apnoea syndrome. *Indian Journal of Otolaryngology and Head & Neck Surgery*, 1–10. https://doi.org/10.1007/s12070-025-04164-8

Kilpinen, R., Saunamäki, T., & Jehkonen, M. (2014). Information processing speed in obstructive sleep apnea syndrome: A review.

Acta Neurologica Scandinavica, 129(4), 209–218. https://doi.org/10.1111/ane.12201

Kim, H. J., Choi, B., Choi, E., Kim, H., Jang, S. N., Lim, J. Y., … Smith-Merry, J. (2025). *Use of the International Classification of Functioning, Disability and Health (ICF) in integrated care for people with disabilities: A scoping review using the SELFIE framework.* Disability and Health Journal**,** *101854.*

Kuo, Y. C., Song, T. T., Bernard, J. R., & Liao, Y. H. (2017). Short-term expiratory muscle strength training attenuates sleep apnea and improves sleep quality in patients with obstructive sleep apnea. *Respiratory Physiology & Neurobiology*, *243*, 86–91. https://doi.org/10.1016/j.resp.2017.05.006

Li, X., Zha, L., Zhou, L., Xu, Y., Li, X., Yang, J., & Li, H. (2025). Diagnostic utility of obstructive sleep apnea screening questionnaires: A comprehensive meta-analysis. *Sleep and Breathing*, 29(1), 14. https://doi.org/10.1007/s11325-024-03014-4

Lin, C. F., Ho, N. H., Hsu, W. L., Lin, C. H., Wang, Y. H., & Wang, Y. P. (2024). Effects of aerobic exercise and resistance training on obstructive sleep apnea: A systematic review and meta-analysis. *Journal of Clinical Sleep Medicine, 20*(11), 1839–1849. https://doi.org/10.5664/jcsm.11612

Lin, C. W., Lin, P. W., Chiu, L. W., Su, M. C., Chai, H. T., Chang, C. T., Chen, Y. W., & Lin, H. C. (2024). Effects of multilevel OSA surgery on patients with poor cardiopulmonary performance: A prospective pilot study. *Auris Nasus Larynx, 51*(6), 1042–1047. https://doi.org/10.1016/j.anl.2024.05.003

Luyster, F. S. (2017). Impact of obstructive sleep apnea and its treatments on partners: A literature review. *Journal of Clinical Sleep Medicine*, 13(3), 467–477. https://doi.org/10.5664/jcsm.6498

Mazza, S., Pépin, J. L., Naegele, B., Plante, J., Deschaux, C., & Lévy, P. (2005). Most obstructive sleep apnoea patients exhibit vigilance and attention deficits on an extended battery of tests. *European Respiratory Journal*, *25*(1), 75–80. https://doi.org/10.1183/09031936.04.00032704

McNicholas, W. T. (2017). COPD–OSA overlap syndrome: Evolving evidence regarding epidemiology, clinical consequences, and management. *Chest*, 152(6), 1318–1326. https://doi.org/10.1016/j.chest.2017.05.009

McNicholas, W. T., & Pevernagie, D. (2022). Obstructive sleep apnea: Transition from pathophysiology to an integrative disease model. *Journal of Sleep Research*, 31(4), e13616. https://doi.org/10.1111/jsr.13616

Morelhão, P., Pinto, R., Grande, G., Gobbi, C., Franco, M., Tufik, S., & Andersen, M. (2024). Are physical activity levels able to predict sleep quality in community-dwelling older adults? A longitudinal study. *Sleep Medicine*, *115*(Suppl. 1), S1. https://doi.org/10.1016/j.sleep.2024.07.001

Moyer, C. A., Sonnad, S. S., Garetz, S. L., Helman, J. I., & Chervin, R. D. (2001). Quality of life in obstructive sleep apnea: A systematic review of the literature. *Sleep Medicine*, *2*(6), 477–491. https://doi.org/10.1016/S1389-9457(01)00072-7

Mulgrew, A. T., Ryan, C. F., Fleetham, J. A., Cheema, R., Fox, N., Koehoorn, M., FitzGerald, J. M., Marra, C., & Ayas, N. T. (2007). The impact of obstructive sleep apnea and daytime sleepiness on work limitation. *Sleep Medicine*, *9*(1), 42–53. https://doi.org/10.1016/j.sleep.2007.01.009

Owens, R. L., Eckert, D. J., Yeh, S. Y., & Malhotra, A. (2008). Upper airway function in the pathogenesis of obstructive sleep apnea: A review of the current literature. *Current Opinion in Pulmonary Medicine*, *14*(6), 519–554. https://doi.org/10.1097/MCP.0b013e3283121c18

