Physical activity and COVIDMOVE

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CONTENT

Disclaimer

The recommendations and information provided in the COVIDMOVE book regarding physical activity are intended for general informational purposes only. They are not a substitute for professional medical advice, diagnosis, or treatment. Before beginning any new exercise program, especially if you have existing health conditions or concerns, please consult with a qualified healthcare professional.

The authors and publishers of this book are not responsible for any injuries or health issues that may arise from following the activities.

Introduction

Movement is more than just physical activity – it is the language through which our body communicates with the world. It is a fundamental expression of life, connecting the soul, mind, and body in harmony. Movement is not just about physical fitness or achieving specific performance goals. It is a way of expressing ourselves, discovering who we are, and building a relationship with our body and surroundings. This book is not merely about exercise or specific techniques.

This textbook is intended for students of various medical and non-medical fields, offering a comprehensive foundation in essential concepts and principles relevant to both disciplines. It is designed to meet the educational needs of learners pursuing careers in healthcare, allied health professions, and other related areas. The material provides a balance of theoretical knowledge and practical applications, ensuring students can develop critical thinking skills and a deeper understanding of the subject matter. Additionally, the content is structured to be accessible and engaging, catering to individuals at different stages of their academic journey while promoting interdisciplinary learning and collaboration.

We live in an era where we've become estranged from our own bodies. Sedentary lifestyles, technology, and constant performance pressures have distanced us from a simple truth: the body is designed to move. Every cell, every muscle, every joint is built to work together in motion. When we stop moving, the body suffers – stiff muscles, decreased energy, and various health issues arise. But more than that, our mind suffers too. Movement is not just a physical activity; it is a way to clear the mind, gain a fresh perspective, and find peace in a hectic world.

This book aims to change the way you perceive movement. You don't have to be an athlete, you don't have to break records. Movement is for everyone, regardless of age, physical condition, or abilities. We want to inspire you to see movement as a natural part of your life, as a source of joy, vitality, and self-expression. Movement can be simple, spontaneous, and fun – whether it's a morning stretch, dancing in the kitchen, a walk in nature, or deliberate exercises to strengthen both body and mind.

Each of us has different abilities, different journeys, and different goals. However, what unites us all is the fact that movement is the key to vitality and happiness. This book offers you a wealth of inspiration, practical advice, and stories to encourage you to discover your potential. It will teach you how to approach movement with love, respect, and awareness. Because it doesn't matter how fast you run, how much weight you lift, or how challenging your workout is. What matters is that you're moving, finding joy in movement, and taking steps toward a healthier and more fulfilling life.

Physical Activity in a pandemic world, the COVID-19 pandemic disrupted lives across the globe, forcing humanity to adapt to an unprecedented set of challenges. As lockdowns, social distancing measures, and other public health interventions became the norm, one critical aspect of daily life was profoundly affected: physical activity. For many, movement is not just about fitness; it's essential for mental health, social well-being, and overall quality of life. The COVIDMOVE project was born out of the need to understand and address how the pandemic altered patterns of physical activity. From gym closures and restrictions on outdoor recreation to the rise of home workouts and virtual fitness communities, the pandemic reshaped the way people move, exercise, and stay active. This book focuses on the intersection of pandemic and physical activity, offering a comprehensive analysis of its impact on movement behaviors across diverse populations. It explores key questions such as: How did lockdowns and restrictions influence exercise habits and routines? The COVIDMOVE project ultimately aims to inspire action—encouraging policymakers, educators, health professionals, and individuals to prioritize physical activity as a cornerstone of public health. By understanding the transformative impact of the pandemic, we can reimagine physical activity not just as a response to crisis, but as an integral part of building healthier, more resilient societies.
Let this book be your guide on this journey. Discover the magic of movement, its ability to transform not just your body, but your mind and soul. Learn to listen to your body, understand its needs, and respect its limits. And most importantly, find freedom and joy in movement that can enrich every day of your life.
We would also like to express our gratitude to the students and doctoral candidates who dedicated themselves to the project beyond their official responsibilities, which is why we have credited them as co-authors of individual chapters in the publication. We appreciate their contribution to better dissemination of the publication to the target audiences.

Move. Live. Discover. Because movement is life.

Dr. Dávid Líška, PhD.

Chapter 1

Sarcopenia, physical activity and COVIDMOVE

The term sarcopenia originates from the Greek words "sarco," meaning muscle, and "penia," meaning loss, and was first used by Irwin Rosenberg (1). Sarcopenia is a musculoskeletal disorder in which significant loss of muscle mass, strength, and performance occurs with advancing age (2–4). This condition is not merely a normal part of aging but represents a serious health issue that can significantly impact an individual's quality of life and independence (4–8). Sarcopenia most commonly affects older people, those with a sedentary lifestyle, and patients with comorbidities that affect the musculoskeletal system or limit physical activity (9,10). Loss of muscle mass and strength leads to decreased physical capability, which may, in turn, increase the risk of falls, fractures, and other injuries (11,12). Sarcopenia also has adverse effects on metabolism, raising the risk of insulin resistance and metabolic syndrome, which can lead to additional serious health issues (13). Sarcopenia has a complex pathophysiology influenced by aging, sociodemographic factors, lifestyle, and various health comorbidities (14). Aging of the musculoskeletal system and sarcopenia in older adults are especially closely linked, as cellular, mitochondrial, and neural disruptions associated with age-related dysfunctions can also lead to the onset of sarcopenia (15). Obesity and excessive calorie consumption can both contribute to sarcopenia. Sarcopenic obesity is a condition in which there is both a decline in muscle mass and excessive fat accumulation, especially visceral fat. This condition is characterized by the combination of low muscle mass and increased fat mass, leading to impaired physical function, increased risk of metabolic disorders, and other health complications. Sarcopenic obesity is more common among older adults, but it can also occur in younger individuals, particularly due to a sedentary lifestyle or improper nutrition (14,15).

The treatment of sarcopenia is multidisciplinary and involves a combination of various approaches aimed at improving muscle mass, strength, and function. The goal of treatment is to slow or halt the progression of sarcopenia and improve the patient's quality of life. A crucial component of this treatment is the collaboration of an interdisciplinary team, including doctors, physiotherapists, dietitians, and other healthcare professionals. This team approach enables the development of a comprehensive and personalized treatment plan tailored to the individual needs and health condition of the patient.

The link between sarcopenia and malnutrition is very close, often creating a vicious cycle where one condition worsens the other. Malnutrition, which is a state of insufficient intake or inadequate utilization of nutrients necessary for the proper functioning of the body, can accelerate sarcopenia (18,19). Insufficient protein and energy intake worsens the body's ability to maintain muscle mass, directly contributing to the development of sarcopenia, which is the progressive loss of muscle mass and strength. On the other hand, sarcopenia reduces an individual's physical capacity to perform daily activities, potentially leading to reduced food intake and consequently to malnutrition. This interrelated relationship means that addressing both conditions simultaneously is essential in treatment and prevention to avoid their mutual exacerbation and to support overall health and quality of life, especially in older adults (18). In many patient groups, malnutrition and sarcopenia occur concurrently and are often clinically manifested by a combination of various factors, such as disease burden, inflammation, reduced nutrient intake, decreased body weight, altered immune and endocrine functions, and reduced resistance to oxidative stress (20). These conditions are also associated with a loss of muscle mass, reduced strength, or physical function.

People in younger and middle ages have varying amounts of muscle mass and function, which gradually diminish with age at different rates. This process is influenced by multiple factors, including genetics, lifestyle, and chronic diseases, and can be accelerated by the occurrence of acute health issues.

Levels of physical activity in Slovakia, the Czech Republic, and Poland

In a study by Líška et al. (21), we compared the levels of physical activity among university students in Poland, Slovakia, and the Czech Republic after the COVID-19 pandemic. We utilized the standardized IPAQ questionnaire. The International Physical Activity Questionnaire is a tool designed to measure levels of physical activity in adults. Developed in the 1990s, it is widely used in research, epidemiological studies, and public health monitoring of physical activity. The questionnaire focuses on assessing physical activity over the past week, covering four main areas: vigorous physical activity, which includes high-intensity activities such as running or fast cycling that lead to increased breathing and heart rate. Moderate physical activity, which includes activities of medium intensity, such as walking or household chores. Daily walking, representing everyday physical activities done on foot. Sedentary behavior, measuring the time spent sitting, such as during work or leisure time in front of the television. The questionnaire results allow for categorizing individuals based on their level of physical activity (low, medium, or high), providing experts with information needed to recommend potential adjustments or improvements in physical activity.

The levels of physical activity, measured using MET scores, varied between countries, with Slovakia having the highest and Poland the lowest median MET score. Post hoc analysis revealed statistically significant differences between the Czech Republic and Poland ($p < 0.035$), where Czechs showed higher MET values, as well as between the Czech Republic and Slovakia ($p < 0.037$), with Slovakia having higher MET values. The results showed that students in Slovakia exhibited the highest level of physical activity, while students in Poland recorded the lowest level. Interestingly, Slovak women were particularly active compared to women from other countries. The level of physical activity was lower than before the pandemic, highlighting the need for increased support for physical activity.

The study indicates that the COVID-19 pandemic significantly impacted the level of physical activity among young people, with restrictions related to lockdowns, school closures, and the closure of sports facilities leading to a significant reduction in opportunities to engage in regular physical activities. Many young people spent more time at home, often engaging in sedentary activities such as watching television, playing video games, or using social media. This decrease in physical activity may have serious long-term consequences for their overall health, including an increased risk of obesity, reduced fitness, and higher susceptibility to chronic diseases, such as diabetes mellitus, cardiovascular diseases, and mental health issues like anxiety and depression. Additionally, the study emphasizes that children and young people lost access to structured forms of physical activity, such as sports teams or training, which further contributed to their decreased activity levels. Returning to previous levels of physical activity may be challenging unless steps are taken to support a healthy lifestyle and motivate young people to engage in regular movement. Thus, the pandemic underscored the need for effective strategies and policies to promote physical activity, essential for the long-term physical and mental health of the younger generation.

The importance of physical activity in the treatment of sarcopenia

Physical activity plays a key role in the treatment of sarcopenia. Regular physical activity, especially targeted exercises, can significantly slow or even reverse this process. Exercise, particularly strength training and resistance exercises, helps increase muscle mass and improve muscle function. Strength training, which includes weightlifting or exercises with resistance bands, directly supports muscle protein synthesis, leading to muscle tissue regeneration and increased strength (22). Additionally, resistance exercises stimulate neuromuscular connections, contributing to better coordination and the ability to respond quickly to stimuli, which is essential for fall prevention. Combining resistance training with aerobic exercises such as walking, swimming, cycling, or Nordic walking can improve overall mobility, coordination, and balance. Aerobic exercises help strengthen the cardiovascular system and support fat burning, which is important for maintaining a healthy body weight. Improved coordination and stability significantly reduce the risk of falls, which are often associated with serious injuries such as fractures in older adults (23,24). Physical activity also stimulates metabolism, supports bone health, and improves insulin sensitivity, which is important in combating sarcopenia and related health complications, such as obesity, type 2 diabetes, and osteoporosis (25,26). Increased bone density and improved structure through exercise can help prevent osteoporosis, a common accompaniment to sarcopenia that increases the risk of fractures. Besides physical benefits, regular physical activity has a significant impact on mental health. It improves mood, reduces stress and anxiety, and boosts self-confidence. Older people who regularly engage in physical activity often have a higher level of self-esteem and feel more independent. Exercise also promotes social interaction, especially if done in groups or under the supervision of instructors, which can reduce the risk of social isolation and depression, often affecting older adults.

Risk factors and sarcopenia

The development of sarcopenia is influenced by multiple risk factors. Among the primary factors is age, which is one of the most significant (27,28). With advancing age, there is a natural loss of muscle mass due to hormonal changes, reduced protein synthesis, and a diminished ability to regenerate muscle tissue. Another critical risk factor is physical inactivity. A sedentary lifestyle and lack of movement lead to rapid muscle loss, as insufficient muscle stimulation accelerates the loss of strength and endurance. In older adults, protein intake is often inadequate, worsening muscle condition. Additional risk factors include hormonal changes, such as a decrease in growth hormone, testosterone, and estrogen, which play a key role in muscle regeneration regulation. Chronic diseases, such as chronic obstructive pulmonary disease (COPD), heart failure, type 2 diabetes, chronic kidney disease, or cancers, also contribute as risk factors, as they lead to inflammation and metabolic changes that accelerate muscle loss (27,29). Chronic inflammation and oxidative stress can contribute to muscle damage and hinder regeneration. Reduced neurological stimulation of muscles due to aging leads to a decline in muscle activation and strength.

Another important factor is genetic predisposition, which may affect the rate of muscle mass loss due to innate metabolic and hormonal factors. Cognitive impairments and depression are also risk factors, as they lead to lower physical activity and often deteriorate nutrition, which can promote the development of sarcopenia. Excessive alcohol consumption and smoking further increase risk, as alcohol has toxic effects on muscle cells, and smoking impairs blood circulation and muscle function.

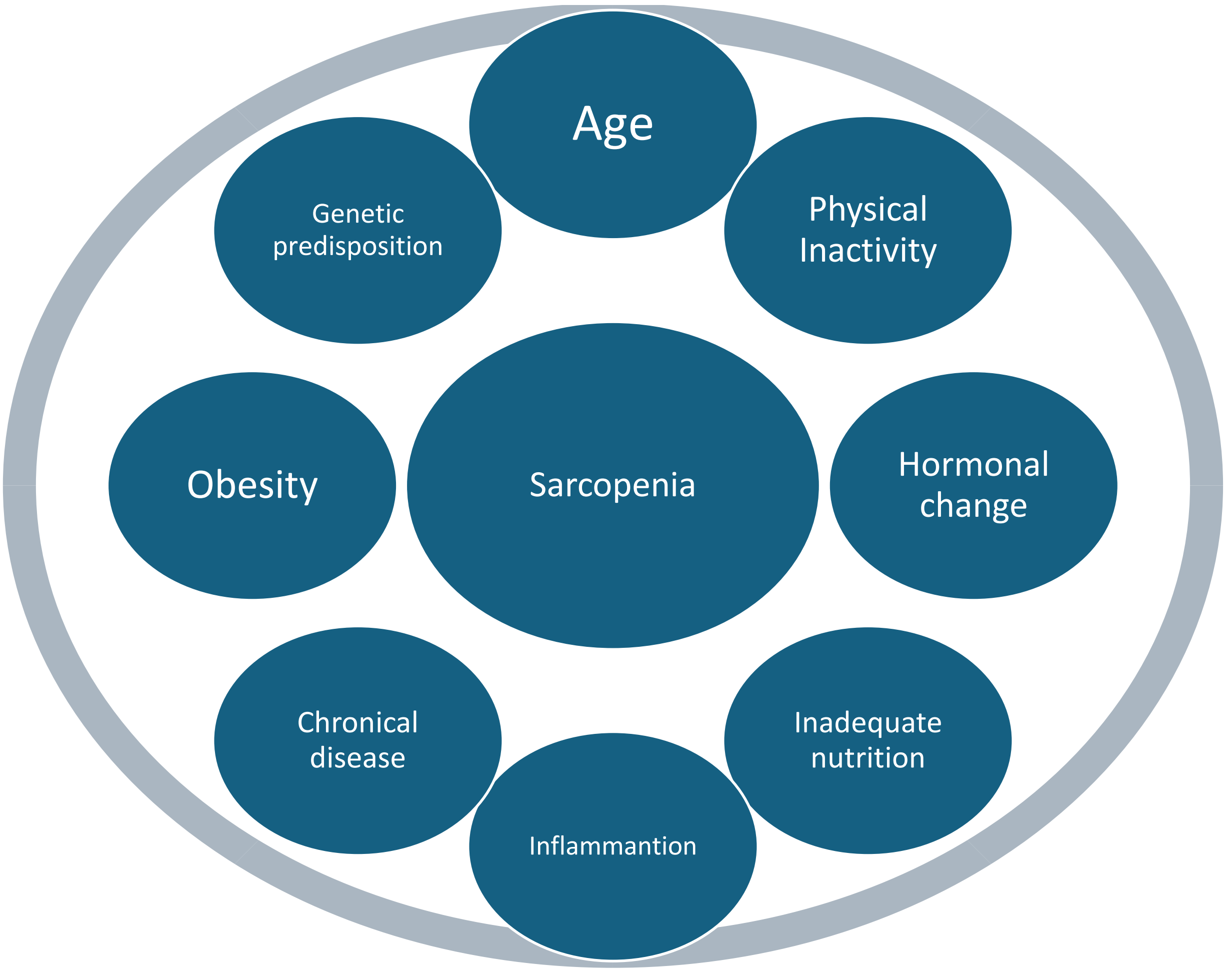

Figure 1 Risk factor of Sarcopenia

Sarcopenia and insulin resistance

Sarcopenia and insulin resistance are closely linked health conditions that often accompany aging, metabolic disorders, and chronic diseases (30). Insulin resistance is a condition in which the body's cells no longer respond adequately to insulin, leading to a reduced ability to absorb glucose from the blood and, consequently, elevated blood sugar levels, which often precedes the development of type 2 diabetes mellitus (31). Muscle tissue is crucial for glucose metabolism, as muscles consume a significant portion of the body's glucose. In sarcopenia, the loss of muscle mass reduces the body's ability to use glucose efficiently, increasing the risk of developing insulin resistance (32). Conversely, insulin resistance impairs the ability of insulin to stimulate muscle protein synthesis, slowing down muscle mass repair and regeneration, which may accelerate the progression of sarcopenia, especially in older adults (33). This relationship is exacerbated by chronic low-grade inflammation, which is common among older people. Inflammation worsens insulin sensitivity and simultaneously promotes muscle mass loss (34). Additionally, both conditions are often accompanied by reduced physical activity. Lack of movement aggravates insulin resistance and weakens muscle regeneration, creating a vicious cycle. The worsening of one condition often leads to the deterioration of the other, mutually reinforcing each other and driving the progression of metabolic and physical disorders.

Molecular mechanisms and sarcopenia

The molecular mechanism of sarcopenia is complex and involves various biological processes that lead to the loss of muscle mass, reduced muscle strength, and impaired muscle function with age. One of the primary factors is the decline in anabolic signals, particularly hormones like growth hormone, IGF-1, and testosterone, which are essential for muscle protein synthesis and muscle mass maintenance (35,36). As these hormone levels decrease with age, the body's ability to sustain muscle mass weakens. Simultaneously, catabolic processes increase primarily through the ubiquitin-proteasome system (UPS) and elevated activity of proteins like myostatin, which negatively regulates muscle mass (37,38). High myostatin activity in old age contributes to muscle atrophy.

Chronic inflammation, known as "inflammaging," is another key factor disrupting the delicate balance between muscle protein synthesis and degradation, contributing to gradual muscle weakening, especially with age. This type of inflammation is not acute, as in infections or injuries, but persists at a low level in the body over the long term, with significant negative health effects. Elevated levels of inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) play a crucial role in this process (39). These cytokines stimulate muscle protein catabolism, promoting muscle mass breakdown and disrupting the regeneration and building of muscle cells. Additionally, TNF-α can interfere with insulin signaling, reducing muscle cells' ability to absorb glucose, which leads to decreased energy availability for muscle work (40). Although IL-6 has some anti-inflammatory effects in the short term, chronic elevation promotes processes leading to muscle mass loss (41). Chronic inflammation also affects mitochondria, leading to reduced function and energy production required for muscle contractions (42). This persistent inflammatory state not only weakens muscles but also reduces the body's ability to respond to anabolic stimuli, such as exercise or adequate protein intake (43,44). Oxidative stress, which results from increased production of reactive oxygen species (ROS) and reduced antioxidant capacity, damages muscle cells and mitochondria. Mitochondrial dysfunction, which worsens with age, leads to decreased energy production and increased ROS production, contributing to the loss and impaired regeneration of muscle cells (45).

These complex mechanisms contribute to the development of sarcopenia, leading to a reduction in muscle mass, strength, and function, and thus increasing the risk of falls, reduced mobility, and an overall decline in quality of life for older adults. Prevention and treatment of sarcopenia include exercise and nutritional support to improve these molecular and cellular mechanisms (46). Sarcopenia, characterized by the loss of muscle mass and strength, is associated with various structural changes at the muscle fiber level. It is a complex process involving not only a reduction in muscle tissue quantity but also qualitative changes in muscle function. These changes often result from multiple factors, including aging, reduced physical activity, hormonal changes, and chronic inflammation, which together contribute to the disruption of muscle structure and function.

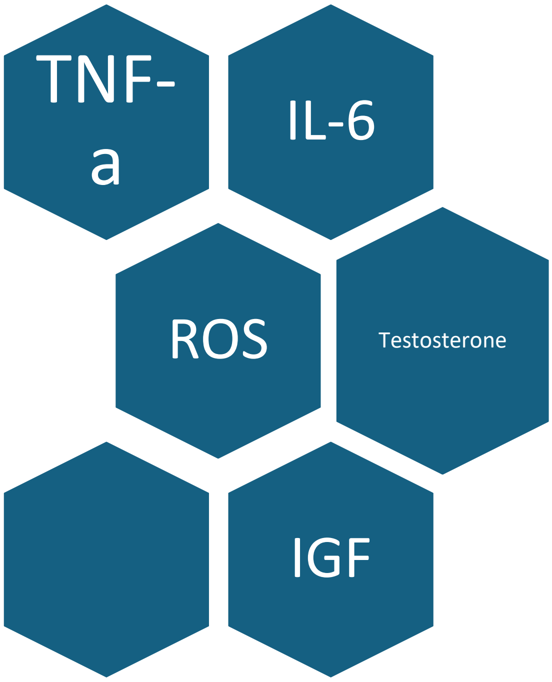

Figure 2 Potential mechanism

Muscle pathologies

Myosteatosis

Myosteatosis is a condition characterized by the abnormal accumulation of fat tissue within skeletal muscle. This condition involves the infiltration of fat cells between muscle fibers and into muscle mass, leading to a decline in muscle quality, function, and strength. Myosteatosis is often associated with aging, obesity, and certain chronic diseases, such as diabetes mellitus and metabolic syndrome (47–50).

Dynapenia

Dynapenia refers to the age-related decrease in muscle strength, independent of muscle mass loss, which is typical of sarcopenia (51). While sarcopenia focuses on the loss of muscle mass and the degeneration of muscle tissue, dynapenia specifically denotes a reduced ability of muscles to generate force (52). Although sarcopenia and dynapenia are related, they can occur independently. Some individuals may experience a significant decline in muscle strength without notable muscle mass loss, suggesting that factors other than muscle mass—such as reduced muscle fiber quality, neuromuscular impairments, or impaired coordination—can impact muscle strength. The consequences of dynapenia can be as serious as those of sarcopenia, making it a critical factor in maintaining functional independence and quality of life in old age (52–54).

Myopenia

Myopenia is a term that describes the reduction of muscle mass, strength, and function regardless of its cause. This term is broader and more general than sarcopenia, which is specifically associated with aging (55). Myopenia may result from various factors, including chronic diseases, malnutrition, inactivity, or hormonal changes, and can occur at any age. Clinically, myopenia is an important indicator of an individual's overall health and functional ability. Reduced muscle mass and strength are associated with an increased risk of falls, disability, impaired ability to perform daily activities, and reduced quality of life (55,56).

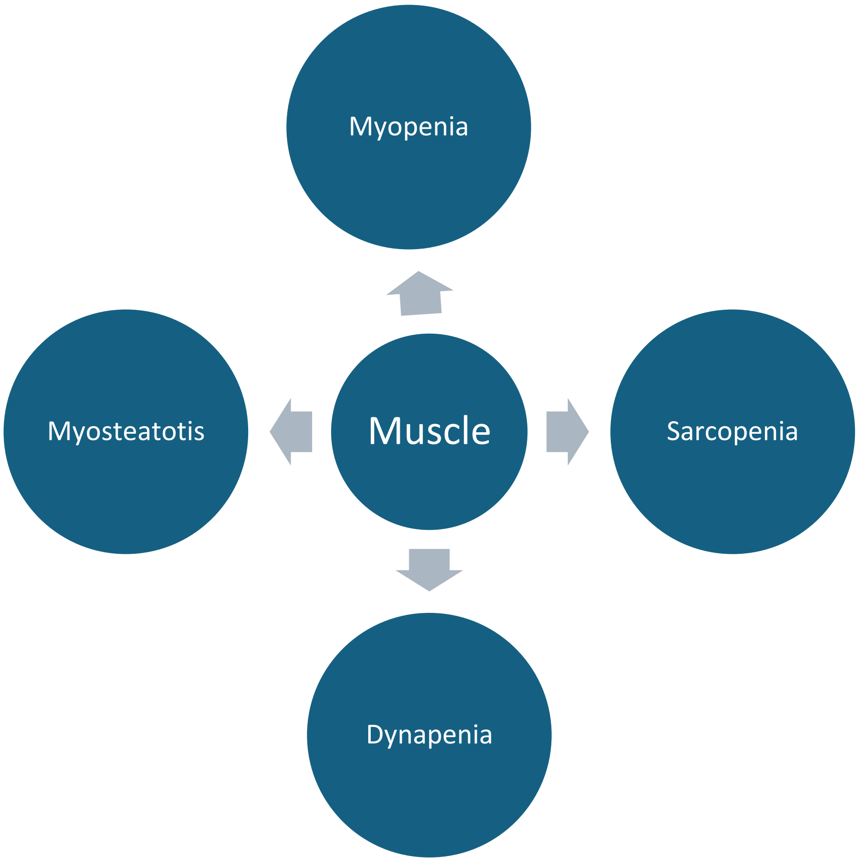

Figure 3 Pathologic muscle

Frailty and sarcopenia

Frailty is a complex geriatric syndrome that often affects older adults and represents a significant risk factor for numerous health complications (57–59). While frailty is related to sarcopenia (loss of muscle mass and strength), it is a broader concept encompassing a wider range of physical, psychological, and social aspects. Frailty may develop as a consequence of sarcopenia since the loss of muscle mass and strength contributes to a decline in the overall functional status of the body. Frailty is defined as a state of increased vulnerability to various stress events, such as infections, hospitalizations, surgeries, or psychological stress (59,60). In this state, the body has limited capacity to respond to stressors and restore balance, leading to an impaired ability to maintain homeostasis. This heightened vulnerability means that even minor health issues can have serious consequences for frail individuals, including long-term functional decline, dependency on others, and, in severe cases, an increased risk of mortality. Frailty reflects overall weakness and reduced reserve, resulting from a combination of factors like chronic diseases, inadequate nutrition, lack of physical activity, cognitive disorders, and social isolation (61,62).

Sarcopenia and cachexia

The connection between cachexia and sarcopenia lies in their shared outcomes of muscle mass and function loss, which increase disability risk, lower quality of life, and raise mortality risk. However, cachexia is a more severe and aggressive process that involves not only muscle mass loss but also significant metabolic and inflammatory changes in the body. Sarcopenia is primarily associated with aging and develops gradually with age. While cachexia and sarcopenia can occur independently, some patients, especially older adults with chronic diseases, may experience both simultaneously, leading to more severe health and functional deterioration (63,64). Cachexia is characterized by unintentional and progressive weight loss, primarily due to significant muscle mass loss, often with minimal or no fat tissue loss. Treating both conditions requires a comprehensive approach focused on improving nutrition, supporting physical activity, and, in the case of cachexia, managing the underlying disease and inflammatory response (65).

Sarcopenia and inflammation

Sarcopenia and inflammation are closely linked, with inflammation playing a key role in the development and progression of sarcopenia, particularly in older adults. Sarcopenia is often associated with chronic, low-grade inflammation, known as "inflammaging," which is characterized by elevated levels of inflammatory cytokines, such as TNF-α, IL-6, and CRP. This chronic inflammation contributes to the breakdown of muscle proteins, leading to loss of muscle mass and strength (66).

Inflammatory cytokines promote the catabolism of muscle proteins while inhibiting the synthesis of new ones, creating an imbalance that accelerates muscle loss, a core feature of sarcopenia. Inflammation increases oxidative stress in muscle tissue, damaging muscle cells and mitochondria, impairing their function, and contributing to muscle atrophy and weakness. Chronic inflammation also hinders muscle regeneration. Satellite cells, crucial for muscle tissue repair and regeneration, may lose their effectiveness in a high-inflammation environment, leading to a reduced ability of muscles to recover after injury or strain (67).

Risk of falls and sarcopenia

Sarcopenia is associated with a higher incidence of falls and increased fracture risk, posing a serious hazard for older adults who are often vulnerable to other health complications. A fall due to sarcopenia can lead to severe consequences, such as femoral neck fractures that may require surgery and long-term rehabilitation (68). Such injuries often result in a permanent reduction in mobility and prolonged stays in healthcare facilities. Reduced muscle mass and weakened muscle function, both key diagnostic criteria for sarcopenia, are significant risk factors for loss of independence, especially in patients over 90 years of age (69). These patients are particularly at risk of losing the ability to perform basic daily activities like walking, dressing, or bathing, leading to reduced quality of life and greater reliance on others. Muscle strength and physical performance measurements are proven to be associated with fracture risk (70).

Neuromuscular activity and sarcopenia

Neuromuscular activity in sarcopenia focuses on the role of the nervous system and its interaction with muscle tissue in the aging process, leading to muscle mass, strength, and function loss. This approach emphasizes that sarcopenia results not only from reduced muscle mass but also from degenerative changes in the nervous system affecting the muscles (71). A key aspect is the loss of motor neurons that innervate muscle fibers. With age, these neurons degenerate, leading to denervation of muscle fibers and subsequent atrophy and loss of function. Additionally, the number of motor units—comprising a motor neuron and the muscle fibers it innervates also changes with age (72). The reduction in motor units and their reorganization lead to alterations in movement coordination and precision. Aging also affects neuromuscular control, resulting in impaired coordination and increased risk of falls and injuries. Reduced excitability and conductivity of motor neurons slow down muscle contraction speed and reduce muscle strength and performance. Degeneration of neuromuscular junctions (synapses) between nerve endings and muscle fibers impairs signal transmission, causing muscle weakness and muscle mass loss (73).

Understanding the neuromuscular mechanisms of sarcopenia is crucial, as these changes impact older adults' overall mobility, strength, and functional independence. Interventions such as strength training and physical activity, which improve neuromuscular function and support muscle reinnervation, can help mitigate sarcopenia symptoms. This perspective highlights the need to focus not only on muscle mass but also on the quality of muscle control in the prevention and treatment of sarcopenia (72).

Sarcopenia and cancer

The relationship between cancer and sarcopenia is complex, as both conditions can significantly affect patients' quality of life and prognosis (74). Sarcopenia, characterized by muscle mass and strength loss, can lead to reduced physical function, an increased risk of falls, and other health complications in cancer patients. Sarcopenia in cancer patients can result from several factors. A primary factor is the inflammatory processes that often accompany cancer. Chronic inflammation can promote catabolic processes in the body, leading to muscle tissue degradation. Cancer treatments, including chemotherapy and radiotherapy, can also contribute to sarcopenia. These treatments often cause side effects, such as loss of appetite, nausea, fatigue, and other symptoms, leading to muscle atrophy and deteriorating physical fitness. Additionally, physical inactivity, common among cancer patients due to fatigue, pain, or other symptoms, can further contribute to sarcopenia development (64).

Sarcopenia and dysphagia

Sarcopenia and dysphagia are two closely related conditions, especially in older adults, and their combination can have serious implications for health and quality of life (76). Dysphagia, a swallowing disorder, impairs the ability to consume food and liquids and can lead to risks of aspiration, malnutrition, and dehydration. The connection between sarcopenia and dysphagia lies in the weakening of muscles, which is responsible not only for movement but also for swallowing. The loss of muscle mass due to sarcopenia can affect oropharyngeal muscles, leading to swallowing difficulties (76). This condition can further exacerbate dysphagia, creating a vicious cycle in which inadequate intake of food and fluids worsens sarcopenia. The combination of these two conditions poses a high risk for malnutrition, deteriorating health status, weakened immune function, and prolonged recovery time after illness or surgery. Therefore, the prevention and treatment of both conditions should be a priority, especially in older adults, to ensure the best possible quality of life and functionality (77).

Functional assessment

Given the functional abilities of a patient with sarcopenia, functional assessment is essential, as sarcopenia, defined by the loss of muscle mass, strength, and function, directly impacts the patient’s ability to perform daily activities and maintain independence. Loss of muscle strength and impaired coordination lead to reduced mobility, increasing the risk of falls, fractures, and subsequent hospitalizations.

Functional assessment is thus crucial for evaluating the patient's current state, predicting risks, and designing an appropriate therapeutic plan. One of the main goals of functional assessment is to assess muscle strength. Measuring muscle strength, especially through dynamometry, is an important indicator of sarcopenia. Muscle weakness, particularly in the lower limbs, is often one of the first symptoms limiting the patient's ability to walk, stand up from a seated position, or climb stairs. Assessing physical performance through tests provides valuable information on how effectively and quickly the patient can perform daily tasks and their endurance. Another essential aspect is assessing balance and coordination, as sarcopenic patients often have impaired balance, increasing their risk of falls (78,79). Functional tests, such as balance tests or evaluating the ability to stand unsupported, can help determine the patient's stability level and predict fall risk.

For muscle mass measurement, methods such as bioelectrical impedance are used to quantify potential muscle mass, which is important for monitoring sarcopenia progression and severity. In addition to physical tests, self-assessment questionnaires can be useful, taking into account the patient's subjective perception of physical performance, fear of falls, and daily limitations. Since sarcopenia is often associated with cognitive impairment, assessing cognitive abilities, especially in older adults, is also important, as the combination of reduced physical and mental abilities can significantly impact the patient's quality of life.

Functional assessment also plays a key role in designing interventions, as it allows for the creation of an individualized rehabilitation plan focused on strengthening muscles, improving balance, and increasing overall physical activity. Anthropometric methods (such as measuring arm muscle, calf circumference, and skinfold thickness) are simple and effective. Computed tomography (CT) and magnetic resonance imaging (MRI) offer high accuracy and reproducibility, though they are limited by availability and cost.

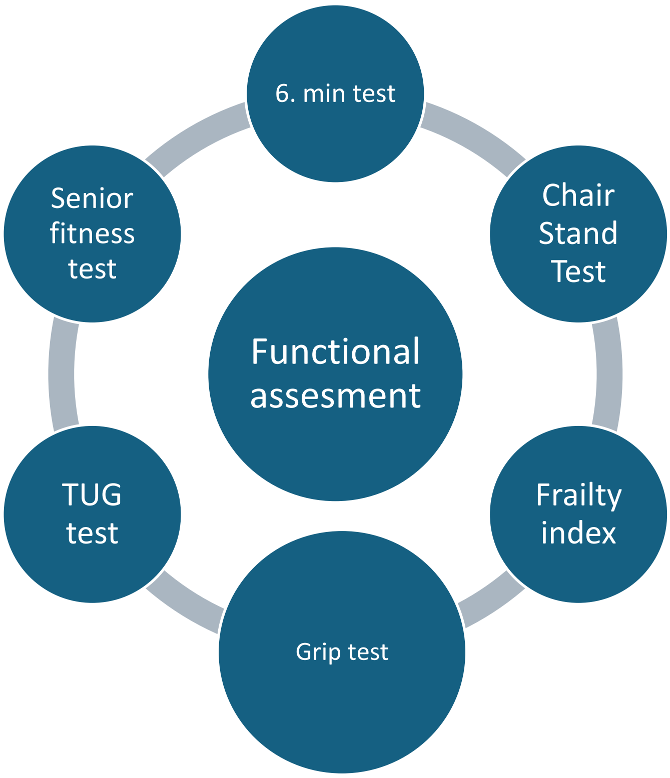

Figure 4 Functional assessment of patients

Grip test

The grip test, also known as the handgrip strength test, is a method used to measure the maximum isometric strength of the hand and forearm muscles (80). This test is commonly used in clinical practice to assess muscle strength in patients with various conditions, as well as in sports medicine and rehabilitation. To perform the grip test, a hand dynamometer is used, which must be properly set and calibrated before the test. The patient sits on a chair with a backrest for adequate back support. The arm being tested should be placed alongside the body, with the elbow joint bent at approximately a 90-degree angle and the forearm in a neutral position (81). The grip test is particularly important in assessing the functional status of older patients, as hand strength loss may indicate overall physical weakness (82,83). The test is repeated at least three times on each hand, with short breaks between measurements. All values are recorded, and the highest value achieved for each hand is used to interpret the results. Results are compared with normative data for the patient's age, gender, and body weight. If the measured values are significantly below the norm, it may indicate muscle weakness or other health issues that could require further evaluation.

Figure 5 Grip test

6-minute walking test (6MWT)

Test is a simple and effective physical fitness test commonly used to assess aerobic capacity and endurance in patients with various conditions, particularly cardiovascular and respiratory diseases (84). The test evaluates a person's ability to cover the greatest possible distance within six minutes. It is one of the most frequently used tests in clinical practice for assessing functional capacity.

To perform the 6MWT, the patient should wear comfortable clothing and appropriate footwear. It is recommended to avoid strenuous physical activity for at least 2 hours before the test. The patient is instructed to walk as quickly as possible, without running or stopping, for six minutes along a flat track. The goal is to cover as much distance as possible within the given time. The patient may slow down, stop, and rest if needed, but the timer keeps running. After the test, the total distance walked within six minutes is recorded. If a patient walks a shorter distance than expected, it may indicate reduced cardiovascular or respiratory function. Any symptoms experienced during the test, such as shortness of breath, chest pain, dizziness, or other discomforts, are also documented. The 6MWT is an effective tool for monitoring changes in patients' functional capacity over time and evaluating the effectiveness of treatments or interventions aimed at improving their physical condition (85,86).

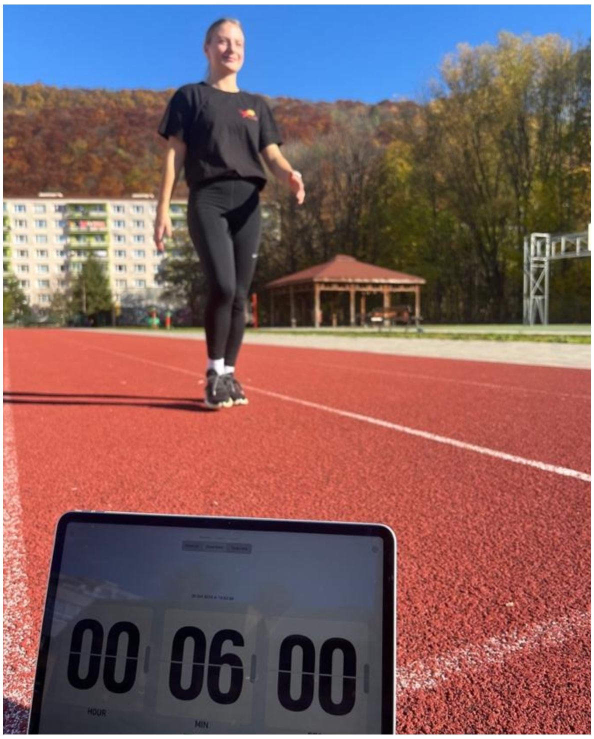

Figure 6 Walking test

Borg dyspnea scale

The borg dyspnea scale is a subjective rating scale that patients use to describe their level of breathlessness or perceived difficulty breathing. It is similar to the Borg Scale for perceived exertion, which measures overall physical effort, but specifically targets breathlessness. The Borg Dyspnea Scale is a numerical scale from 0 to 10 (87–89).

0: No breathlessness

0.5: Very, very slight breathlessness (just noticeable)

1: Very slight breathlessness

2: Slight breathlessness

3: Moderate breathlessness

4: Somewhat severe breathlessness

5–6: Severe breathlessness

7–8: Very severe breathlessness

9: Very, very severe breathlessness (almost maximal effort)

10: Maximum possible breathlessness (unable to breathe)

Chair stand test

The chair stand test is a quick and simple physical fitness test used to assess lower limb muscle strength, particularly in older adults. It is widely used in clinical practice to monitor fall risk, evaluate functional capacity, and track rehabilitation progress (90).

To conduct the test, the patient sits in a stable, armless chair on a flat surface. They should sit in the middle of the chair with a straight back, feet firmly on the ground, roughly shoulder-width apart. Arms are crossed over the chest to prevent using hands for assistance when standing. The patient is instructed to stand up from a seated position and return to sitting as quickly as possible within a set time limit, typically 30 seconds. The goal is to count how many times the patient can perform this movement in the allotted time (91,92).

It is essential that the patient performs the movements as quickly and safely as possible without using hands to push up. After the time is up, the total number of successful repetitions is recorded. A lower number of repetitions may indicate weakness in the lower limb muscles, which can be a risk factor for reduced mobility and a higher fall risk. The Chair Stand Test is straightforward, requires minimal equipment, and can be conducted nearly anywhere, making it highly useful in routine clinical practice.

Figure 7 Chair stand test

Gait speed analysis

Gait speed analysis is an important diagnostic tool for assessing sarcopenia, providing valuable information about muscle function, strength, and overall mobility. Gait speed is considered a sensitive indicator of general health and physical fitness, especially in older adults. In sarcopenia diagnosis, reduced gait speed is often linked to diminished muscle strength, coordination, and the ability to perform daily activities. Reduced gait speed can signal a loss of independence and an increased risk of falls and hospitalization.

Gait speed is a predictor of sarcopenia and other serious health conditions. A gait speed below a certain threshold (e.g., less than 0.8 meters per second) typically indicates impaired muscle function and decreased performance. In addition to overall gait speed, other gait parameters such as step length, cadence, foot angle, and movement stability can be analyzed. These factors provide a more comprehensive understanding of how muscle weakness affects movement mechanics. Based on these data, the degree of sarcopenia can be evaluated, and appropriate therapeutic interventions, such as strength training or rehabilitation focused on gait improvement and overall mobility, can be planned.

Overall, gait speed is a simple, quick, and effective indicator in sarcopenia diagnosis, helping identify at-risk patient groups and monitor treatment progression or improvements in physical fitness resulting from therapeutic interventions. This analysis can be enhanced with devices that measure body movement, body mechanics, and muscle activity (49).