Pajediene, E., Bileviciute-Ljungar, I., & Friberg, D. (2018). Sleep patterns among patients with chronic fatigue: A polysomnography-based study. *The Clinical Respiratory Journal*, *12*(4), 1389–1397. https://doi.org/10.1111/crj.12659

Park, J., & Kim, K. I. (2024). Effects of manual therapy on obstructive sleep apnea: Study protocol for a systematic review. *Journal of Korean Medicine Rehabilitation*, *34*(3), 65–74. https://doi.org/10.18325/jkmr.2024.34.3.65

Patel, N., Chong, K., & Baydur, A. (2022). Methods and applications in respiratory physiology: Respiratory mechanics, drive, and muscle function in neuromuscular and chest wall disorders. *Frontiers in Physiology*, *13*, 838414. https://doi.org/10.3389/fphys.2022.838414

Patrick, D. L., & Peach, H. (1989). *Disablement in the community.* Oxford, UK: Oxford University Press.

Piccirillo, J. F., Gates, G. A., White, D. L., & Schectman, K. B. (1998). Obstructive sleep apnea treatment outcomes pilot study. *Otolaryngology–Head and Neck Surgery*, *118*(6), 833–844. https://doi.org/10.1016/S0194-5998(98)70263-5

Pihtili, A., Kiyan, E., Balcan, B., Arbatli, S., Cilli, A., Altintas, N., … Akkoyunlu, M. E. (2025). Sex differences in clinical and polysomnographic features of obstructive sleep apnea: The Turkish Sleep Apnea Database (TURKAPNE) cohort. *Sleep Medicine*, 126, 228–234. https://doi.org/10.1016/j.sleep.2025.01.012

Saldıran, T. Ç., Kara, İ., Kutlutürk, S., & Durgun, M. (2021). Interaction between physical performance and health metrics in patients with obstructive sleep apnea syndrome. *Journal of Basic and Clinical Health Sciences*, *8*(3), 590–602. https://doi.org/10.30621/jbachs.887905

Salepçi, B., Aktin Güngör, G., Torun Parmaksız, E., Fidan, A., Kıral, N., & Sener Cömert, S. (2016). Expiratory and inspiratory muscle functions in obstructive sleep apnea syndrome. *Journal of Turkish Sleep Medicine*, *3*(3), 65–68. https://doi.org/10.4274/jtsm.225

Sanchez Gomez, J., Pramono, R. X. A., Imtiaz, S. A., Rodriguez-Villegas, E., & Valido Morales, A. (2024). Validation of a wearable medical device for automatic diagnosis of OSA against

standard PSG. *Journal of Clinical Medicine*, 13(2), 571. https://doi.org/10.3390/jcm13020571
Saunamäki, T., & Jehkonen, M. (2007). A review of executive functions in obstructive sleep apnea syndrome. *Acta Neurologica Scandinavica*, *115*(1), 1–11. https://doi.org/10.1111/j.1600-0404.2006.00744.x
Sauter, C., Asenbaum, S., Popovic, R., Bauer, H., Lamm, C., Klösch, G., & Zeitlhofer, J. (2000). Excessive daytime sleepiness in patients suffering from different levels of obstructive sleep apnoea syndrome. *Journal of Sleep Research*, *9*(3), 293–301.* https://doi.org/10.1046/j.1365-2869.2000.00211.x
Schneidert, M., Hurst, R., Miller, J., & Üstün, B. (2003). The role of environment in the International Classification of Functioning, Disability and Health (ICF). *Disability and Rehabilitation*, 25(11–12), 588–595. https://doi.org/10.1080/0963828031000137090
Sforza, E., Haba-Rubio, J., De Bilbao, F., Rochat, T., & Ibanez, V. (2004). Performance vigilance task and sleepiness in patients with sleep-disordered breathing. *European Respiratory Journal*, *24*(2), 279–285. https://doi.org/10.1183/09031936.04.00041404
Shechter, A. (2017). Obstructive sleep apnea and energy balance regulation: A systematic review. *Sleep Medicine Reviews*, *34*, 59–69. https://doi.org/10.1016/j.smrv.2016.07.001
Shengrui, M., Yue, Z., Wenjun, W., Xiaochuan, C., Peng, Y., & Shukun, D. (2025). Cross-sectional study on exercise capacity in obese patients with severe obstructive sleep apnea syndrome.