Timed Up and Go (TUG) test

The TUG test is a simple and quick assessment used to evaluate mobility, balance, and fall risk, particularly in older adults or patients with mobility limitations. Widely used in clinical practice for its simplicity and effectiveness, the TUG test helps identify individuals at risk of reduced functional capacity or increased fall risk. The test starts with the patient seated on a chair with armrests placed on a flat surface, feet firmly on the ground, approximately shoulder-width apart. A 3-meter distance is marked from the front edge of the chair. The patient is instructed to, on the "start" command, stand up from the chair, walk 3 meters forward, turn around, return to the chair, and sit down again, performing the movement smoothly and safely (93,94). If the patient usually uses walking aids, such as canes or walkers, they may use them during the test. The timer starts when the patient begins and stops when they sit back down. Generally, a TUG time under 10 seconds is normal for healthy, active older adults, while a time between 10 and 20 seconds is typical for independent, mobile older adults. Times above 20 seconds may indicate reduced mobility and increased fall risk, suggesting the need for further evaluation or intervention. Times over 30 seconds indicate significant mobility limitations and a high risk of falls. Although the TUG test is safe and easy to administer, it should be conducted under healthcare supervision for patients with severe mobility restrictions or a high fall risk (95).

Figure 8 Timed Up and Go (TUG) test

Y Balance Test (YBT)

The Y Balance Test is a functional balance test used to evaluate postural control and lower limb stability. It is a variation of the Star Excursion Balance Test (SEBT) and focuses on the patient's ability to maintain balance while moving one leg in three directions: anterior (forward), posteromedial (backward and inward), and posterolateral (backward and outward). The result is the distance reached in each direction, while the opposite leg remains firmly on the ground. This test is useful for assessing balance, muscle strength, and coordination in patients with sarcopenia (96,97). The Y Balance Test can identify deficiencies in maintaining balance in challenging positions, an important indicator of functional fitness. The test engages multiple muscle groups, including the lower limbs and core, allowing for an assessment of overall muscle system function. The YBT is relatively simple, requiring minimal equipment, making it suitable for clinical and home settings. However, the test may be challenging or unrepresentative for patients with severe muscle atrophy or motor impairments.

Dynamometer testing

Dynamometer testing is an objective method of measuring muscle strength used in clinical practice and research. A dynamometer measures force generated by muscles during isometric contraction, where muscles create force without joint movement. The patient should be in a stable position to prevent other body movements that could affect results. The muscle group to be tested is chosen, with handgrip strength and lower limb muscles (such as the quadriceps) being the most common measurements.

The patient is instructed to exert maximum force against the dynamometer for 3–5 seconds, and the test is typically repeated 2–3 times to ensure consistent results. Dynamometry provides precise, quantitative data on muscle strength, facilitating standardized comparison across populations.

Figure 9 Grip test

Liver frailty index (LFI)

The liver frailty index is a clinical tool used to assess frailty in patients with chronic liver disease, especially those awaiting liver transplantation (98,99). Frailty represents a state of reduced physical reserve and stress tolerance, increasing the risk of complications, lower survival rates, and decreased quality of life. LFI combines physical tests to evaluate muscle strength, endurance, and balance, including grip strength measured with a dynamometer, the Chair Stand Test to assess lower limb strength, and balance tests.

The total LFI score helps predict the prognosis of patients with liver disease, identifying high-risk individuals and optimizing their care.

Figure 10 Dynamometer

Figure 11 Chair stand test LFI

Figure 12 Balance Tests, a – side by side, b – semi tandem, c – tandem

4-meter walk test

The 4-meter Walk Test is a simple and efficient test to assess gait speed, an important indicator of functional capacity, mobility, and overall health. It is frequently used in older adults to identify fall risk, reduced mobility, and increased health risks. The patient stands at the start of a 4-meter marked path on a flat, safe surface. They are instructed to walk the distance at their usual pace as quickly as possible without running. The time is recorded and converted to walking speed in meters per second (m/s). Reduced gait speed is often associated with higher fall risk and mobility issues, making it a valuable measure of functional capacity.

Figure 13 4-Meter walk test

Harvard step test

The Harvard step test is a simple cardiovascular fitness test that assesses aerobic conditioning and the heart and lungs' ability to recover after physical exertion. Developed in the 1940s at Harvard University, it remains widely used in sports medicine, physical therapy, and fitness training (100,101). The test uses a step or bench 45 cm high for men and 40 cm for women. The person steps up and down at a rate of 30 steps per minute for up to 5 minutes or until they can no longer maintain the pace. Afterward, heart rate is measured in three intervals (1–1.5 minutes, 2–2.5 minutes, and 3–3.5 minutes post-exercise), with a score calculated based on recovery. The score indicates cardiovascular fitness, ranging from very good to poor. Although simple and requiring minimal equipment, the test does not account for individual differences in body weight or height and may be challenging for older or less fit individuals.

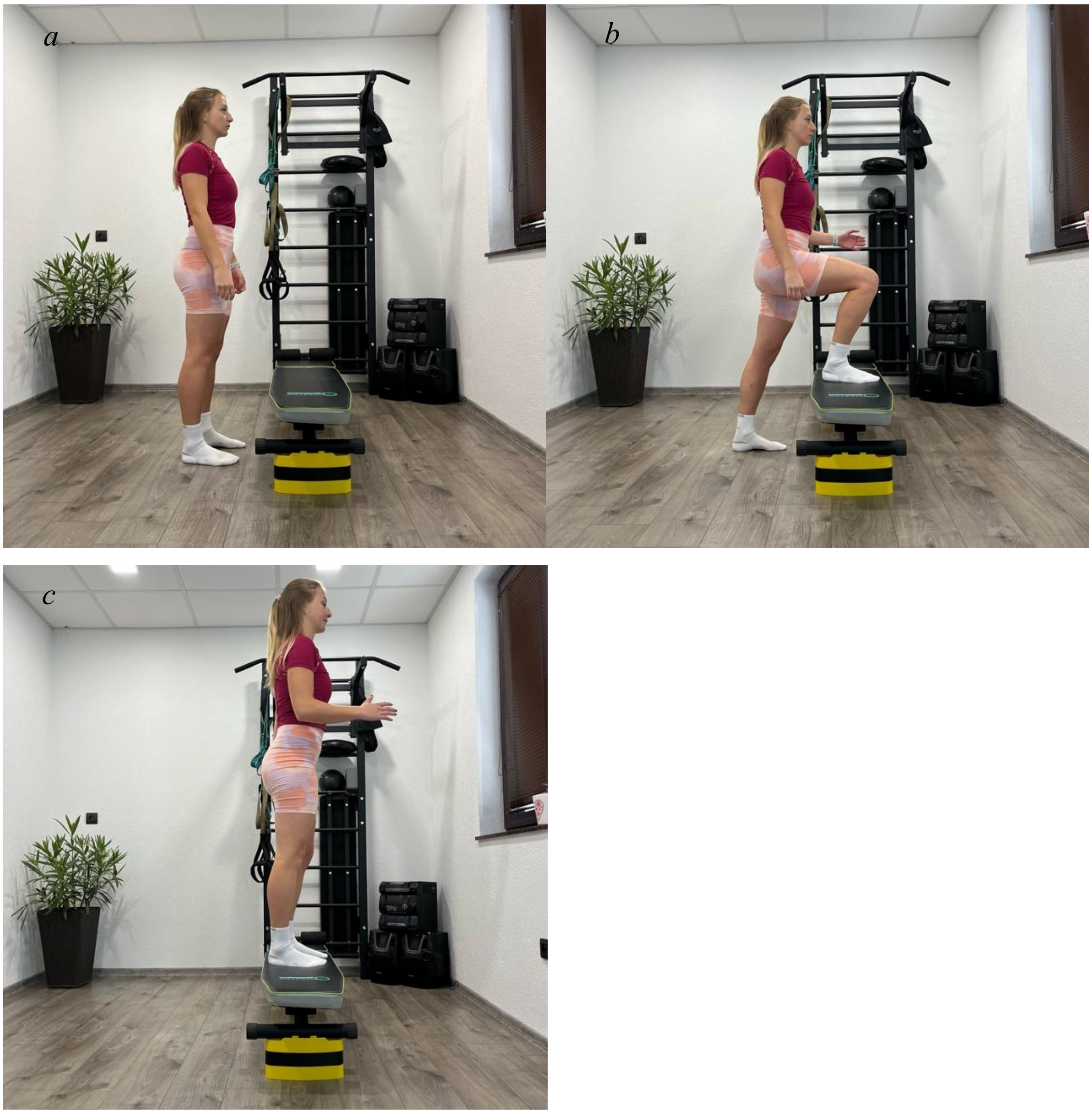

Figure 14 Harvard step test, a – starting position, b – execution, c – final position

Pedometer

Tracking physical activity with a pedometer is a popular way to monitor an individual's activity level. A pedometer is a small electronic device that records the number of steps taken during the day. It uses motion sensors, such as an accelerometer or gyroscope, to detect vibrations and body movements. These sensors capture each step-like motion and convert it into a digital signal. When walking, the pedometer analyzes data from motion sensors to identify patterns associated with walking. Modern pedometers can differentiate between walking, running, and other activities, allowing for more accurate measurement.

The recorded steps are counted and stored in the device. Advanced models can also capture additional data, such as stride length, walking speed, and total distance covered. The information is displayed on the device's screen or in a mobile app, where users can view their daily results. In addition to total steps, pedometers often provide other metrics, such as estimated calories burned, activity time, and distance traveled. Many devices allow users to set goals, such as reaching 10,000 steps per day, and provide feedback to support motivation. Some pedometers also include reminders to move if the user has been sitting for an extended period. These features make pedometers a simple and effective way to track physical activity, boost motivation, and improve health and fitness.

International physical activity questionnaire (IPAQ)

The international physical activity questionnaire (IPAQ) is a standardized tool for measuring physical activity in adults. It was developed to provide a uniform and internationally comparable way of collecting data on the population's physical activity level. IPAQ is widely used in research and public health practice for monitoring and assessing physical activity levels in various populations (102–104).

IPAQ exists in two main versions:

short form: Contains 7 questions and is designed for a quick assessment of physical activity over the past seven days. It focuses on vigorous and moderate physical activity, time spent walking, and sedentary behavior.

long form: Contains 27 questions and provides more detailed information on physical activity in areas such as work, household chores, recreational activities, and movement during transportation. This version allows for a comprehensive analysis of physical activity in multiple contexts.

The questionnaire records data on activity intensity (light, moderate, vigorous) and duration, allowing calculation of the total energy expenditure in MET-minutes per week (Metabolic Equivalent of Task), which quantifies the activity level. Based on these data, individuals are categorized into low, moderate, or high activity levels. IPAQ is widely recognized for its simplicity, versatility, and reliability, making it a frequent choice for tracking physical activity in large-scale population studies, interventions, and public health research.

Strength training

Strength training is a form of exercise where individuals use their strength to overcome external resistance (such as weight machines, dumbbells, resistance bands) or internal resistance (body weight). For individuals with sarcopenia, strength training brings numerous positive effects, such as increased muscle strength and mass, which improve functional ability and combat oxidative stress associated with aging (105–107).

Strength training is closely linked to the prevention and treatment of sarcopenia, a condition marked by loss of muscle mass, strength, and function with aging. Regular strength training stimulates muscle protein synthesis, essential for maintaining or even increasing muscle mass, countering muscle loss due to sarcopenia. Additionally, strength training enhances muscle strength by exposing muscles to greater loads than usual, crucial for maintaining functional independence, reducing fall risk, and improving quality of life in older adults. Strength training also improves neuromuscular function, supporting better muscle coordination and activation, which helps mitigate sarcopenia-related functional decline.

The benefits extend to bone health, as weight-bearing exercises increase bone density, reducing fracture risk, especially important for those with sarcopenia, who are prone to muscle weakness. Strength training also promotes metabolic health by increasing muscle mass, supporting glucose metabolism, and improving insulin sensitivity, reducing the risk of coexisting conditions often linked with sarcopenia, such as type 2 diabetes and obesity. Regular strength training helps reduce chronic inflammation, which contributes to muscle degradation in sarcopenia, thus protecting muscle tissue.

In summary, strength training is a key intervention for sarcopenia prevention and treatment, preserving muscle mass and strength, enhancing neuromuscular function, boosting bone density, promoting metabolic health, and reducing inflammation. Regular participation in strength training can significantly alleviate sarcopenia's effects and improve older adults' quality of life (108).

Prehabilitation and sarcopenia

Prehabilitation, sarcopenia, and exercise are closely related, as exercise is essential for both preventing and managing sarcopenia and is a core component of prehabilitation. Prehabilitation is the process of preparing a patient for an upcoming surgery or intensive medical procedure, aiming to improve the patient's physical condition to better handle the procedure and speed up recovery (12). It includes various measures, such as exercise and nutritional adjustments, to optimize the patient's health status. Sarcopenia leads to reduced physical performance, increased injury risk, and a lower quality of life. Exercise is an effective tool in combating sarcopenia, as regular strength and aerobic exercises can increase muscle mass and strength, improving physical performance and reducing complications associated with muscle loss. In the context of prehabilitation, exercise is particularly crucial for patients with sarcopenia. Reduced muscle mass and strength can worsen surgical outcomes, making prehabilitation essential for these patients. Improving physical fitness through preoperative exercise can decrease postoperative complications, accelerate recovery, and reduce hospital stay. Through prehabilitation and exercise, patients can better cope with the physical and mental challenges associated with surgery, achieving faster and more successful recovery.

Liver cirrhosis and sarcopenia

Liver cirrhosis and sarcopenia are closely linked, especially in patients with advanced liver disease (60). Liver cirrhosis is a chronic condition characterized by the progressive degeneration of liver tissue, which is replaced by scar tissue, leading to impaired liver function and various complications (109,110). Sarcopenia, defined by the loss of muscle mass, strength, and function, can result in reduced physical capability and increased risk of falls and injuries (111).

Patients with cirrhosis often suffer from malnutrition due to decreased nutrient intake, nausea, reduced nutrient absorption, and increased energy requirements, contributing to sarcopenia. Cirrhosis impacts the metabolism of proteins, fats, and carbohydrates, leading to muscle catabolism. Chronic inflammation in cirrhosis promotes muscle degeneration through inflammatory cytokines (112). Patients with cirrhosis also experience fatigue and weakness, reducing their ability to maintain regular physical activity, further contributing to muscle atrophy. Additionally, cirrhosis affects hormone production, such as testosterone and IGF-1 (113), which are crucial for muscle maintenance.

Sarcopenia in patients with liver cirrhosis significantly worsens their prognosis (114,115), increasing the risk of complications and mortality. Therefore, regular monitoring of nutrition and muscle mass and measures to improve nutrition and physical activity are critical for these patients.

Sarcopenia and rheumatic diseases

Sarcopenia and rheumatic diseases are interconnected conditions that can influence each other's course and severity. Sarcopenia leads to reduced physical capability and a diminished quality of life (6,116). Although sarcopenia commonly occurs in older individuals, it can also be associated with chronic conditions, including rheumatic diseases such as rheumatoid arthritis, systemic lupus erythematosus, polymyositis, and osteoarthritis (117–119).

Chronic inflammation in rheumatic diseases can accelerate muscle tissue breakdown, contributing to sarcopenia. Inflammatory cytokines, such as tumor necrosis factor-alpha (TNF-α) and interleukins, promote muscle catabolism. Furthermore, pain and stiffness from these diseases often lead to reduced physical activity, resulting in muscle mass and strength loss. Malnutrition, frequently associated with chronic rheumatic conditions, exacerbates the body's ability to maintain muscle mass due to a lack of essential nutrients, such as proteins. Rheumatic diseases can also impair the body's ability to regenerate muscle tissue, increasing the risk of sarcopenia.

Sarcopenia in patients with rheumatic diseases worsens their overall health, decreases functional capacity, and raises the risk of complications, such as falls and fractures. Regular monitoring of muscle mass and physical fitness and promoting appropriate physical activity and nutrition are essential for preventing or mitigating sarcopenia in these patients.

Non-alcoholic fatty liver disease (NAFLD) and sarcopenia

NAFLD and sarcopenia are two distinct health conditions, yet they are interconnected, particularly in the context of metabolic syndrome, obesity, and chronic inflammation. NAFLD is characterized by fat accumulation in liver cells, potentially leading to liver inflammation and damage. This condition is often associated with obesity, insulin resistance, and metabolic syndrome. Sarcopenia, on the other hand, is characterized by the loss of muscle mass and strength, typically associated with aging but can be accelerated by factors such as chronic inflammation, inactivity, and malnutrition (120,121).

The connection between these two conditions can be explained through several mechanisms. First, metabolic syndrome and insulin resistance, common in people with NAFLD, can contribute to sarcopenia. Insulin resistance disrupts normal glucose and fat metabolism, leading to increased fat storage in the liver while reducing glucose and amino acid utilization in muscles, accelerating muscle mass loss (122,123). Second, chronic inflammation associated with NAFLD can promote muscle catabolism, contributing to sarcopenia. Inflammatory cytokines, such as TNF-α and IL-6, accelerate muscle tissue breakdown. Third, NAFLD can impact hormone production, such as growth hormone and insulin-like growth factor 1 (IGF-1), which are crucial for muscle maintenance; their decline can contribute to sarcopenia. A comprehensive management approach that includes dietary adjustments, increased physical activity, and control of metabolic risk factors is important for managing patients with NAFLD and sarcopenia (121).

Sarcopenia and colorectal cancer

Sarcopenia and colorectal cancer (CRC) are two clinically significant conditions interconnected through various mechanisms (124). Sarcopenia in CRC patients is associated with a poorer prognosis, as reduced muscle mass can negatively affect the patient’s tolerance to treatment, including chemotherapy, and increase the risk of postoperative complications, such as infections, slow wound healing, and longer recovery times (125,126). CRC is often linked to chronic inflammation, leading to increased muscle tissue catabolism and sarcopenia, as inflammatory cytokines produced by the tumor or the immune response promote muscle breakdown (127,128).

Nutritional deficits, commonly seen in CRC patients due to poor appetite, malabsorption, or treatment side effects, lead to muscle mass loss. Malnutrition is associated with a lack of proteins, vitamins, and minerals, a common cause of sarcopenia. Additionally, CRC patients may reduce physical activity due to illness or treatment, causing further muscle loss and increasing sarcopenia risk.

The link between sarcopenia and CRC indicates that sarcopenia can worsen the disease course and prognosis, while CRC and its treatment can contribute to sarcopenia's development or progression. It is essential to focus not only on tumor treatment but also on sarcopenia prevention and management, which may involve nutritional interventions, physical rehabilitation, and adequate treatment of inflammatory conditions.

Sarcopenia and cardiovascular diseases

The connection between sarcopenia and cardiovascular diseases is increasingly studied, as both conditions frequently occur in older adults and may have a mutually reinforcing effect (129). Sarcopenia leads to decreased muscle strength and endurance, often resulting in reduced physical activity, which increases the risk of cardiovascular diseases such as hypertension, coronary artery disease, and atherosclerosis. Additionally, sarcopenia is associated with impaired insulin sensitivity and an elevated risk of metabolic syndrome, characterized by high blood pressure, elevated blood sugar levels, and abdominal obesity, which contribute to the development of cardiovascular diseases. Chronic inflammation, commonly observed in sarcopenia, can also promote atherosclerosis and other cardiovascular conditions. Inflammatory markers, such as C-reactive protein (CRP), are often elevated in individuals with sarcopenia and are associated with a higher risk of cardiovascular events. Sarcopenia further reduces quality of life and the ability to perform daily activities, indirectly affecting cardiovascular health by limiting physical activity and increasing psychological stress. People with both sarcopenia and cardiovascular disease face a heightened risk of mortality, as the combination of these conditions represents a dual burden that can lead to faster health deterioration and increased risk of severe complications. Given these links, it is crucial to consider a patient's cardiovascular risk profile when treating sarcopenia and to encourage physical activity, a healthy diet, and a lifestyle that can help reduce the risk of both conditions.

Quality of life and sarcopenia

The relationship between quality of life and sarcopenia is tightly interwoven, as sarcopenia significantly impacts physical and mental well-being. Quality of life is a complex concept encompassing physical, emotional, social, and functional health dimensions. Sarcopenia, characterized by loss of muscle mass, strength, and function, negatively affects all these aspects. The loss of muscle mass and strength reduces physical performance and mobility, limiting the ability to perform daily activities such as walking, rising from a chair, or carrying objects. This limitation can lead to a loss of independence, an increased risk of falls and injuries, and thus a decline in quality of life.

Sarcopenia can also cause feelings of frustration, helplessness, and lowered self-esteem, as individuals are no longer able to engage in activities they once managed. These feelings may contribute to depression and anxiety, further deteriorating quality of life. The reduction in physical abilities and subsequent social interaction limitations can lead to social isolation, as individuals with sarcopenia may struggle to participate in social activities, diminishing their social connections and support, thereby impacting their quality of life. Reduced muscle strength and function directly affect the ability to live independently and perform routine tasks, increasing dependency on others and lowering quality of life. Preventing or managing sarcopenia through regular exercise, adequate nutrition, and an overall healthy lifestyle is crucial to maintaining or improving quality of life (1).

Aerobic exercise

The link between aerobic exercise and sarcopenia highlights how physical activity affects muscle health, particularly in older adults. Aerobic exercise includes activities that improve cardiovascular health, such as walking, running, swimming, or cycling. While aerobic exercise is not traditionally aimed at building muscle mass, it has several indirect benefits for muscles relevant to preventing and treating sarcopenia. Aerobic exercise enhances cardiovascular health, leading to better blood flow and oxygenation of muscles, thereby supporting their regeneration and function. Regular aerobic exercise increases basal metabolism, which can help prevent muscle mass loss by promoting efficient energy and nutrient utilization (130). Improved overall physical fitness from aerobic exercise can help maintain muscle mobility and functionality, crucial in sarcopenia prevention (131). Additionally, aerobic exercise positively influences hormonal balance, including hormones essential for muscle maintenance, such as growth hormone and testosterone (132). While strength training is considered the most effective for sarcopenia prevention and management, aerobic exercise also plays an important role, particularly as part of a comprehensive approach to muscle health and physical fitness.

Tai chi and exercise in sarcopenia

Tai chi is a traditional Chinese exercise that involves slow, controlled movements and deep breathing, known for its positive effects on physical and mental health, especially in older adults (133). Tai Chi and sarcopenia are connected in that Tai Chi can help slow down or even reverse some symptoms of sarcopenia. Tai Chi enhances muscle strength and endurance through its movements, which is crucial for combating sarcopenia. It also improves balance and coordination, reducing the risk of falls and injuries often associated with weakened muscles. The exercise promotes flexibility and mobility, helping to prevent stiffness and reduced range of motion frequently accompanying muscle loss.

The slow, fluid movements of Tai Chi improve blood circulation, contributing to better nutrient and oxygen supply to muscles, essential for maintaining muscle mass (134). Moreover, Tai Chi helps reduce stress levels, which may accelerate muscle mass breakdown. Overall, Tai Chi is a safe and effective form of exercise for older adults, helping prevent or alleviate sarcopenia by supporting muscle strength, balance, flexibility, and overall physical and mental health (135).

Strength training and sarcopenia

Strength training is a form of regular exercise where internal or external weights provide a progressive stimulus to skeletal muscles, promoting increased muscle mass and strength (136). This type of training involves moving limbs against resistance, which can be created by body weight, gravity, resistance bands, dumbbells, or weights. The health benefits of strength training are well established, making it recommended for most populations, including adolescents, healthy adults, older people, and patients with various health issues (137). Strength training has proven effective in increasing or maintaining muscle mass and strength in older adults, which is critical given the strong link between muscle mass and strength with sarcopenia and fall risk. Strength training is one of the most effective exercise forms for older individuals with sarcopenia. Therefore, considering strength training is essential when developing optimal exercise programs (138).

Preventive exercises for sarcopenia

Preventive exercises not only strengthen muscles to prevent sarcopenia but also increase overall physical activity, providing numerous health benefits for adults across all age groups. Regular exercise and physical activity positively impact not only the muscular system but also support heart health, improve metabolism, increase bone density, and help maintain optimal body weight. These factors are essential for long-term health and quality of life. Strength training is crucial for enhancing muscle strength and mass, helping to prevent muscle loss that naturally occurs with aging. Strong muscles are important not only for physical performance but also for daily activities such as walking, standing up, or carrying objects. Improved muscle mass also accelerates basal metabolism, aiding in weight management and reducing the risk of type 2 diabetes.

Regular aerobic activities like running or cycling support cardiovascular health and reduce the risk of heart disease. Exercises focusing on balance and coordination, such as yoga or Pilates, are especially important for older adults, as they help reduce the risk of falls and related injuries. Exercise also supports bone density, helping to prevent osteoporosis and fractures.

Besides physical benefits, regular physical activity positively affects mental health. The release of endorphins improves mood, relieves stress, and reduces symptoms of depression and anxiety. Physical activity also enhances sleep quality and supports cognitive functions such as memory and concentration, potentially lowering the risk of neurodegenerative diseases. Physical activity contributes to functional independence for older adults, enabling them to perform everyday tasks independently. This strengthens their sense of self-sufficiency and improves quality of life. For these exercises to have a lasting effect, it’s important to maintain regularity and incorporate various training types, including strength, aerobic, balance, and flexibility exercises. Proper technique and consistency are key to maximizing benefits and preventing injuries.

Below are examples of exercises that can be used to strengthen muscles:

Biceps curl

- **Starting position**: Stand upright with feet shoulder-width apart. Keep the pelvis stable and your head aligned with your spine. Hold a dumbbell or kettlebell in one hand, palm facing up (supination).
- **Execution**: Exhale as you pull your arm towards your body, bending at the elbow. Focus on controlled movement without engaging unnecessary muscles. Stabilize your core and slightly bend your knees. Press your shoulders downward throughout the movement.

Figure 15 Biceps curl

Overhead triceps extension

- **Starting position**: Stand upright with feet shoulder-width apart and knees slightly bent. Hold a kettlebell with bent elbows at a 90-degree angle, positioned behind your head. Maintain a proper posture, reducing the weight if leaning backward.
- **Execution**: Exhale as you extend your arms at the elbows, bringing the kettlebell above your head. Engage your core to stabilize your torso.

Figure 16 Overhead triceps extension

Bent-over row

- **Starting position**: Stand in a staggered stance, with one foot forward. Lean forward with knees slightly bent, holding a dumbbell or kettlebell with your arm aligned with your shoulder. Keep your head in line with your spine.
- **Execution**: Exhale as you pull the weight toward you, aiming to bring it to your chest. Ensure that your back remains straight and your torso stable throughout the exercise.

Figure 17 Bent-over row

Mountain climbers

- **Starting position**: Begin in a high plank position with hands under shoulders and fingers pointing forward. Keep the pelvis and head aligned with the spine.
- **Execution**: Exhale as you bring one knee towards your chest. Maintain a strong core and a straight back as you alternate legs quickly.

These exercises can significantly contribute to muscle maintenance, independence, and improved quality of life in older age when practiced consistently and with proper form.

Figure 18 Mountain climbers

Plank

- **Starting position**: Get into a push-up position, placing your forearms on the floor with elbows directly under shoulders, keeping arms parallel and shoulder-width apart.
- **Execution**: Hold a neutral spine and glutes. Keep your neck aligned with your spine and gaze at the floor. Start with a 30-second hold, gradually increasing time with each repetition.

Figure 19 Plank

Heel touch

- **Starting position**: Lie on your back with knees bent hip-width apart. Arms should rest along your sides.
- **Execution**: Lift your upper torso off the floor, bringing it closer to your knees. Alternately reach for your heels while stabilizing your core.

Figure 20 Heel touch

Forward lunge

- **Starting position**: Stand upright with feet shoulder-width apart. Hold a kettlebell or dumbbells in each hand.
- **Execution**: Exhale as you step forward, bending the front knee. Maintain core stability and ensure your front knee and toes face forward, not outward.

Figure 21 Forward lunge

Squat

- **Starting position**: Stand with feet shoulder-width apart, toes pointed forward or slightly outward. With a straight back and neutral pelvis, hold a kettlebell with arms extended in front.
- **Execution**: Exhale and squat deeply, directing knees outward and keeping arms extended.

Figure 22 Squat

Leg kickbacks

- **Starting position**: Start on all fours with knees under hips and hands under shoulders, head aligned with the spine.
- **Execution**: Lift one leg upward, keeping it bent at the knee. Stabilize your torso and lift the leg to hip level. For added difficulty, hold the top position for a few seconds.

Figure 23 Leg kickbacks

Single-leg bridge

- **Starting position**: Lie on your back with knees bent and feet on the ground. Lift one leg to a 90-degree angle.
- **Execution**: Press through the grounded foot, lifting your pelvis upward. Hold at the top, then return to the starting position on an inhale.

Figure 24 Single-leg bridge

Calf raises

- **Starting position**: Stand upright with a neutral pelvis and slightly bent knees. Hold dumbbells, positioning arms to form a 90-degree angle with your body.
- **Execution**: Exhale and rise onto your toes, hold for a few seconds, and then return to the starting position.

Figure 25 Calf raises

Plank on stability ball

- **Starting position**: Assume a push-up position, placing your forearms on a stability ball with elbows under shoulders and arms parallel.
- **Execution**: Maintain a neutral spine and engaged glutes. Keep your neck aligned and look down. Focus on engaging your core, holding the position for 30 seconds initially, then increase time gradually.

Figure 26 Plank on stability ball

Push-ups on stability ball

- **Starting position**: Get into a push-up position with your legs supported by a stability ball. Keep your pelvis, back, and head aligned, with hands under shoulders.
- **Execution**: Bend your elbows to lower your torso toward the floor, inhaling on the way down. Exhale as you push back up to the starting position.

Figure 27 Push-ups on stability ball

Kettlebell swing

- **Starting position**: Hold a kettlebell between your legs in a slight forward bend, ensuring a straight back.
- **Execution**: Swing the kettlebell between your legs, then drive it upward using your hips, legs, and glutes while extending your arms. Let the kettlebell swing back down between your legs and smoothly transition into the next swing, focusing on body tension and stability.

By incorporating these exercises into a routine, you'll build strength, improve balance, and support overall muscular health, reducing the risk of sarcopenia as you age.

Figure 28 Kettlebell swing

Single-leg deadlift

- **Starting position**: Stand upright with feet shoulder-width apart. Hold a kettlebell in one hand while placing the other hand on your hip for balance. Shift your weight onto one leg, slightly lifting the opposite leg off the floor. You can bend the knee of the standing leg slightly.
- **Execution**: Slowly hinge forward at the hips, extending the raised leg behind you as your torso leans forward. Your torso and raised leg should form a straight line. Keep your spine neutral and core engaged. Let the arm with the kettlebell hang naturally toward the ground.

Figure 29 Single-leg deadlift

Chest press on back

- **Starting position**: Lie on your back with knees bent, keeping your pelvis in a neutral position. Hold a kettlebell with both hands or one dumbbell in each hand, with elbows bent and weights positioned just above the chest.
- **Execution**: Exhale as you press the weights away from your chest, fully extending your arms. Keep shoulders pressed into the ground and engage your core throughout the movement.

Figure 30 Chest press on back

Dead dug with stability ball

- **Starting position**: Lie on your back with arms extended toward the ceiling. Bend your knees at a 90-degree angle so that your shins are parallel to the floor. Place a stability ball between your hands and knees, pressing it gently. Engage your core so your lower back stays pressed against the floor.
- **Execution**: Slowly extend your right arm overhead while simultaneously extending your left leg toward the floor, keeping them just above the ground. Ensure that the stability ball stays in place, held firmly between your left hand and right knee. Return to the starting position and switch sides.

Figure 31 Dead bug with stability ball

Leg abductions

- **Starting position**: Lie on your side with the bottom leg bent and the top leg extended. Prop yourself up on your bottom elbow, placing the other hand on your hip. Keep your head aligned with your spine, looking forward.
- **Execution**: Slowly lift the top leg as high as possible without moving your torso. Keep the leg straight and controlled throughout the motion.

These exercises target various muscle groups, supporting core stability, balance, and strength. Incorporating these movements into a regular routine can help prevent sarcopenia, improve mobility, and support functional independence.

Figure 32 Leg abductions

Conclusion

Sarcopenia, characterized by the progressive loss of muscle mass, strength, and function, represents a significant health challenge, particularly among older adults. Its multifactorial nature arises from aging, physical inactivity, malnutrition, chronic diseases, and hormonal changes. The condition not only diminishes physical performance but also increases the risk of falls, fractures, and a decline in overall quality of life. Furthermore, the interplay between sarcopenia and other conditions such as insulin resistance, obesity, and chronic inflammation exacerbates its impact on health, forming a vicious cycle of metabolic and functional decline. The COVID-19 pandemic further highlighted the importance of maintaining physical activity, as restrictions led to increased sedentary behavior, particularly among younger populations. Reduced opportunities for structured physical activity may have long-term consequences, emphasizing the need for effective strategies to promote active lifestyles. Comparisons among populations in Slovakia, the Czech Republic, and Poland post-pandemic revealed significant disparities in physical activity levels, underscoring the importance of tailored interventions to address regional and demographic differences.

The chapter also demonstrates the critical role of physical activity, particularly resistance training, in the prevention and treatment of sarcopenia. Regular exercise not only enhances muscle mass and function but also improves balance, coordination, and overall metabolic health. Combining aerobic exercises with resistance training offers comprehensive benefits, reducing the risk of falls, promoting cardiovascular health, and improving insulin sensitivity. Targeted interventions such as strength training can mitigate sarcopenia's impact, particularly in vulnerable populations, including individuals undergoing surgeries or managing chronic diseases.

Addressing sarcopenia requires a multidisciplinary approach that includes healthcare professionals, personalized exercise programs, and nutritional support. Functional assessments such as the grip test, walking tests, and gait speed analysis are valuable tools for evaluating muscle strength, mobility, and fall risk, facilitating early diagnosis and intervention. Moreover, recognizing the connection between sarcopenia and conditions like frailty, cachexia, and dysphagia highlights the need for holistic treatment strategies to improve outcomes and maintain independence in older adults. Combating sarcopenia demands a comprehensive approach that prioritizes physical activity, nutritional optimization, and timely clinical interventions. Promoting awareness and implementing preventative measures can significantly enhance the quality of life, functionality, and longevity of individuals affected by sarcopenia.

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Chapter 2

Physical activity in incontinence problem

Many women worldwide struggle with urinary incontinence (UI), a multifaceted issue influenced by various factors. Urinary incontinence can be defined as a loss of bladder control or unintentional, involuntary leakage of urine (1). This condition is more prevalent among women than men and becomes increasingly common with age. It imposes a range of psychological, physical, and social burdens that negatively impact the quality of life (2). Epidemiological studies have shown that the prevalence of UI varies from approximately 5% to 70%. Most studies report that different types of UI occur in 25% to 45% of the population. Among women aged 70 years and older, over 40% of the female population is affected by this condition (3). Urinary incontinence poses a significant economic burden, with annual costs estimated between 19.5 billion and over 76 billion dollars. The demand for treatments related to UI is projected to increase by approximately 35% between 2010 and 2030 (4).

Managing urinary incontinence requires a personalized approach to diagnosis and treatment to improve patients' quality of life and reduce the discomfort associated with this condition. The Women's Preventive Services Initiative recommends annual screening for urinary incontinence in women. These screenings primarily involve screening questionnaires, a three-day bladder diary, a cough stress test, and post-void residual urine measurement. Subsequent treatment plans are based on the data obtained. Preventive measures, including physical activity and lifestyle modifications, are also being implemented. Overweight patients are informed about weight loss strategies, as obesity can lead to a fourfold increase in the risk of stress urinary incontinence (5).

Physical activity is a key and long-term form of therapy for UI because the functions of the lower urinary tract—storage and periodic voiding of urine—are regulated by a complex neuromuscular control system in the brain, spinal cord, and peripheral autonomic ganglia (6). Proper bladder emptying requires a coordinated, sustained contraction of the bladder with appropriate strength and duration. It is necessary to reduce the resistance of the bladder neck and urethra and ensure no obstruction in the urinary flow (7).

There are several treatment options available for UI. Weight reduction and improved posture through physical activity and diet can decrease pressure on the bladder and alleviate UI symptoms. Regular voiding can help avoid bladder overdistension. Reducing fluid intake, especially those containing caffeine and alcohol, can decrease the frequency of incontinence episodes. Pharmacotherapy may also help manage UI symptoms (8).

QUALITY OF LIFE IN WOMEN WITH URINARY INCONTINENCE

Studies assessing quality of life using the Health Utility Index (HUI) indicate that women report urinary incontinence (UI) as having a more negative impact than diabetes, hypertension, epilepsy, or connective tissue diseases (9). Quality of life deteriorates across all domains: psychological, social, functional, and sexual. Women often highlight a decline in self-confidence, a diminished sense of attractiveness, and reduced femininity (10). Body image perception may be a key determinant of quality of life in women and can serve as an important outcome measure in clinical trials (11). Urinary incontinence is associated with increased prevalence of depression and anxiety. A study conducted in Norway found a link between UI and depression in over 16,000 women over the age of 20 (12). Further studies indicate that 50-68% of women with UI suffer from sexual dysfunction, reporting issues such as decreased libido, anorgasmia, and dyspareunia. Symptoms of urinary tract infections also caused emotional distress and low self-esteem during sexual intercourse. As the condition progresses, women may gradually withdraw from professional, social, and personal activities (12). Due to the intimate nature of the disorder, many women consider genitourinary dysfunctions a taboo topic. Research shows that patients typically seek medical or physiotherapeutic help approximately five years after the onset of symptoms (13,14).

Despite the growing body of knowledge on urinary incontinence, women often feel underinformed and wish to know more about managing this condition. This is confirmed by a 2017 study involving 1,092 women aged 19-30, which found that 33% of respondents believe education on genitourinary disorders should be introduced at the school level. The authors emphasize the necessity of implementing preventive practices and educational programs targeting adolescent and young women (15). At the Józef Dietl Hospital in Krynica-Zdrój, a study was conducted on the impact of UI on depressive disorders in 100 women with incontinence admitted to the Gynecology Department. The research tools included a self-constructed questionnaire and the standardized Beck Depression Inventory. The results indicated that the most common type of UI was stress urinary incontinence. Depressive disorders were observed in 64% of respondents, with most women experiencing mild or moderate depression (63%). The predominant emotions among women with UI were shame (39%), anger (20%), and sadness (15%). The findings suggest that the prevalence of depressive disorders in women with UI increases with age and the duration of the condition. Psychological support was desired by 41% of the participants (16).

In their study, Perry et al. assessed anxiety and depression levels in women with urge urinary incontinence using the Hospital Anxiety and Depression Scale (HAD). They found that 56.6% of the participants experienced anxiety, while 37.6% suffered from depression (17).

Urinary incontinence significantly impacts the economic situation of patients, primarily due to the need for specialist consultations, procedures, therapies, and the purchase of specialized underwear, medications, or protective pads. Annually, over 12 billion dollars are spent on treatment. Patients bear 70% of the cost of conservative treatment out of pocket, which represents a substantial individual financial burden (18). In Poland, data from the National Health Fund (NFZ) estimated that in 2015, the costs associated with treating patients with genitourinary disorders amounted to 416 million PLN. Alarmingly, these costs are increasing by an average of 10% per year. When considering all expenditures related to treatment, the costs of managing urinary incontinence are comparable to those associated with breast cancer treatment (19).

The health status of women also negatively affects their professional lives. Due to the discomfort caused by urinary incontinence, women are more frequently absent from work, have lower productivity, and work at a slower pace (20). Given the aforementioned epidemiological data and risk factors, it seems prudent to implement physical activity for all patients as the most effective and economical intervention to improve the quality of life for women suffering from urinary incontinence.

TYPES AND FORMS OF INCONTINENCE

The term "urinary incontinence" refers to any involuntary leakage of urine, as defined by the World Health Organization (WHO) and the International Continence Society (ICS). Urinary incontinence (UI), also known as incontinence, has been recognized by the WHO as a lifestyle-related disease (21). The ICS has identified four types of urinary incontinence, based on physiological causes. The most common type is stress urinary incontinence (SUI), which results from excessive mobility of the bladder neck and failure of the sphincter mechanism. The next type is overactive bladder (OAB), caused by detrusor muscle overactivity and low bladder wall compliance, which can also include neurogenic bladder. The third type is overflow incontinence, primarily caused by detrusor underactivity and obstruction to urine outflow. The final type is extra-sphincteric incontinence, resulting from fistulas and developmental abnormalities (22).

Stress urinary incontinence (SUI) is the most frequently encountered form in women. The prevalence of this type of incontinence increases significantly with age. Studies indicate that approximately 24% of women aged 18-48, 37% of women aged 35-54, and 39% of women over the age of 55 are affected by SUI (23). In addition to age, risk factors for SUI include pelvic floor muscle weakness, often caused by pregnancy, vaginal delivery, obesity, and certain gynecological and obstetric procedures. Another factor influencing SUI is menopause, and the associated estrogen deficiencies negatively affect the epithelial condition of the bladder and urethra. The most common procedure leading to SUI is radical hysterectomy (24). SUI is characterized by uncontrolled, involuntary urine leakage occurring during coughing, sneezing, or physical exertion. A key feature of SUI is the absence of the sensation of urgency during urine leakage.

SUI can be classified into three degrees of severity according to Stamey (25). Grade I involves urine leakage only during sudden and significant increases in intra-abdominal pressure. Grade II is characterized by involuntary urine loss during moderate increases in intra-abdominal pressure, such as walking up stairs, jumping, or light physical work. Patients with Grade III SUI may experience urine leakage while lying down, standing, or walking. The ICS Standardization Committee recommends an alternative classification (according to Blaivas), considering the position of the bladder neck (26).