Frontiers in Physiology, *16*, 1580308.
https://doi.org/10.3389/fphys.2025.1580308

Silva de Sousa, A., Pereira da Rocha, A., Brandão Tavares, D. R., Frazão Okazaki, J. É., de Andrade Santana, M. V., Fernandes Moça Trevisani, V., & Pereira Nunes Pinto, A. C. (2024). Respiratory muscle training for obstructive sleep apnea: Systematic review and meta-analysis. *Journal of Sleep Research*, *33*(3), e13941.
https://doi.org/10.1111/jsr.13941

Silva, A., Mello, M. T., Serrão, P. R., Luz, R. P., Bittencourt, L. R., & Mattiello, S. M. (2015). Influence of obstructive sleep apnea syndrome on the fluctuation of the submaximal isometric torque of knee extensors in patients with early-grade osteoarthritis. *Brazilian Journal of Physical Therapy*, *19*(4), 271–278.
https://doi.org/10.1590/bjpt-rbf.2014.0112

Stauffer, J. L., White, D. P., & Zwillich, C. W. (1990). Pulmonary function in obstructive sleep apnea: Relationships to pharyngeal resistance and cross-sectional area. *Chest*, *97*(2), 302–307.
https://doi.org/10.1378/chest.97.2.302

Stojic, S., Boehl, G., Rubinelli, S., Brach, M., Jakob, R., Kostanjsek, N., … Glisic, M. (2025). *Twenty years of the International Classification of Functioning, Disability and Health (ICF) in health research: A bibliometric analysis*. Disability and Rehabilitation: Assistive Technology, 20(2), 444–451.

Tanellari, O., Koci, B., Baruti Papa, E., Balcos, C., Armencia, A. O., Panaite, T., & Zetu, I. (2025). Study on quality of life of

patients with obstructive sleep apnea: Pilot study. *Medicina (Kaunas)*, 61(7), 1234. https://doi.org/10.3390/medicina61071234
Tankéré, P., Taillard, J., Armeni, M.-A., Petitjean, T., Berthomier, C., Strauss, M., & Peter-Derex, L. (2024). Revisiting the maintenance of wakefulness test: From intra-/inter-scorer agreement to normative values in patients treated for obstructive sleep apnea. *Journal of Sleep Research, 33*(3), e13961. https://doi.org/10.1111/jsr.13961
Wang, Y., Zhou, B., Yue, W., Zhang, J., He, Y., Wang, M., & Hu, K. (2025). Independent association between hourly apnea-hypopnea duration and prevalence of diabetes in male adults. *Sleep Medicine*. Advance online publication. https://doi.org/10.1016/j.sleep.2025.106807
Ware, J. E. (1996). The SF-36 Health Survey. In B. Spilker (Ed.), *Quality of life and pharmacoeconomics in clinical trials* (2nd ed., pp. 337–345). Philadelphia, PA: Lippincott-Raven.
Weaver, T. E., Laizner, A. M., Evans, L. K., Maislin, G., Chugh, D. K., Lyon, K., Smith, P. L., Schwartz, A. R., Redline, S., Pack, A. I., & Dinges, D. F. (1997). An instrument to measure functional status outcomes for disorders of excessive sleepiness. *Sleep, 20*(10), 835–843. https://doi.org/10.1093/sleep/20.10.835
Weaver, T. E., Maislin, G., Dinges, D. F., Bloxham, T., George, C. F., Greenberg, H., ... & Pack, A. I. (2007). Relationship between hours of CPAP use and achieving normal levels of sleepiness and

daily functioning. *Sleep*, *30*(6), 711–719. https://doi.org/10.1093/sleep/30.6.711

White, D. P., & Younes, M. K. (2012). Obstructive sleep apnea. *Comprehensive Physiology*, *2*(4), 2541–2594. https://doi.org/10.1002/cphy.c110064

Works, H. P., N. Y., R. O., & Patient, F. (2023). The science of sleep: Functional medicine for restorative sleep. *Science*, 381(2), 45–52.

Xu, Q., Xie, H., Lin, Y., Yao, Y., Ye, Z., Chen, J., Yang, S., & Wang, Y. (2020). Family support is beneficial to the management and prognosis of patients with obstructive sleep apnoea. *Annals of Palliative Medicine*, *9*(4), 1375–1381. https://doi.org/10.21037/apm-19-310

Yılmaz, S., & Küpçü, Z. (2025). Obstructive sleep apnea risk and sleep quality in adolescents with polycystic ovary syndrome: A case–control study. *Revista da Associação Médica Brasileira*, 71(4), e20241615. https://doi.org/10.1590/1806-9282-20241615

Zhang, F., Liang, C., Zhang, C., Xu, K., Chen, Q., Xu, H., & Zhang, H. (2024). The link between fear of disease progression and health promotion behaviors in patients with obstructive sleep apnea hypoventilation syndrome (OSAHS): The mediating role of social support. *BMC Psychology*, *12*(1), 557. https://doi.org/10.1186/s40359-024-02059-z

BİDGE