- Type 0: The bladder neck is closed and located above the pubic symphysis. It is incompetent during coughing, but there is no urine leakage.
- Type I: The bladder neck is lowered by 2 cm relative to the pubic symphysis. It is incompetent during coughing, and uncontrolled urine leakage occurs during exertion.
- Type II A: The bladder neck is lowered more than 2 cm relative to the pubic symphysis and is incompetent during coughing. Incontinence is observed in the bladder diverticulum with accompanying anterior vaginal wall prolapse.
- Type II B: At rest, the bladder neck is below the pubic symphysis. During coughing, it descends even further, accompanied by urine leakage.
- Type III: This type involves external sphincter incompetence.

Understanding these various forms and their underlying mechanisms is crucial for accurate diagnosis and tailored treatment approaches, aiming to improve the quality of life for those affected by urinary incontinence.

According to the International Continence Society (ICS) definition, overactive bladder (OAB) is characterized by involuntary detrusor muscle contractions that can be either spontaneous or provoked. The exact cause of OAB is not well understood, but it is believed to have a multifactorial origin. The main functions of the lower urinary tract are storage and voiding, and these functions are controlled by a balance between neurotransmitter systems via both autonomic and somatic pathways (27). Studies indicate that over 10% of the general population experience symptoms of OAB. Diagnosis begins with a targeted history and examination of the genitourinary system to assess the patient's burden of disease. First-line treatment includes conservative measures such as physical activity, fluid optimization, and pelvic floor muscle exercises. The next stage of treatment involves pharmacotherapy and minimally invasive procedures, such as intravesical injections of botulinum toxin A (28).

Overflow incontinence is characterized by dribbling urine loss due to bladder overdistension and significant distension of the bladder walls. This condition can be caused by impaired central nervous system function, such as medication effects or certain diseases like diabetic polyneuropathy or a herniated nucleus pulposus with nerve pathway damage. Urethral damage may also occur during surgical procedures (29).

Extra-sphincteric incontinence involves involuntary urine leakage through a fistula that bypasses a functionally competent urethral mechanism. This type of incontinence is marked by continuous urine leakage both day and night. Causes can be congenital, such as ectopic ureteral openings, or acquired, following surgery, radiotherapy complications, or childbirth (30).

In addition to above classification, there are other types of urinary incontinence (UI). Mixed urinary incontinence (MUI) is a combination of two types: stress and urge incontinence. The primary cause of MUI is poorly understood, and without a clear understanding of the underlying pathophysiological and anatomical changes, treatment is often incorrect (31). There are also unclassified types of UI (where symptoms do not fit into any specific category) and other types of UI that occur in various situations, such as during laughter or sexual intercourse.

Among women, stress urinary incontinence is the most common type. Depending on age and the population studied, its prevalence is estimated to be between 30% and 75%, urge urinary incontinence between 7% and 30%, and mixed incontinence between 14% and 61% (32).

DIAGNOSTICS AND ASSESSMENT METHODS

Urinary incontinence (UI), regardless of its type, is often not an isolated condition but rather a symptom of various abnormalities occurring within the human body (33). Initial diagnostics typically begin in the primary care setting, usually with a family physician. The primary examination aims to identify potential causes of UI. The next step involves determining the type of incontinence and appropriate treatment methods through the use of a questionnaire. This process includes reviewing a completed bladder diary, conducting a physical examination, and performing a cough stress test. Additional assessment components may include laboratory tests and measurement of post-void residual urine volume. If there are signs of hematuria, obstructive symptoms, or recurrent urinary tract infections, referral to a urologist or urogynecologist should be considered (34).

The patient history is often the most crucial factor in identifying the type and severity of urinary incontinence. It encompasses basic information such as age, body mass index (BMI), comorbidities (e.g., thyroid disorders, diabetes, asthma, neurological diseases), previous surgeries, occupational activities, and associated burdens, as well as pregnancies and childbirths. The detailed and varied nature of the questions allows for a precise assessment of symptoms and their severity (35).

During the diagnostic process, an evaluation of posture, breathing mechanics, and gait and mobility tests is also performed. Posture, joint mobility, and gait pattern significantly impact the proper functioning of the pelvic floor. A specific examination performed by a urogynecological physiotherapist is the palpation of the pelvic floor muscles—both static and dynamic per vaginam—using the Oxford scale in conjunction with the PERFECT scale test. This assessment evaluates proper contraction and relaxation of the pelvic floor, muscle strength through closure force and inward movement, maximal voluntary contraction (MVC), endurance, contraction symmetry, coordination with other muscles, and any compensatory mechanisms (36).

Ultrasound examinations are frequently used due to their ability to assess therapeutic effects for stress urinary incontinence (SUI). The most common and primary ultrasound method is two-dimensional (2D) ultrasound, which includes both transperineal (TP) and transabdominal (TA) approaches. Transperineal ultrasound allows visualization of the bladder neck, urethra, and vagina, as well as measurement of bladder neck mobility during contraction, conscious pelvic floor muscle activation, and the Valsalva maneuver (37).

The success of UI therapy largely depends on accurate diagnosis and appropriately tailored treatment.

POSTURAL CONTROL AND THE ISSUE OF URINARY INCONTINENCE

Urinary incontinence (UI) is a multifaceted problem influenced by various factors, including body posture, joint mobility, and gait pattern, all of which significantly impact the proper functioning of the pelvic floor. Women with UI often exhibit a reduced base of support and a forward shift of the center of gravity. This posture reduces the activity of postural muscles, including the pelvic floor muscles (38). Postural defects that predispose individuals to overloads in the pelvic floor area include forward head and shoulder posture (protraction) (39), increased thoracic kyphosis, and flattened lumbar lordosis (40). Limitations in the mobility of the hip joints and intervertebral lumbar segments directly affect pelvic mobility, leading to muscle atrophy, myofascial contractures, and altered muscle tone. Consequently, the reactive and reflexive efficiency of the pelvic floor muscles is compromised (41).

Restrictions in foot joint mobility can impact gait patterns. The absence of proper foot rolling leads to inefficient gait, faster fatigue, compensatory mechanisms in the trunk, and abnormal muscle tension in the lower limbs (42). Moreover, there is a strong correlation between diaphragm function and pelvic floor muscle (PFM) activity. Research indicates that PFM activation facilitates more efficient breathing, highlighting the interrelationship between diaphragmatic function and pelvic floor muscles (43). Factors affecting diaphragm function and leading to respiratory dysfunction primarily include postural defects, such as scoliosis, excessive thoracic kyphosis, and excessive anterior or posterior pelvic tilt (44). Another critical factor is limited spinal joint mobility due to increased tension in musculoskeletal structures, such as the iliopsoas muscle, hamstring muscle group, erector spinae, or thoracolumbar fascia (45).

Studies on postural responses in women with and without UI suggest that women suffering from UI performed step initiation tasks more slowly than women without UI (46). Urinary continence in women is maintained through the integrated action of pelvic floor muscles, supportive ligaments, fascial structures, and nerves. In women with stress urinary incontinence (SUI), the postural activity of the pelvic floor muscles is delayed, and their ability to maintain balance is reduced. Learning the correct timing of pelvic floor muscle contractions during activities such as coughing or sneezing can help women eliminate SUI. Proper timing is a crucial aspect of motor coordination and may be linked to proprioception. This relationship was demonstrated in a review study conducted by Kharaji et al. between 1998 and 2017 (47). The authors observed changes in motor control, balance, coordination, and the role of proprioception in women with SUI.

Physical activity, as a form of prevention and therapy, should be tailored to the patient's posture and gait pattern to ensure that the effects of exercise are more beneficial and long-lasting.

SCIENTIFIC EVIDENCE SUPPORTING THE POSITIVE IMPACT OF PHYSICAL ACTIVITY IN WOMEN WITH URINARY INCONTINENCE

According to the World Health Organization (WHO), physical activity is a crucial and modifiable health factor across all age groups. Strong evidence suggests that, for adults aged 18 to 64, physical activity improves both cardiorespiratory and muscular fitness (48). Moreover, other studies have indicated that mild to moderate physical activity is associated with a reduced incidence of urinary incontinence (UI) in women (49, 50, 51). Research highlights numerous methods, both conservative and interventional, whose effectiveness in treating urinary incontinence has been clinically validated. The Agency for Health Care Policy Research and the European Association of Urology recommend that, for patients with genitourinary disorders, the initial focus should be on conservative treatment. This should include physical activity, pelvic floor muscle exercises, habit modifications, and physiotherapy treatments such as endovaginal electrostimulation or magnetic stimulation (52).

A synthesis of scientific evidence conducted by experts using modified Oxford and GRADE criteria provides guidelines for the treatment of patients with moderate UI. According to these guidelines, targeted physical activity is one of the most well-established forms of UI rehabilitation (53).

Scientific evidence for the protective effects of physical activity on UI can be found in numerous publications. Cross-sectional analyses by Hannestad et al. suggest that leisure-time physical activity is associated with a lower risk of UI, whereas the absence of physical activity increases this risk (54). Similarly, several prospective cohort studies, particularly the Nurses' Health Study, found that higher levels of physical activity reduce the risk of developing UI and decrease the risk of persistent UI (55). Mishra et al., in a study involving women born in 1946, demonstrated a higher prevalence of severe urinary incontinence in the group with a BMI >25 kg/m² maintained from age 20, compared to the group with normal body weight and a third group of women who were classified as overweight or obese at age 43 (56).

An observational study conducted in Spain between 2021 and 2022 included 1,446 women with UI. Women under 18 and those who had given birth in the past 12 months were excluded from the study. The Urogenital Distress Inventory (UDI-6) scale was used to assess the impact of urinary symptoms. The primary variable was the level of physical activity, measured using the International Physical Activity Questionnaire (IPAQ), which classifies adult populations based on activity levels (low, moderate, and high). The study analyzed how low levels of physical activity affect UI symptoms. After adjusting for all variables, it was found that more severe urinary symptoms were associated with lower levels of physical activity or a complete lack of it (57).

Current scientific evidence suggests that overweight and obesity are significant risk factors for urinary incontinence (UI) in women. A cohort study conducted among young women aimed to investigate the association between physical activity and UI, taking into account body mass index (BMI). Data were collected from women born 17 years apart: 1973–1978 (group T1) and 1989–1995 (group T2). Women in both groups completed surveys on the day of the study and again four years later. The surveys assessed self-reported UI and BMI. In total, nine transitional BMI categories (based on BMI status at baseline and during follow-up) and four physical activity categories were created to evaluate the prevalence of UI using Poisson regression analysis. The obesity rate increased in both groups over the four years: from 6.6% to 10.4% in group T1 and from 11.7% to 19.6% in group T2. The incidence rate of UI was higher among women with a BMI >30 compared to women with a BMI <30. An inverse relationship was observed between physical activity and UI, suggesting that higher physical activity levels are associated with lower UI prevalence (58).

A systematic review and meta-analysis project was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The target group consisted of pregnant women without contraindications to physical activity. According to the study results, physical activity should be employed as a preventive measure against UI. Currently, it is recommended that all pregnant women without medical contraindications begin or continue regular aerobic exercise for at least 150 minutes per week (59). Another systematic review, which included fifty-seven articles considered to have the highest level of scientific evidence, indicates the protective effect of physical activity in pregnant women. Exercise can help prevent significant disorders such as gestational diabetes, excessive weight gain during pregnancy, hypertensive disorders, UI, fetal macrosomia, lumbopelvic pain, anxiety, and prenatal depression. To achieve the most benefits, adherence to current guidelines is essential, and the type and intensity of exercise should be tailored to the woman's previous fitness level (60). Additionally, in pregnant women who perform pelvic floor muscle (PFM) exercises (primary prevention), the risk of developing UI in late pregnancy is reduced by 62%, and the risk of UI 3–6 months postpartum is lowered by 29% (61).

It is estimated that the prevalence of any type of urinary incontinence (UI) during the first year postpartum ranges from 32% to 64% for stress urinary incontinence (SUI) and 15% to 30% for other types of UI (62). The objective of a prospective cohort study conducted among postpartum women was to determine whether objectively measured moderate or vigorous physical activity in the early postpartum period could improve pelvic floor support. The study included nulliparous women in their third trimester of pregnancy, later excluding those who had a cesarean section or preterm delivery. Participants wore triaxial wrist accelerometers from 2 to 3 weeks and from 5 to 6 weeks postpartum for at least four days. The primary outcomes assessed one year postpartum included the burden of pelvic floor symptoms, including UI, evaluated using the Epidemiology of Prolapse and Incontinence Questionnaire.. The primary predictor was the average daily physical activity, ranging from moderate to vigorous intensity. Among the 825 participants eligible postpartum, 611 completed accelerometry and the one-year follow-up. The average age was 29 years. The study results indicated that moderate or vigorous physical activity postpartum either had a protective effect or no impact on other pelvic floor health parameters. Only a few women engaged in substantial physical activity, so these findings may not apply to women performing strenuous exercises soon after childbirth (63).

Davenport et al., in their systematic review and meta-analysis, demonstrated the protective effect of aerobic exercises combined with pelvic floor muscle training (PFMT) in women with postpartum UI. The review included 24 studies (982 women). Scientific evidence showed that antenatal PFMT combined with aerobic exercises reduced the risk of UI during pregnancy (15 randomized controlled trials) and in the postpartum period. Physical activity was beneficial in preventing the development of UI in women and reducing the risk and severity of prenatal and postnatal UI symptoms (64).

A randomized study was conducted involving a total of 40 women in the climacteric period with stress urinary incontinence (SUI), aged between 46 and 75 years. Participants were randomly assigned to two groups: one group performed an abdominopelvic exercise program, while the other group performed both abdominopelvic exercises and exercises to strengthen postural muscles. The primary outcome measures included SUI symptoms assessed using a 48-hour pad test and the International Consultation on Incontinence Questionnaire-Urinary Incontinence Short Form (ICIQ-UI-SF). These were evaluated at baseline, post-intervention, and after three months of follow-up. Differences between the groups were observed immediately after the intervention. SUI symptoms improved in both groups from baseline to three months of follow-up. The addition of postural exercises to the abdominopelvic exercise program enhanced the therapeutic outcomes for women with SUI (65).

Additionally, a cohort of 36,843 women aged 54 to 79 years with urinary incontinence (UI) was examined. Surveys were conducted every two years from 2000 to 2008. Over 18,000 women reported persistent UI, which was noted in all surveys during this eight-year period. Odds ratios for persistent UI were estimated in comparison to no UI across various demographic categories related to age and lifestyle, based on reports from 2000. Increasing age, lower levels of physical activity, Caucasian race, higher number of childbirths, and higher body mass index (BMI) were associated with a higher likelihood of persistent UI, as were several health-related factors (e.g., stroke, type 2 diabetes, and hysterectomy). Black women had significantly lower odds of persistent UI compared to Caucasian women (66).

The interdisciplinary guidelines of the Polish Urogynecological Society regarding the diagnosis and treatment of stress urinary incontinence (SUI) highlight the adverse effects of excessive physical activity in women with urinary incontinence (UI). Activities such as lifting weights over 5 kg, intensive sports training, and other exercises that significantly increase intra-abdominal pressure are contraindicated for these patients (67).

A study conducted in Italy by Salvatore et al. in 2008 involved 679 women participating in various sports. The study aimed to assess the prevalence of SUI, identify specific sports disciplines more strongly associated with UI, and evaluate related risk factors. The questionnaire included questions about the general characteristics of the participants, the occurrence of UI related to sports or general daily activities, the timing of the onset of the condition, the frequency of UI episodes, the correlation of UI with specific movements or sports, subjective perception of limitations in such situations, and the need to modify the type of sport. UI was reported by 101 women (14.9%). Of these, 32 (31.7%) reported UI only during sports activities, 48 (47.5%) only in daily life, and 21 (20.8%) in both cases. Body mass index (BMI) and the number of childbirths were significantly associated with the risk of developing UI. Analyzing different types of sports activities, a higher percentage of UI was found among women participating in basketball (16.6%), athletics (15%), and tennis or squash (11%) (68).

A cross-sectional study conducted between September 1, 2020, and January 29, 2021, in the Czech Republic included 249 women who were professional athletes with a mean age of 22.18 ± 6.11 years. The study used the International Physical Activity Questionnaire (IPAQ), the

International Consultation on Incontinence Questionnaire-Urinary Incontinence (ICIQ-UI), the Overactive Bladder Questionnaire (OAB-q), and the Contilife Quality of Life Questionnaire for UI to assess participants. Sports were divided into six groups: functional mobilization sports (FMS), strength sports (SS), aesthetic-coordination and sensory-concentration sports (ACS), heuristic-individual and martial arts (HIS + MAS), team sports with a hockey stick (HCS-A), and team sports with a ball (HCS-B). Inclusion criteria were age 18–35 years, nulliparity, high-intensity physical activity confirmed by IPAQ (over 3000 MET-min/week) in the past 3 months, and participation in the sport at least 3 days per week for more than 2 years. Sports groups were classified according to the international classification created by Kodým in 1985.

The overall scores revealed significant differences between the sports groups. The highest incidence of UI was observed in the FMS group, while the lowest incidence was noted in the team sports group. In the FMS group, the risk of developing UI was 1.96 times higher compared to the team sports group. Other sports groups did not present a significant relative risk for developing UI (69).

Women with urinary incontinence (UI) can benefit from various forms of physical activity that are both safe and advantageous for their health. Yoga and Pilates are particularly beneficial because many of their exercises focus on strengthening the core and pelvic floor muscles. Research has shown that these forms of exercise can enhance pelvic floor muscle function and reduce the symptoms of urinary incontinence (70). Low-intensity aerobic exercises, such as brisk walking, stationary cycling, and swimming, are also safe activities for women with UI. These activities help maintain a healthy body weight, which is a critical factor in preventing and managing urinary incontinence (71).

Breathing techniques and exercises that improve posture can support pelvic floor muscle function, thereby reducing the risk of urine leakage during daily activities (72). An important aspect of physical activity for women with UI is balance exercises. In a study conducted by Chmielewska et al., eighteen women with urinary incontinence and twelve women without incontinence, aged 50–55, were assessed under four different test conditions: eyes open/full bladder, eyes open/empty bladder, eyes closed/full bladder, and eyes closed/empty bladder. The study recorded center of pressure (COP) parameters, including sway range, mean square, velocity, and COP area. Women suffering from UI had more difficulty maintaining postural balance than those in the control group. Therefore, developing a therapeutic program aimed at strengthening the trunk muscles and improving postural balance in women appears warranted (73).

Hypopressive exercises are a specific form of training involving certain postures and breathing techniques designed to reduce intra-abdominal pressure and strengthen the pelvic floor and abdominal muscles. In a study, 117 participants were randomly assigned to a hypopressive exercise group (n = 62) or a control group that did not receive any intervention (n = 55). Clinical and sociodemographic data were collected, as well as pelvic floor muscle strength (using the Modified Oxford Scale), symptoms of pelvic organ prolapse, bowel symptoms, and urinary symptoms (using the Pelvic Floor Distress Inventory-20, PFDI-20), and the impact of pelvic floor disorders (PFD) on women's lives (using the Pelvic Floor Impact Questionnaire-7, PFIQ-7), as well as the severity of urinary incontinence symptoms (using the International Consultation on Incontinence Questionnaire, ICIQ). The results showed improvement in the hypopressive exercise group regarding pelvic floor muscle strength after 8 weeks of intervention compared to the control group. Additionally, pelvic floor muscle contractility improved, and the severity and symptoms associated with urinary incontinence decreased (74).

Women engaging in targeted strength training may have stronger pelvic floor muscles (PFM) than non-exercising women. However, PFMs may still be too weak or slow to counteract intra-abdominal pressure or ground reaction forces during high-intensity activities (75).

These findings suggest that while targeted exercises such as yoga, Pilates, and hypopressive training can be highly beneficial for managing UI, care must be taken when engaging in high-intensity activities, especially those that significantly increase intra-abdominal pressure. It is essential for women with UI to choose appropriate forms of physical activity to strengthen their pelvic floor muscles while avoiding exercises that may exacerbate their condition.

Conclusion

The conducted research as part of the grant The movement activity enhancement after the COVID-19 pandemics (COVIDMOVE), project number: 2021-1-SK01-KA220-HED-000023008, indicates varied levels of physical activity among students from Poland, the Czech Republic, and Slovakia after the COVID-19 pandemic, measured in MET units (Metabolic Equivalent of Task). Slovak students demonstrated the highest level of physical activity, while Polish students showed the lowest. Among women, Slovak participants were more physically active than their peers from Poland and the Czech Republic (76). In light of the presented data highlighting gender differences in physical activity, it is essential to emphasize the role of educating young women on the importance of physical activity in protecting against urinary incontinence. Regular physical activity, especially exercises engaging various muscle groups, including the lower torso, promotes the maintenance of a healthy body weight, which also reduces the risk of developing incontinence. Additionally, physical activity improves the flexibility and endurance of muscle tissues and positively affects the nervous system, supporting optimal bladder control functions. For young adults, particularly after periods of limited activity, such as the COVID-19 pandemic, recommendations to maintain the required level of physical activity appear crucial for long-term prevention, including counteracting issues related to urinary incontinence.

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Chapter 3

Impact of physical activity on mental health – psychological and physiological aspect in the general population among students

Despite strong scientific evidence indicating that leisure-time physical activity is associated with reduced mortality and numerous health benefits, few individuals currently engage in regular physical activity. A 2021 report by the Public Health Committee of the Polish Academy of Sciences highlighted insufficient levels of physical activity across all age groups in Poland, representing a significant public health risk (1). Similarly, the MultiSport Index 2023 report reveals that one in three Poles does not engage in physical activity even once a month (2). These findings align with global trends. In the European Union, 45% of people report not exercising or playing sports at all (Eurobarometer Report), with similar data reflected in the 2022 Global Status Report on Physical Activity issued by the World Health Organization (WHO Global Status Report on Physical Activity). Current data indicate that 81% of adolescents and 27.5% of adults do not meet the WHO-recommended levels of physical activity. This lack of adequate physical activity has a negative impact on individual health, the well-being of families, and burdens the healthcare system and society as a whole (3).

The economic burden resulting from physical inactivity is substantial. Globally, nearly 500 million new cases of preventable chronic diseases are expected between 2020 and 2030, with treatment costs exceeding $300 billion. Almost half of these new cases (47%) will be due to hypertension, and 43% will be attributed to depression (3). If this trend continues, physical inactivity levels among adults are projected to increase to 35% by 2030 (4). The WHO's 2020 physical activity guidelines recommend that adults engage in at least 150 minutes of moderate-intensity activity per week, 75 minutes of high-intensity activity, or an equivalent combination of these activities to reap health benefits.

Individuals who do not meet the aerobic activity recommendation are considered insufficiently physically active—this applies to all adults (aged 18 and older), including those living with chronic conditions or disabilities, as well as pregnant and postpartum women. The World Health Assembly has set a goal of a 15% relative reduction in insufficient physical activity between 2010 and 2030. The highest rates of physical inactivity were observed in high-income countries in the Asia-Pacific region (48%) and South Asia (45%). In other regions, physical inactivity ranged from 28% in Western countries to 14% in the Oceania region. Poland's physical inactivity rate was one of the highest in Europe. It was also found that physical inactivity is more prevalent among women (34%) than men (29%). Furthermore, individuals over the age of 60 are less physically active than younger adults, highlighting the need to promote physical activity among seniors. Given the persistent disparities in participation across genders and age groups, all countries are urged to significantly increase the implementation of policies and programs to address these inequalities (4).

A priority is to establish a habit of regular physical activity across all social groups, as research shows that half of those who start physical activity programs abandon them within the first six months, regardless of the chosen activity (5). Numerous epidemiological studies have demonstrated that lower amounts of physical activity or higher amounts of sedentary behavior are associated with a greater risk of poor mental health. The concept of habitual physical activity serving as a protective factor against the development of mental health disorders is further supported by data suggesting that higher levels of physical activity are associated with progressively lower risks of mental health issues. In light of this information, the following section presents scientific evidence on the impact of physical activity on various aspects of mental health.

THE IMPACT OF PHYSICAL ACTIVITY ON MENTAL HEALTH - PSYCHOLOGICAL AND PHYSIOLOGICAL ASPECTS

In scientific literature, three psychological hypotheses have been proposed to explain the positive impact of physical activity on mental health. The first hypothesis is the distraction hypothesis, which suggests that diverting attention away from adverse stimuli, such as repetitive negative thoughts and emotions, leads to mood improvement during and after exercise (6,7). The second hypothesis involves self-efficacy, positing that physical exercise can be perceived as a challenging and demanding activity, and regularly engaging in it can lead to enhanced mood and self-confidence (7,8). The third hypothesis, known as the social interaction hypothesis, emphasizes the mutual support that occurs between individuals participating in physical activity, which plays a crucial role in the mental health benefits derived from exercise (7,9).

In exploring the relationship between physical activity and mental health, researchers have also identified physiological hypotheses that may link these two aspects. The monoamine hypothesis suggests that physical activity increases synaptic transmission of monoamines (e.g., serotonin, dopamine), acting similarly to antidepressant medications. While this hypothesis is plausible, it is considered overly simplistic to fully explain the mood improvements resulting from exercise (6,7,9-11). The endorphin hypothesis is based on the observation that physical activity triggers the release of endorphins, which may contribute to improved mood and a sense of calm. There is also speculation that feelings of irritability and anxiety after cessation of exercise may be linked to endorphin withdrawal. Some studies indicate that opioid receptor blockers reduce the affective response to exercise, supporting the role of endorphins in mood regulation (7,10-13).

Physical activity can positively impact brain structure and function, measurable through modern technologies such as MRI. For example, a study on children demonstrated that a 9-month exercise intervention improved the structure and function of brain networks associated with cognitive functions. Additionally, exercise increases the levels of brain-derived neurotrophic factor (BDNF) in the central nervous system, which is crucial for the growth and health of neurons. Elevated BDNF levels may reduce symptoms of anxiety and depression (14-16).

PSYCHIC HEALTH DISORDERS IN YOUNG ADULT POPULATION VS. COVID-19 PANDEMIC

Based on a review of numerous studies conducted across various countries during the pandemic, findings indicate that students were at high risk for mental health disorders. Young adults, especially students, were exposed to psychological stress related to health threats, with results showing that approximately 36% to 73% of the sample exhibited symptoms of anxiety and depression during the COVID-19 pandemic (17). These results align with findings from studies conducted in France, the UK, and the United States among students during the COVID-19 lockdown (18–20).

Research conducted between 2020 and 2023 demonstrates the following trends: an increase in levels of stress, anxiety, and depression among students. Additionally, indicators such as insomnia, obsessive-compulsive disorder (OCD), and suicidal thoughts also rose (21). Anxiety disorders are the most prevalent mental health disorders and are associated with substantial healthcare costs and a significant burden of disease. According to large population studies, up to 33.7% of the population experiences anxiety disorders at some point in their lives (23).

There are many types of anxiety, each manifesting somewhat differently, but several common elements can be identified: persistent feelings of worry and anxiety, difficulty calming down, a sense of being overwhelmed or terrified by sudden feelings of panic or anxiety, recurring anxious thoughts, unpleasant emotional states (e.g., memories or nightmares) after a traumatic event, and physical symptoms such as cardiovascular, respiratory, or gastrointestinal issues (specific somatic symptoms are characteristic of particular anxiety disorders) (22).

Following the introduction of quarantine, lockdowns, and the suspension of in-person learning, universities transitioned to remote education. This sudden shift impacted students' functioning, as evidenced by increased stress and anxiety levels (21). The dominance of technology-based university education, coupled with long hours of online work and potential Internet addiction, has led to a significant increase in anxiety levels (24).

The first multifaceted studies on screen time, sleep patterns, and mental health among students during the COVID-19 pandemic reveal that extended screen time spent on electronic devices (computers, tablets, mobile phones) among students was positively associated with symptoms of depression and anxiety (25). At this point, it is essential to define depression. It belongs to a group of mood disorders, alongside mania, bipolar affective disorders (BD), cyclothymia, and dysthymia. Depression is characterized by a low mood, lack of energy, sadness, insomnia, and an inability to enjoy life (26). An episode of depression is diagnosed when a low mood persists for at least two weeks. Key diagnostic symptoms of depression include low mood (sadness, emptiness, hopelessness) or loss of interest and the ability to feel pleasure, which are revealed through subjective complaints. These symptoms may be accompanied by significant changes in appetite and body weight (exceeding 5% within a month), almost daily insomnia or excessive sleepiness, psychomotor agitation or retardation, fatigue or lack of energy, feelings of worthlessness, inappropriate guilt, reduced ability to think or concentrate, recurrent thoughts of death beyond fear of death, or recurrent suicidal thoughts without a specific plan (27).

Research conducted on students in the United Arab Emirates and China shows depression rates before and after the pandemic. Pre-pandemic depressive symptoms were reported at 22% in the United Arab Emirates (28) and 16.9% in China (29), while post-pandemic rates rose to 40% and 30.6%, respectively. The authors of both studies suggest that depression rates nearly doubled during the COVID-19 pandemic. They attribute the increased depression rates to family stress (29) and academic demands. Studies conducted on Jordanian students (29) link home confinement to COVID-19-related problems, including increased stress, anxiety, sleep and eating disorders, feelings of loneliness, dissatisfaction with remote learning, and home quarantine as a potential precursor to prolonged pandemic-related depression (29). Researchers concluded that pandemic-related factors, such as the effects of isolation, increased anxiety, and fear of infection, are associated with a higher risk of depressive symptoms (28).

Researchers have shown an increased prevalence of depressive symptoms among female students (29,30). A Serbian study (31) estimated that the rate of increased depression among female students is nearly 2.5 times higher than among males. Other studies have demonstrated that women are significantly more susceptible to developing symptoms of depression and anxiety compared to men, while better lifestyle habits, including physical activity, tend to have a protective role against depression (32).

Chinese researchers (33) described the relationship between anxiety levels among Chinese students who engaged in physical activity during the pandemic and those who remained inactive. Physically active students experienced improvements in mental health (33). Exercise stimulates endorphin production, and students who exercised regularly experienced lower stress levels compared to inactive students (33). Regular physical activity was a protective factor against heightened anxiety levels. Studies conducted during the pandemic revealed an inverse relationship between resistance training and anxiety levels (33). Despite numerous factors contributing to the intensification of depressive symptoms, researchers identified specific forms of physical activity, such as stretching and resistance training, that were negatively correlated with both anxiety and depression. Additionally, participation in household chores was negatively correlated with depression (34).

In addition to the elevated levels of anxiety and depression among students, obsessive-compulsive disorder (OCD), sleep problems, and suicidal thoughts were also observed.

Obsessive-compulsive disorder (OCD), previously known as obsessive neurosis, falls under the category of anxiety disorders and is characterized by unwanted thoughts and repetitive behaviors. The most common obsessions include concerns about dirt ("I got dirty by touching the doorknob"), doubts ("Did I lock the door?"), the need for symmetry ("Books must be arranged perfectly"), and aggression ("What if I hurt someone?"). The most common compulsions include checking, counting, washing, and the need for reassurance. The global prevalence of OCD is approximately 2.3% (35). During the COVID-19 pandemic, government recommendations for increased handwashing and other preventive measures provided cognitive justification for excessive compulsions, leading to the reinforcement and spread of such behaviors (36-38). By the end of 2021, researchers from Iraq indicated that OCD symptoms were present in about 43% of the university students surveyed (37), showing a significant increase with symptoms manifesting in the following ways: unpleasant thoughts (58.1%), washing (14%), contamination fears (19.4%), and repetitive counting (8%).

Suicidal thoughts, which may be one of the symptoms of depression, deserve particular attention. Each year, more than 800,000 people worldwide die by suicide (39), with more than half of these deaths occurring before the age of 50. Many authors have reported increased suicidal ideation among students during the COVID-19 pandemic (40-43). It has been found that gender predicts mortality in suicide attempts, as more men than women engage in attempts with high perceived and medical lethality (44). Experts agree that a single event does not cause suicide; it is linked to various risk factors, including individual, relational, and societal factors (39). During the COVID-19 pandemic, students experienced pressures and stress related to all aspects of life, which increased the likelihood of developing suicidal thoughts and progressing from ideation to attempts and suicide (39,43,45).

The pandemic disrupted daily routines, including sleep-wake cycles. Researchers linked the rise in suicidal thoughts among students to insomnia symptoms. There is a direct connection between increased levels of insomnia and the intensification of suicidal ideation (46). Most authors agree that sleep disturbances among students worsened during the COVID-19 pandemic, with increased stress and anxiety playing a significant role in sleep disruptions (24.40.47-53). The combination of social restrictions, physical isolation, and stress associated with remote learning resulted in disrupted sleep-wake cycles (24.47.50.54). Over 52% of students reported difficulties falling asleep, and 43% reported insufficient sleep due to stress and anxiety, which was self-reported by 78% of the student population (53). This contributed to a deterioration in mental health (55).

The scientific studies referenced above confirm the negative impact of COVID-19 on students' mental health. Young adults experienced stress, anxiety, depression, sleep problems, and suicidal thoughts. Female students found themselves at a greater disadvantage in terms of developing mental health problems. Male students, on the other hand, were at greater risk of mortality if suicidal thoughts were realized. A negative correlation between physical activity and depressive symptoms was found, suggesting that physical activity could serve as a protective factor for students' mental health.

SCIENTIFIC EVIDENCE CONFIRMING THE POSITIVE EFFECT OF PHYSICAL ACTIVITY ON PSYCHIC HEALTH IN THE GENERAL POPULATION.

There is ample scientific evidence supporting the positive relationship between physical activity and mental health across all age groups. Life satisfaction and a sense of happiness are some of the first general aspects positively influenced by physical activity. A study conducted in 24 countries showed that young adults (aged 18-30) who reported moderate or high levels of physical activity experienced greater life satisfaction and happiness. This group also had a positive perception of their health (56). A positive relationship between physical activity and life satisfaction has also been observed in both younger and older populations (57.58).

Preventing depression, which is the leading cause of mental health-related disease burden and a major cause of disability worldwide, requires effective interventions, including the modification of established risk factors. Narrative reviews suggest that physical activity can help prevent the onset of depression. A meta-analysis of prospective studies found that individuals with higher levels of physical activity had a 17% lower chance of developing depression compared to those with low levels of activity (59). Another meta-analysis of 65 studies showed a 21% lower risk of depression (60). In 2022, a broad analysis involving over 2 million individuals was conducted in a systematic review examining the correlation between physical activity and the risk of depression. The authors concluded that differences in physical activity levels have a strong impact on the occurrence of depression. Engaging in activities equivalent to 2.5 hours of fast walking per week was associated with a 25% lower risk of depression, and even half of that amount of activity was linked to an 18% lower risk compared to inactivity. These results suggest that significant mental health benefits can be achieved even at levels of physical activity below public health recommendations, with additional benefits gained by reaching the minimum recommended goals (60).

Other researchers have also demonstrated a link between postpartum depression and physical activity levels. Women in the postpartum period may experience three major depressive disorders: baby blues, postpartum depression, and postpartum psychosis. Baby blues, which refers to postpartum sadness, can occur four days after childbirth and last up to 12 days, affecting an estimated 15.3% to 84% of mothers. Baby blues is a risk factor for postpartum depression, which affects 25% of women after childbirth. This is a significant social issue, as depressive disorders in the postpartum period can negatively impact the development of the mother-child relationship (61-63). Treatment for postpartum depression typically involves the use of pharmacological agents, which can be contraindicated for natural breastfeeding. The safest form of treatment is physiotherapy based on physical activity, which has no side effects. The authors' conclusion from the cited research; is that physical activity during both pregnancy and the postpartum period reduces symptoms of postpartum depression. It also improves quality of life and reduces fatigue levels in young mothers. Supervised physical training, aquatic training, as well as home exercise have positive effects on the mental health of postpartum women (64).

Available evidence strongly suggests that physical activity-based interventions significantly reduce anxiety symptoms in both clinical and non-clinical populations. Due to their low cost and minimal risk, these interventions can serve as an effective option for treating anxiety. Inactivity among study participants has been identified as a risk factor for the development of anxiety (65). However, recent reviews have shown that interventions based on aerobic and resistance exercises are effective as both standalone and adjunct therapies for reducing anxiety symptoms. The effects of these interventions range from small to moderate (66-68).

Population-level data demonstrate that the relationship between physical activity and anxiety extends to non-clinical groups, indicating that promoting physical activity can be used as a universal approach to primary anxiety prevention (69). Additionally, it is important to note that individuals with anxiety may be at increased risk of cardiovascular diseases and reduced cardiorespiratory function, and physical activity can positively influence the course of these conditions (70.71).

The impact of physical activity on sleep disorders is another aspect that has been the subject of numerous studies over the years, as its prevalence in the population is high. A comprehensive meta-analysis highlights the various benefits of regular and intense physical exercise. Researchers have demonstrated that physical exertion positively influences total sleep time, slow-wave sleep, and sleep latency. Additionally, it improves sleep efficiency, reduces wake time after sleep onset, and affects stage 1 sleep. These findings provide strong evidence that exercise reduces sleep disturbances. The meta-analysis revealed moderate to strong positive effects of regular exercise on overall sleep quality in older adults. These positive findings regarding the impact of regular exercise are noteworthy, given that perceived sleep quality is associated with daytime functioning, life satisfaction, and mental health symptoms in healthy individuals (72).

The existing literature also largely supports the connection between stress and physical activity. Psychological stress has a detrimental impact on a wide range of physical and mental health outcomes. In contrast to the seemingly debilitating effects of persistent stress, physical activity appears to have a beneficial influence on many health factors. Exercise is associated with lower subjective stress levels, a phenomenon observed in numerous populations (73-75). Individuals who engaged in moderate-intensity exercise reported about half the perceived stress compared to those who did not exercise at all (76).

The literature confirms that physical activity reduces the negative effects of psychological stress; however, it is important to recognize that stress also affects the initiation and maintenance of exercise routines. There is a dynamic, bidirectional relationship between stress and physical activity. Stress can lead to unhealthy behaviors such as poor dietary habits, lack of exercise, smoking, alcohol consumption, and substance abuse. Studies show that stress is a predictor of negative health behaviors, suggesting that stress similarly impacts physical activity levels, thereby creating a cycle of unhealthy habits (77).

A comprehensive systematic review with meta-analysis assessed the impact of physical activity on another component of mental health disorders, specifically post-traumatic stress disorder (PTSD). Researchers found that exercise had an overall beneficial effect on PTSD symptoms. The results also indicated positive effects of exercise on secondary symptoms, including depressive symptoms and sleep disorders. The effect was most pronounced with higher volumes of exercise lasting over 20 hours, suggesting that to some extent, more exercise may result in greater benefits (78).

THE MOVEMENT ACTIVITY ENHANCEMENT AFTER THE COVID-19 PANDEMICS

During the COVID-19 pandemic own study conducted on a group of 3,051 Slovak students participating in remote learning revealed alarmingly high levels of stress and depression, particularly among women. The average stress score (PSS-10) was 20.85, and the depression score (BDI) was 14.35. Over 47% of respondents reported depressive symptoms, with 9% suffering from severe depression. Women were more likely to feel social isolation, financial issues, and family conflicts, experiencing higher levels of both stress and depression. The results showed that 83% of students had limited social contacts, and 69% felt isolated (79). Similar studies conducted in Poland on a group of 753 students revealed that 58% experienced elevated stress levels, and 56% showed depressive symptoms, with 18% reporting suicidal thoughts (80). These alarming findings prompted the research team to undertake the project The Movement Activity Enhancement after the COVID-19 Pandemics (COVIDMOVE), project number: 2021-1-SK01-KA220-HED-000023008, aimed at assessing physical activity levels among students from Poland, the Czech Republic, and Slovakia. The results indicated that Polish students had the lowest physical activity levels among the groups studied (81). Based on these findings, it can be predicted that, without adequate educational and preventive programs, the mental health of students will deteriorate, as there is a strong link between physical activity and mental health. The COVIDMOVE project addressed these issues by promoting educational and preventive actions regarding the mental health of young people, aiming to increase awareness and physical activity levels in this demographic.

Conclusion

For centuries, we have known that regular physical activity is the most effective and affordable non-pharmacological form of prevention and treatment for chronic diseases. Physical therapy is based on this principle, aiming to restore physical fitness and functional capacity following illness and treatment. Physio-prevention also provides access to knowledge in the prevention of chronic diseases, including the use of physical activity. It is also important to highlight that a physiotherapist's role is to appropriately tailor physical exertion for patients, which is essential for safe training in individuals with chronic conditions or those looking to begin a physical activity regimen.

If unsure where to start with health-promoting physical activity, it is beneficial to seek guidance from a physiotherapist or personal trainer. They can assess exercise tolerance and muscle strength and customize training to one's abilities and preferences. Every moment is the right time to take care of your health.

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Chapter 4

Basics of home fitness training for the general population

It is now well-established that low levels of physical activity are associated with an increased risk of health complications across various domains. A sedentary lifestyle has significant negative metabolic effects, including a heightened risk of obesity, diabetes, hypertension, and a weakened immune system (1,2). In relation to the musculoskeletal system, insufficient physical activity has been shown to result in increased muscle stiffness, muscle atrophy, cartilage shrinkage and hardening, joint pain, and adverse effects on posture. These issues often lead to compensatory movement patterns (1,4). From a performance perspective, reduced physical activity contributes to diminished functional lung capacity, loss of strength, muscle imbalances, decreased joint mobility, and associated joint pain (1,2). Between 2019 and 2021, the COVID-19 pandemic and its associated measures brought significant lifestyle changes, exacerbating the global decline in physical activity (4). The lingering effects of the pandemic remain evident years later, as both reduced physical activity and COVID-19 have caused widespread health consequences. Reduced physical activity, for example, has been linked to weakened cardiovascular health, increasing the long-term risk of sudden cardiac arrest (2). A lack of movement also leads to decreased aerobic fitness, potentially heightened inflammatory processes, and reduced insulin sensitivity, the latter contributing to increased accumulation of subcutaneous fat (5,6). In terms of brain function, reduced physical activity negatively impacts sleep quality, concentration, and mental health, contributing to a higher prevalence of mental health issues (7).

WHO recommendations on physical activity

Physical activity is among the most underestimated methods for promoting health and preventing various diseases. On the contrary, it actively helps improve the quality of life for people of all age groups (4). From an evolutionary and anatomical perspective, it is evident that the human body was created for frequent movement, as demonstrated by the systems representing body motion. The skeletal system provides structure and facilitates movement through bones and joint connections, which anchor connective tissues. The muscular system enables movement through muscle contractions triggered by chemical reactions at the cellular level, sliding actin filaments between myosin components, and electrical impulses transmitted through nerve endings. The human body operates as a cohesive unit, constantly communicating and cooperating even in the simplest tasks. Without movement, life would not be possible, and our body is the only place where we must live for the entirety of our lives. It is, therefore, crucial to adopt a proactive approach to our body and provide it with at least the so-called recommended minimum doses of physical activity, which are proven to bring benefits in terms of health, performance, prevention, and aesthetics. What Are the Minimum Recommendations for Physical Activity? The World Health Organization (WHO) recommends the following activities for adults, as they most significantly contribute to health promotion for various reasons (8, 9, 10). Breathing and stretching exercises, low-intensity activities (walking, yoga, household chores), aerobic activities, strength training, breathing and stretching exercises help reduce stress and relieve muscle tension accumulated due to daily stressful situations, which negatively affect health. Low-intensity activities allow people of any fitness level to engage in safe physical activity without the risk of injury or exacerbation of existing issues. Aerobic activities improve cardiovascular efficiency, influencing the effort and energy expenditure during movement and the burden that activity places on the body. This affects performance, recovery, and endurance the duration and intensity of activity and recovery time after it. Strength training plays a vital role in fitness and health. It minimizes issues such as osteoporosis (loss of bone mass), sarcopenia (loss of muscle function), arthritis (joint pain and reduced range of motion), and more. These problems can be actively mitigated through regular strength training (11, 12, 13).

Specific Benefits of Strength Training (13)

-Increased muscle mass and improved functionality

-Enhanced bone and tissue density

-Weight management—more muscle mass increases resting energy expenditure

-Stress and anxiety reduction—exercise releases endorphins, hormones that improve mood

-Reduced joint and musculoskeletal pain, especially in the cervical spine and lower back

-Improved performance—strength, balance, coordination, range of motion, endurance

-Aesthetic benefits—body composition and posture improvements

-Injury prevention and faster recovery—reducing falls, non-contact injuries, and tissue repair after injury

-Strength training has been widely studied. Performing strength training twice weekly for 12 weeks is sufficient to achieve the benefits mentioned above. Training three times per week yields even greater effects (14). For example, in adult women, three weekly strength training sessions resulted in an average strength increase of 12.2%, a 2.9% reduction in subcutaneous fat, and a 1.7% increase in muscle mass (15). Strength training also strengthens the immune system and improves quality of life without pharmacological interventions (16). WHO's Specific Recommendations for Adults (2018-2030 Global Action Plan on Physical Activity)

(13): 10,000 steps per day. 150–300 minutes of moderate-intensity activities per week. Or 75–150 minutes of high-intensity activities per week. Strength training focused on major muscle groups 2–3 times per week.

Home conditioning training – A basic guide for beginners

From the previous chapters, it's clear that regular movement is essential. But how can we effectively train at home if there's no clear guide and we lack the necessary knowledge to know where and how to begin? In the following subchapters, we aim to answer this question. Conditioning training can be described as "functional training." This term is frequently used but often interpreted differently. Functional training means "Prepare according to the activity you perform." It refers to a specific, progressive training approach tailored to the sport or individual needs of the client. It involves multi-joint, multi-directional, proprioceptive movements performed at varying resistances and speeds (17). This type of training is designed to prepare us for all activities, movements, and tasks we encounter in everyday life or sports, making them easier, better, and safer to perform, reducing the risk of injury.

Conditioning training can be divided into several components, each contributing to a complete whole, like puzzle pieces fitting together to form a picture.

The pillar as the foundation for posture, performance, and health

The first component of modern conditioning training is teaching our bodies to work efficiently and correctly, using energy where it's needed and in just the right amounts. Every movement we perform involves the joints, with energy transferred through the core to the limbs. The core is not designed to generate force but rather to transfer or absorb it. Therefore, this component is called the pillar a combination of mobility (range of motion) and stability (firmness) across the hips, core, and shoulders. The pillar determines how efficiently we can move and how technically correct our exercises are, ensuring we avoid harm and achieve optimal performance. This is why it is the first focus of conditioning training (18).

What functions does the pillar serve in the human body?

Breathing

The pillar supports posture, which in turn affects how we breathe and how much oxygen we can take in with each breath. Learning proper breathing is essential because compensatory breathing patterns can reduce performance, affect posture, and impair the technique of any exercise performed. To gain deeper insight into this topic, consulting a physiotherapist.

Hardware

Another function of the pillar is to ensure that the body moves as it should anatomically. Each joint should have a certain range of motion and mobility while also providing stability and energy transfer during movement. While all joints serve both functions, anatomically, one typically dominates. For example, the hip joint primarily provides mobility, whereas the knee joint mainly provides stability during movement, absorbing loads to prevent injury. Joints in the body are interconnected, like Lego blocks, and work together as a whole. If the dominant function of one joint is compromised, it affects the joints above and below it, potentially causing movement dysfunction or compensatory patterns. (If you've ever experienced lower back pain, the issue might stem from the hip joint or thoracic spine.)

For a clearer understanding of the mobility and stability of individual joints.

Software – The final function of the pillar is to improve communication along the axis of the head and body. In this part of the pillar, we learn the correct execution of movements, exercises, proper muscle engagement during movement, and how to perform movements economically and efficiently. Pillar Components and How to Train the Pillar In the previous chapter, we defined the pillar and the role pillar training can play in conditioning training. In the next chapter, we will introduce specific training methods used for pillar development, the tools we utilize, and how to implement these methods.

Methods Used for Pillar Development: a) Soft Tissue Release This method involves the so-called myofascial massage (self-massage), where tools like massage rollers, balls, or other aids are used to release the tissue, making it more pliable for subsequent movement. Due to the sedentary lifestyle, tissue tension increases, which restricts blood flow and the distribution of nutrients to the tissue or, conversely, prevents the removal of waste products from the tissue after prior exertion. On the skin's surface, there are cells called mechanoreceptors, which constantly inform the nervous system about the tension within the tissue. Myofascial massage works on the principle of acupressure massage, where pressure is applied to the tissue, and the mechanoreceptors on the skin notify the nervous system of this activity. The result is a command from the nervous system to reduce the tension in the tissue, improving its ability to move or its contractile properties.

How to Perform Myofascial Massage: Direct pressure on stiff or painful spots Longitudinal or transverse rolling over the tissue Pressure combined with movement in the joint being targeted General Recommendations: To avoid discomfort, increased pain, or complications, adhere to these guidelines: Never massage bony protrusions or bones themselves; focus only on muscles and soft tissues. Follow the concept of mobility and stability (it is advisable to massage tissues around joints that should predominantly be mobile). Whichever method you choose, remain on the targeted area until you feel a release or reduction in pain. Initially, use a softer roller that does not cause intense pain during self-massage to get accustomed and avoid causing the opposite effect of increased tension and stress in the tissue.

Tissue mobilization

Once we manage to improve tissue tension and prepare it for work, the next step is to increase the range of motion in the given joint. For this, we use a wide variety of stretching techniques, whether static stretching, where we hold an end position for a certain period (ideally between 60–120 seconds), dynamic stretching, which involves exercises that stretch the muscles during movement, or techniques that manipulate the range of motion by regulating the stretch reflex through various forms of isometric activation, followed by relaxation and potential muscle elongation (17).

Figure 1 Mobilisation of joint

Motor control

After increasing and improving the range of motion in the joints, we perform exercises that aim to "store" these newly acquired ranges, so the body remembers them and learns to control and manage any movement effectively. In the final phase of pillar training, we focus on stabilization/activation exercises, which require us to use strength in various positions, perform movements in a coordinated manner, and enhance muscle engagement. This creates a foundation for further strength training focused on performance while minimizing the risk of injury and improper technique (17).

Figure 2 Motor control exercise

Strength training at home

Completing pillar training lays the foundation for a safe transition into strength training. However, just as every country has its own language, strength training encompasses a vast array of exercises, names, and variations, which can often seem confusing to the average person. When it comes to conditioning/functional training, the first step is to learn to "speak the same language." Functional training focuses on preparing the body to handle activities we commonly perform in sports or daily life. During any functional movement, our joints and tissues work in coordination and never in isolation. Therefore, in modern conditioning training, exercises are no longer categorized by muscle groups. "If we train muscles, we forget movement. But if we train movements, we always engage the muscles involved in that movement" (17). From this perspective, the basic categorization of exercises in strength training is straightforward.

Exercises can be divided as follows:

Primary body region involvement

Type of movement performed

Specific execution details of the movement

Categorization based on primary body region involvement:

Full-body exercises

Upper-body exercises

Lower-body exercises

Rotational exercises

Full-body exercises engage a large number of motor units simultaneously.

These are typically dynamic and technically demanding.

Categorization based on movement Type:

Push exercises

Pull exercises

Push exercises: Movements where force is used to push oneself or an object forward or away.

Pull exercises: Movements aimed at pulling oneself or an object toward the body.

Figure 3 Example of complex exercise

Rotational Exercises

Rotational exercises primarily serve either a stabilizing or propulsive function. These exercises train the hips and torso statically by resisting rotational forces acting on the body, with the goal of maintaining the desired body position. These exercises focus on learning to coordinate dynamic movements through the hips, torso, and shoulders, optimizing the use of kinetic chains. This approach helps to develop efficient and powerful movement patterns (17).

Figure 4 Rotatory stability

Depending on which part of the body we use to perform the exercises, strength training is further divided based on focus into upper body and lower body exercises. The following images illustrate how exercises targeting the upper and lower body are categorized.

As we can see, exercises for the upper body are first distinguished by the type of movement, specifically whether the exercise involves a push or a pull motion. Then, the direction of the movement is added as a distinguishing factor. Finally, it is specified whether the exercise is performed with both limbs or unilaterally.

Figure 5 Horizontal push

Figure 6 Vertical Push

Figure 7 Horizontal pull

Figure 8 Vertical pull

Similarly, exercises targeting the lower body can also be categorized. Again, they are first distinguished by the type of movement performed (push or pull). However, for the lower limbs, pull exercises are further divided based on whether the movement predominantly occurs in the hip joint, with the knee joint serving a stabilizing function, or vice versa.

A squat can be classified as a push exercise, while examples of pull exercises include the deadlift or lying leg curls.

Figure 10 Squat

Figure 11 Bridge

Figure 12 Unilateral deadlift

In training programs, we aim to maintain a balance between different types of exercises to prevent overloading and ensure the comprehensive development of the entire body.

Designing a conditioning training program at home

Conditioning training can be defined as an individualized prescription of exercises based on the personal profile of a given client or athlete. An individual profile is, and always should be, developed based on objective measurements and data gathered through collecting information about the client, assessing body composition, analyzing lifestyle habits, and conducting tests to evaluate movement technique, quality, and performance. These steps help identify the client’s specific needs.

The development of any conditioning training or training plan always stems from an analysis of the individual profile. Only through this approach can a conditioning coach accurately identify movement and health limitations, possible restrictions, and performance deficiencies of the client. It's no coincidence that conditioning coaching is a university-level academic discipline.

For designing any training program, even in a home setting, it is therefore highly recommended to seek the assistance of an expert.

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Chapter 5

Physical activity, the cardiovascular system and the COVID-19 pandemic

Introduction

The COVID-19 pandemic, which emerged in 2019, impacted all aspects of modern life, including healthcare, the economy, and social interactions. One of its most significant effects was the alteration of lifestyles brought about by mobility restrictions and lockdowns, forcing much of the population to adapt. Physical activity, a cornerstone of health, became even less accessible for many, raising concerns about its long-term effects on both physical and mental health.

The cardiovascular system is among the most vulnerable systems in the human body, profoundly influenced by two major factors linked to the pandemic: the SARS-CoV-2 virus and reduced physical activity. COVID-19 is known not only for its acute respiratory symptoms but also for its long-term complications, such as heart damage, vascular inflammation, and increased risk of thrombosis. These complications can affect individuals regardless of age, with cardiovascular diseases being one of the primary risk factors for severe outcomes of the infection.

On the other hand, physical activity plays a key role in preventing and managing cardiovascular diseases. Its benefits include improved heart function, blood pressure regulation, reduced cholesterol levels, and enhanced immunity. However, the pandemic significantly limited opportunities for exercise—closure of gyms, remote work, and fear of social contact made it difficult for many to maintain an active lifestyle. This situation not only highlighted existing disparities in access to health but also underscored the importance of physical activity as an essential component of resilience against illness.

The aim of this chapter is to explore the connections between physical activity, cardiovascular health, and the COVID-19 pandemic. It provides an overview of the physiological and epidemiological aspects of this complex relationship, emphasizing the importance of promoting movement as an integral part of strategies to mitigate the negative health impacts of the pandemic. This analysis offers insights into current findings as well as recommendations for future research and practice that could foster healthier and more resilient lifestyles.

The cardiovascular system and COVID-19

The human cardiovascular system is an extraordinary network that has intrigued and inspired clinicians and researchers for centuries. Historically, the heart was viewed as the center of emotions, a belief that persists symbolically even today. In 1628, William Harvey introduced the groundbreaking idea that the heart drives blood circulation through a closed vascular system (1). Now, basic knowledge of the cardiovascular system's role in sustaining life is common, even among high school students. Yet, scientists continue to uncover new and exciting insights, particularly at the cellular and molecular levels of cardiovascular function (2).

This intricate system works in harmony with other physiological systems and comprises three main components: the heart, the vasculature, and the blood. These elements collaborate to perform the cardiovascular system's primary task: delivering oxygen and nutrients to body cells and removing waste products. Beyond this foundational role, the cardiovascular system is essential to numerous other functions, which can be grouped into three key categories(2):

1. **Transport and Delivery**
    - Facilitating the exchange of oxygen and carbon dioxide.
    - Transporting nutrients and eliminating waste products.
    - Carrying hormones and chemical messengers throughout the body.
2. **Hemostatic Regulation**
    - Maintaining fluid balance across compartments.
    - Regulating pH levels and thermal stability.
    - Controlling blood pressure.
3. **Protection**
    - Preventing blood loss through clotting mechanisms.
    - Defending against infections using white blood cells and lymphatic tissues.

The essential functions of the cardiovascular system are made possible through its close interactions with other major body systems, including the nervous, respiratory, endocrine, digestive, urinary, skeletal, and integumentary systems. The cardiovascular system supports both pulmonary and systemic circulation.

In pulmonary circulation, partially deoxygenated blood flows from the right ventricle to the pulmonary capillaries, where it becomes oxygenated before returning to the left atrium. This process underscores the crucial relationship between the cardiovascular and respiratory systems. While the respiratory system brings oxygen into the alveoli, the cardiovascular system distributes it to the body’s cells. Additionally, the cardiovascular system carries carbon dioxide produced by cellular metabolism to the pulmonary capillaries, where it diffuses into the lungs to be exhaled (2,3).

Systemic circulation, on the other hand, delivers oxygenated blood to all major tissues and systems in the body. It works closely with systems like the digestive, urinary, and integumentary systems to fulfill critical cardiovascular functions. These functions are vital for maintaining homeostasis, including:

- Ensuring adequate blood pressure to supply tissues with sufficient oxygen.
- Regulating pH levels within narrow limits.
- Managing body temperature through processes like sweating (plasma-derived) and increased blood flow to the skin.
- Supporting metabolic regulation, particularly in maintaining stable blood glucose levels.

The emergence of the novel coronavirus, formally identified as Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2), has posed an extraordinary challenge to healthcare systems worldwide. Its high infectiousness, capacity for transmission even during the asymptomatic phase, and relatively low virulence have facilitated the virus’s swift spread across geographic boundaries, culminating in a global pandemic. The first recorded case of this disease, termed coronavirus disease 2019 (COVID-19), was reported on December 8, 2019, in China's Hubei province (4). In just over three months, the infection rapidly spread to 177 countries, areas, and territories worldwide, resulting in 266,073 confirmed cases and 11,184 deaths, according to World Health Organization data as of March 21, 2020 (5).

COVID-19, caused by SARS-CoV-2, an RNA beta-coronavirus, primarily targets the respiratory system but also impacts the cardiovascular (CV) system (6) in various ways (7–10):

1. **Direct myocardial injury**: The virus binds to ACE2 receptors in the heart and lungs, disrupting signaling and causing acute damage.

2. **Systemic inflammation**: Severe cases trigger cytokine storms, leading to multi-organ damage.
3. **Impaired myocardial oxygen balance**: Hypoxia and increased metabolic demand can result in heart injury.
4. **Plaque rupture and thrombosis**: Systemic inflammation increases risks of acute coronary events.
5. **Therapeutic side effects**: Some COVID-19 treatments negatively impact the heart.
6. **Electrolyte imbalances**: Issues like hypokalemia heighten risks of arrhythmias, especially in preexisting conditions.

Preexisting CV Conditions

Patients with conditions like hypertension, diabetes, or cardiovascular disease face heightened risks of severe COVID-19 and poor outcomes. For example, studies show significantly higher case fatality rates (CFRs) among those with CV comorbidities. While overall CFRs vary globally, regions with higher prevalence of comorbidities report worse outcomes (8).

Cardiovascular Manifestations in COVID-19

1. **Acute myocardial injury**: Observed in 8–17% of cases, marked by elevated cardiac troponin, indicating poor prognosis (11).
2. **Arrhythmias**: Both tachy- and brady-arrhythmias are common, especially in ICU patients (12).
3. **Potential long-term effects**: Prior data from SARS suggests lasting CV complications, emphasizing the need for follow-up in COVID-19 survivors.

The interplay between COVID-19 and the cardiovascular system underscores the importance of integrated care. A careful balance is required to manage CV complications without compromising safety or resources, while long-term monitoring may help mitigate future risks (12,13).

Cardiovascular (CV) risk factors, including hypertension and diabetes, as well as chronic cardiovascular diseases (CVD) like ischemic heart disease and heart failure, are common among patients hospitalized with severe COVID-19. Studies have shown that diabetes and chronic CVD (but not hypertension) are linked to higher mortality rates. Currently, individuals with pre-existing CVD or CV risk factors are considered to be at greater risk. However, it is still unclear whether the increased vulnerability to severe COVID-19 in these patients is due to existing CVD or if those with only CV risk factors, but no diagnosed CVD, experience similarly severe outcomes (14–18).

Physical activity: A pillar of cardiovascular health

Physiology is the study of how the body functions, examining processes at various levels, such as molecular, cellular, organ, and system. To fully understand body function in health and disease, it is crucial to appreciate the processes that occur at each of these levels. Homeostasis and integration are key principles in physiology, explaining how organ functions and overall body processes remain relatively stable despite significant environmental changes. This stability is maintained through coordinated chemical and electrical signaling within and between cells, organs, and systems. Exercise is a physiological response that increases metabolic rate to improve physical fitness. It is one of the most demanding physiological activities, leading to increased metabolic rate, heart rate, blood flow, respiration, and heat production. The body meets the heightened metabolic demand during exercise by increasing blood flow (functional hyperemia) and oxygen supply to the muscles, regulated by both local and systemic mechanisms. Local mechanisms adjust muscle homeostasis and vascular conductance to meet the metabolic needs, while systemic mechanisms maintain blood pressure and overall cardiovascular stability, including the increase and redistribution of cardiac output, largely through sympathetic activation. For example, the significant drop in vascular resistance and resulting increase in blood flow during exercise requires higher blood pressure and cardiac output to ensure that the active muscles receive adequate blood flow (3).

There is a well-established consensus in the scientific community that regular physical activity is a cornerstone of healthy living, a notion supported by an extensive body of research. Studies have consistently demonstrated that physical inactivity significantly increases the risk of cardiovascular disease, with inactive individuals facing a 150% to 240% higher risk. A pivotal study conducted by the Centers for Disease Control and Prevention (CDC) compared individuals who met the recommended physical activity guidelines (150 minutes of moderate-intensity physical activity per week) with those who were inactive. According to the study, 80% of the U.S. population fails to meet these activity standards, and 60% are classified as "very inactive." The results revealed that inactive individuals had twice the risk of coronary heart disease (CHD) compared to their physically active counterparts. Given these findings, there exists a clear mandate and significant opportunity to promote increased physical activity across the American population, addressing the growing public health issue of inactivity. This challenge represents a central opportunity for practitioners of lifestyle medicine to intervene (19,20).

Benefits of physical activity and risks of physical inactivity

Any physical movement produced by skeletal muscle that requires energy expenditure is defined as physical activity by the World Health Organization (WHO) (21). Physical activity includes all movement in leisure time, during transport or during the performance of one's job. As further confirmed by various research, physical activity helps prevent chronic noncommunicable diseases such as heart disease, stroke, diabetes and some types of cancer. It also helps prevent hypertension, maintain a healthy body weight and contributes to improving mental health, quality of life and well-being. On the contrary, one of the main risk factors for mortality from chronic noncommunicable diseases is physical inactivity. People who are not sufficiently physically active have a 20-30% higher risk of death compared to people who are sufficiently physically active (21).

The World Health Organization (WHO) defines physical activity as any bodily movement produced by skeletal muscles that requires energy expenditure. It encompasses various activities, including leisure pursuits, transportation, occupational tasks, and domestic chores. Both moderate and vigorous physical activities are recognized for their health benefits. Common forms of physical activity include walking, cycling, sports games, and active recreation, which can be performed at any skill level for enjoyment and health benefits (22).

Physical activity is crucial for maintaining health and well-being (23), while physical inactivity and sedentary behavior significantly increase the risk of noncommunicable diseases (NCDs) and other adverse health outcomes. Insufficient physical activity is a leading risk factor for mortality, with inactive individuals facing a 20–30% higher risk of death compared to those who are sufficiently active. Regular physical activity offers numerous health benefits, including:

- **For children and adolescents**: Improved physical fitness, cardiometabolic health, mental health, and cognitive outcomes, along with reduced body fat and enhanced bone health.
- **For adults and older adults**: Lower risks of mortality from all causes, cardiovascular disease, hypertension, specific cancers, and type-2 diabetes, along with improved mental health, sleep quality, and cognitive function.

- **For pregnant and postpartum women**: Reduced risks of complications such as pre-eclampsia, gestational diabetes, and postpartum depression, with no adverse effects on birth outcomes.

In contrast, sedentary behavior, characterized by low-energy activities such as sitting or reclining, is associated with poor health outcomes. Among children, it contributes to increased adiposity and reduced fitness, while in adults, it correlates with higher risks of mortality and chronic diseases like cardiovascular disease, cancer, and diabetes (24).

WHO guidelines on physical activity and sedentary behavior

WHO's global guidelines on physical activity provide recommendations tailored to different age groups, including children, adolescents, adults, older adults, pregnant women, and individuals with chronic conditions or disabilities. The guidelines emphasize that any level of physical activity is better than none and that all age groups should minimize sedentary time. Key recommendations include regular muscle-strengthening activities and integrating movement into daily routines. For young children under five, WHO also provides specific guidance on balancing physical activity, sleep, and screen time to support healthy development.

WHO monitors global trends in physical inactivity, revealing a concerning rise in sedentary lifestyles. As of 2022, approximately 31% of adults worldwide—equivalent to 1.8 billion individuals do not meet the recommended 150 minutes of moderate-intensity activity per week. If this trend persists, the proportion of inactive adults is projected to reach 35% by 2030. Physical inactivity is more prevalent among women, adolescents, and older adults, with notable disparities influenced by social, cultural, environmental, and economic factors. The WHO Global Action Plan on Physical Activity outlines policy recommendations to encourage active lifestyles. These include improving access to walking, cycling, and non-motorized transport; increasing opportunities for physical activity in schools, workplaces, and communities; and ensuring availability of public spaces for recreation. Implementation requires coordinated efforts across multiple sectors, including health, transport, education, and urban planning, alongside engagement from nongovernmental organizations and stakeholders. Policies should prioritize addressing disparities, enabling equitable access to opportunities for physical activity for all populations. By fostering greater physical activity, countries can mitigate the health and economic burden of inactivity, achieve global NCD targets, and contribute to the Sustainable Development Goals (22–24).

Extensive research over several decades has established a robust connection between physical activity and positive physical health outcomes in children and adolescents (25,26). Studies employing cross-sectional, longitudinal, quasi-experimental, and experimental designs consistently demonstrate that physical activity enhances musculoskeletal and cardiovascular health, reduces the risk of obesity, and lowers the likelihood of developing metabolic syndrome. Additionally, a dose-response relationship has been identified, wherein greater physical activity correlates with increased health benefits, with the most significant advantages arising from vigorous activities that improve aerobic capacity and muscular fitness. These findings underpin current guidelines advocating daily moderate-to-vigorous physical activity for children and adolescents, supplemented with regular vigorous and muscle- and bone-strengthening exercises (2,27–31).

Conversely, evidence regarding the health benefits of reducing sedentary behavior and increasing light activity remains less clear due to a scarcity of studies and inconsistent findings. Emerging research suggests that prolonged sedentary behavior, particularly uninterrupted screen time, adversely affects physical health and follows a dose-response pattern, where increased sedentary behavior is associated with negative health outcomes. However, isolating the unique impact of sedentary behavior is challenging due to the interdependent nature of movement behaviors, which include sleep, sedentary time, and physical activity of varying intensities. Unlike other health behaviors that can coexist (e.g., smoking while eating), individuals engage in only one movement behavior at any given time. A reduction in sedentary time inherently increases time spent in other activity levels, such as light, moderate, or vigorous activity, complicating efforts to study these behaviors in isolation (27,28).

To address this complexity, researchers are increasingly adopting compositional data analysis methods. These approaches assess the proportional relationship between different movement behaviors within a 24-hour period rather than treating them as independent variables. Preliminary findings from these studies suggest that higher-intensity physical activity is particularly beneficial for children and adolescents, while limiting sedentary time, especially screen-based behaviors, promotes better physical health (27,29,30).

This emerging field of research holds promise for refining public health guidelines. Future recommendations may emphasize a 24-hour perspective, prescribing optimal durations for each intensity level of physical activity, sedentary behavior, and sleep to maximize health outcomes (25).

Regular exercise is a fundamental component of a healthy lifestyle. It is widely recognized for its benefits, including improved cardiovascular health, reduced blood pressure, effective weight management, and protection against various diseases. But can it also support immune health? Similar to a nutritious diet, physical activity contributes to overall well-being, which includes a robust immune system. Factors such as a Western diet, chronic stress, smoking, sleep deprivation, and inactivity have been linked to immune dysfunction and chronic inflammation. Therefore, incorporating regular exercise into daily routines may offer significant immunological benefits (31–33). Physical activity can prevent and/or attenuate atherosclerosis, a disease clearly linked to inflammation. Paradoxically, even brief exercise induces a stress response and increases inflammatory cells like monocytes in the circulation (34).

Physical inactivity increases the risk of numerous chronic diseases, including type 2 diabetes, cardiovascular disease, chronic obstructive pulmonary disease, certain cancers, dementia, and depression, largely due to the accumulation of visceral fat and activation of inflammatory pathways. Chronic inflammation promotes insulin resistance, atherosclerosis, neurodegeneration, and tumor growth, contributing to disease development. Regular exercise mitigates these risks through its anti-inflammatory effects, achieved by reducing visceral fat and altering the inflammatory environment during each exercise session. Mechanisms include the release of interleukin-6 (IL-6) from muscles, stimulating anti-inflammatory cytokines like IL-10 and IL-1 receptor antagonist, reducing pro-inflammatory monocytes, and downregulating Toll-like receptor expression. While moderate exercise lowers infection risk compared to inactivity, prolonged intense training, as seen in elite athletes, may increase susceptibility to infections due to exercise-induced immunosuppression, emphasizing the need for balanced exercise regimens (35).

The rise in sedentary lifestyles and declining physical activity has contributed to obesity, type 2 diabetes, hypertension, hypercholesterolemia, and other metabolic syndrome factors, which increase the risk of atherosclerosis and cardiovascular diseases. While high-calorie diets are often implicated, evidence suggests that adequate physical activity alone can mitigate these risks and maintain metabolic balance without dietary changes. Exercise has been shown to reverse the development of metabolic syndrome, even in individuals consuming high-fat diets. For example, the physically active Amish community exhibits lower rates of type 2 diabetes and obesity despite high caloric intake. Conversely, even brief periods of inactivity, such as bed rest, reduce insulin sensitivity and glucose utilization in healthy individuals. A long-term study

(1970–1998) of 2,501 men found an inverse relationship between physical activity and weight gain, with higher-intensity activities offering greater health benefits (36–38).

Wild animals generally avoid metabolic diseases due to their inherently active lifestyles, a state of continuous physical activity that benefits their metabolic health. Similarly, exercise and physical activity in humans reduce high blood pressure, insulin resistance, glucose intolerance, cholesterol, triglycerides, and obesity. A 12-week study involving obese middle-aged women engaging in resistance and aerobic exercises three times a week demonstrated significant reductions in metabolic syndrome markers, including blood pressure, body fat percentage, fasting glucose, triglycerides, cholesterol, and visfatin levels. Resistance training over 12 weeks has been shown to improve heart rate, blood pressure, and cholesterol, while aerobic exercise enhances factors such as waist circumference, fasting glucose, and blood pressure, also offering protection against obesity-related inflammation and β-adrenergic receptor desensitization. Additionally, activities like Bikram yoga improve glucose tolerance, arterial stiffness, and insulin resistance in older obese adults. A decade-long study of 4,100 men and 963 women further revealed that regular physical activities, such as walking, running, or using treadmills, were associated with lower BMI and triglyceride levels compared to inactive individuals (39–42).

Physical inactivity contributes to approximately one in every 10 deaths annually, accounting for 6–10% of major noncommunicable diseases globally, such as coronary heart disease (CHD), type 2 diabetes, breast cancer, and colon cancer. Eliminating physical inactivity could prevent 5.3 million deaths each year and increase global life expectancy by an average of 0.68 years, according to findings by Dr. I-Min Lee and colleagues in the Lancet Physical Activity Series (43). Their study defined physical inactivity as engaging in less than 2.5 hours of moderate-intensity exercise weekly and used WHO data from 122 countries to calculate the population-attributable factors (PAFs) for various diseases and mortality. The prevalence of physical inactivity was highest among individuals with diabetes (43.2%) and lowest among those with breast cancer (40.7%), with median PAFs for CHD and all-cause mortality at 5.8% and 9.4%, respectively. The Eastern Mediterranean region stood out, with the highest potential gains in life expectancy (0.95 years) and significant reductions in CHD and mortality rates if inactivity were eliminated. Despite its severe health risks, physical inactivity is less recognized than tobacco smoking, which accounts for a similar number of deaths annually. Dr. Lee emphasizes that inactivity should be regarded as equally dangerous to health as smoking, calling for coordinated efforts across sectors such as health, education, transport, and business to promote physical activity worldwide (43,44).

Impact of the COVID-19 pandemic on physical activity levels

The COVID-19 pandemic has significantly affected nearly every aspect of life, reshaping public health systems, economies, and individual lifestyles worldwide. Beyond its direct health impact, the virus has exacerbated existing social and economic inequalities, disrupted education, and caused widespread uncertainty. For individuals, the pandemic has resulted in increased social isolation, economic hardship, and mental health challenges such as anxiety and depression. Measures like lockdowns, remote work, and quarantine have led to reduced physical activity, raising concerns about the increased risk of noncommunicable diseases such as obesity and cardiovascular disease. The pandemic has underscored the interconnectedness of physical health, mental well-being, and social conditions, highlighting the need for a comprehensive approach to health and resilience in future crises.

The rapidly changing circumstances due to the COVID-19 pandemic have profoundly impacted people's lives and disrupted multiple sectors of the global economy, including tourism, aviation, agriculture, and finance. These industries have seen significant declines, as governments worldwide imposed restrictions that affected both supply and demand. The uncertainty surrounding the virus, along with widespread lockdowns and economic downturns, is expected to lead to a rise in suicides and mental health disorders linked to these stressors. For instance, Canadian reports project a sharp increase in suicides, from 418 to 2,114 cases, due to job losses. Similar trends have been observed in the USA, Pakistan, India, France, Germany, and Italy. Research has also highlighted an increase in psychological distress among the general population, individuals with pre-existing mental health conditions, and healthcare workers. These findings call for urgent attention to public mental health and the implementation of policies to support people during this difficult period (45–51).

The COVID-19 pandemic has led many governments to implement strict indoor isolation measures to prevent the spread of the virus by limiting human-to-human contact (52). These necessary but restrictive measures have significantly reduced the opportunities for outdoor and gym-based physical activity (PA). Physical inactivity is a well-known risk factor for cardiovascular disease (53). A large study of 185,000 people in the US found a 48% decrease in PA, as measured by Fitbit trackers, following the declaration of a federal emergency in April. However, there is limited research on the specific decline in PA among cardiac patients during the pandemic. The growing prevalence of physical inactivity raises concerns about the potential loss of the well-established benefits of PA for physical and mental health, particularly in these patients. The relationship between the immune system and PA is often described by a J-shaped curve, emphasizing the importance of regular, moderate-intensity exercise for improving immune function. As a result, there is widespread agreement on the importance of staying physically active during quarantine, especially for older patients (54–56).

Systematic review of 66 studies found that (57), during the COVID-19 pandemic lockdown, physical activity (PA) generally decreased while sedentary behavior (SB) increased, regardless of the subpopulation or research methods used. In both healthy adults and children, PA levels were lower during the lockdown compared to before, despite guidance from government agencies and health professionals on how to stay active during self-quarantine. When examining pre-lockdown PA levels, three studies showed that individuals who were more active before the lockdown experienced greater reductions in PA. PA is known to be associated with various mental health conditions, so the decrease in PA likely contributed to an increase in negative mental health outcomes, such as higher levels of anxiety and depression. Given that reduced PA can lead to negative emotions, increased anxiety, and lower energy, promoting PA during lockdowns should target not only sedentary individuals but also those who were highly active prior to the lockdown. With the possibility of future COVID-19-related restrictions or similar pandemics, promoting digital PA, such as through apps, online fitness classes, or virtual training, is recommended. Digital PA initiatives showed positive effects during the initial lockdown, with studies indicating favorable results and increased PA through these digital platforms (58–62).

The review (57) also found that participants with medical conditions experienced a reduction in physical activity (PA) levels, with the exception of those with eating disorders. This decline in PA is particularly worrying for several of the medical conditions studied, as PA is often used as a treatment or to alleviate symptoms. For instance, PA has been positively linked to improved quality of life in individuals with type 1 and type 2 diabetes. In contrast, increased sedentary behavior (SB) has been shown to have negative effects on patients with these conditions, except in those with eating disorders. Given the added risks associated with decreased PA and increased SB in these vulnerable populations, promoting PA and implementing strategies to reduce SB is essential in the event of further lockdowns. Additionally, healthcare providers working with these patients should be particularly cautious about the negative impact that reduced PA and increased SB could have during lockdowns and should prioritize monitoring PA levels. Interestingly, patients with eating disorders were found to increase their PA, particularly through exercise, during lockdowns. This is concerning, as there is often a pathological relationship between eating disorders and exercise, which can increase the risk of physical complications such as stress fractures. As such, healthcare providers working with patients with eating disorders should closely monitor these individuals during future lockdowns (63–66).

Elite athletes also experienced significant reductions in both training volume and intensity during the lockdown, resulting in a decrease in sport-specific physical performance after the lockdown. This decline in athletic preparedness for competition should be acknowledged and taken into account by practitioners working with elite athletes, particularly when it comes to managing training loads and scheduling competitions post-lockdown (67).

The Behavioral Change Wheel suggests that three components are needed for a behavior, such as physical activity (PA) or sedentary behavior (SB), to occur: capability (both psychological and physical), opportunity (both physical and social), and motivation (both reflective and automatic) (68). While information on safe exercise during lockdown was available from exercise professionals and some governments (psychological capability), the included studies did not clearly explain why people did or did not engage in PA. However, we can speculate on potential reasons for these outcomes. A decrease in PA was expected as lockdowns led to the closure of sports and leisure facilities, suspension of group activities, and outdoor time restrictions in many countries (69). This likely disrupted people's regular PA routines, as reflected in evidence showing that individuals significantly altered their modes of PA during lockdown (70). For instance, one study found a decrease in all types of PA, except for moderate-intensity leisure-time activities like housework and gardening, which increased. Other studies also reported an increase in yard work and housework. However, despite these mode-specific increases, total PA levels still declined. This suggests that promoting house-related PA may not be enough to boost overall PA during lockdowns (71–73).

During the lockdown, there was a significant rise in the number of people working from home, which resulted in a sharp decline in physical activity (PA) typically gained through commuting (74) . A prior study of UK adults (average age 50.5 years) revealed that they accumulated about 195 minutes per week of active travel (75). Those who commuted actively reported higher overall PA levels compared to those who did not, even though there were no notable differences in recreational activity. Additionally, with schools closed, many parents had to juggle working from home while managing home-schooling responsibilities. In the UK, this situation affected 85% of employees with school-aged children. This reduction in opportunities for physical activity, combined with increased household responsibilities, likely contributed to a decline in overall PA (76,77).

Most of the studies in this review found an increase in sedentary behavior (SB) during the lockdown, which is expected given that many people transitioned to working from home, resulting in longer periods of inactivity and more screen time (78,79). For example, de Haas et al. (80) reported that 44% of Dutch workers either began working from home or increased their working hours, with 30% noting more remote meetings, such as via videoconferencing. Furthermore, with gyms, leisure centers, and sporting facilities closed, and limited or no outdoor activities allowed, staying active during the lockdown became challenging for many. With more free time, people often turned to sedentary activities like reading, playing video games, or watching television (81,82).

As most studies indicated a decline in physical activity (PA) alongside an increase in sedentary behavior (SB) during the lockdown, and considering the impact these changes have on both physical and mental health, it is recommended that interventions or policies be put in place to promote PA (such as home workouts, online exercise classes, or outdoor activities like walking, running, and cycling) and reduce SB (for instance, by using standing desks and taking regular breaks from sitting) in the event of future lockdowns. Additionally, post-lockdown interventions should take into account that individuals may experience deconditioning as a result of the lockdown period (57).

Conclusion

This chapter explores the complex relationships between physical activity, cardiovascular health, and the COVID-19 pandemic. It highlights the critical importance of regular physical activity for overall health, especially cardiovascular well-being, and examines how the pandemic has affected activity levels across various global populations. The chapter begins by discussing the essential role of the cardiovascular system in maintaining health, its vulnerability to COVID-19 infection, and the negative effects of reduced physical activity. It provides a thorough overview of the benefits associated with regular physical activity, not just for cardiovascular health but also for mental well-being, immune function, and overall quality of life.

Next, the chapter delves into the direct and indirect effects of COVID-19 on the cardiovascular system, including acute complications observed in COVID-19 patients, such as myocardial injury, arrhythmias, and thromboembolic events. It also explores potential long-term cardiovascular issues arising from COVID-19 infection, stressing the need for continued research and monitoring in this area.

A significant portion of the chapter addresses the marked decrease in physical activity levels observed during pandemic-related lockdowns and restrictions. It presents data from studies conducted in various countries and demographics, illustrating the global scale of this phenomenon. The chapter further examines the short-term and long-term health consequences of this sudden and sustained reduction in physical activity, particularly focusing on cardiovascular health.

The chapter also discusses the unique challenges different populations faced in maintaining physical activity during the pandemic, including elderly individuals, children and adolescents, people with pre-existing health conditions, and those living in urban areas with limited access to outdoor spaces. It emphasizes the disparities in access to resources for physical activity, which have been exacerbated by the pandemic.

In response to these challenges, the chapter highlights innovative strategies to promote physical activity during restricted movement periods, such as the rise of virtual fitness classes, home-based exercise programs, and the increased use of wearable technology and fitness applications. It assesses the effectiveness of these approaches and their potential for long-term adoption beyond the pandemic.

The chapter also examines policy-level interventions to support physical activity during times of restricted movement. It discusses various strategies implemented by governments and public health organizations worldwide, such as designating exercise as an essential activity, adapting urban spaces to accommodate social distancing during outdoor activities, and incorporating physical activity promotion into broader public health messaging.

In conclusion, the chapter stresses the significant impact of the COVID-19 pandemic on global physical activity levels and its potential long-term consequences, particularly for cardiovascular health. It calls for comprehensive strategies to promote and maintain physical activity during and beyond times of restricted movement. The chapter underscores the importance of adaptability and innovation in ensuring continued engagement in physical activity, such as utilizing digital platforms to reach diverse populations.

The research emphasizes the intricate connections between physical activity, cardiovascular health, and the broader public health impacts of the pandemic. It argues for prioritizing physical activity in public health strategies, both during the pandemic and in the future, to strengthen communities and healthcare systems. The chapter concludes by advocating for continued research, policy development, and community engagement to ensure that physical activity remains central to public health initiatives. It calls for interdisciplinary collaboration among healthcare professionals, policymakers, urban planners, and community leaders to create environments and systems that support and encourage regular physical activity for all individuals, regardless of age, socioeconomic status, or location. Additionally, the chapter advocates for integrating physical activity promotion into broader pandemic preparedness and response strategies, suggesting that lessons learned from COVID-19 should inform future public health approaches, ensuring physical activity is recognized as a key component of population health and resilience.

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Chapter 6

Rehabilitation for patients after lung transplantation with gastroesophageal reflux. Using the methodology of dynamic neuromuscular stabilization

Gastroesophageal reflux (GER) is when stomach contents flow back into the esophagus (1). This occurs due to impaired esophageal sphincter function, which prevents the return of stomach contents into the esophagus. Gastro-esophageal reflux is common in the general population (2-4). It can manifest heartburn, difficulty swallowing, a feeling of a lump in the throat, chest pain, or a sour taste in the mouth (5-6). In patients after lung transplantation, gastroesophageal reflux increases the risk of pulmonary complications and may be associated with a decline in the function of the transplanted lungs (7-8).

In some patients, reflux may develop only after lung transplantation, even if they did not have the condition prior to the surgery. Some medications can suppress reflux symptoms but do not eliminate the backflow of stomach contents, and the underlying problem persists. As a result, patients may not experience heartburn or other symptoms, but the risk to their lungs remains.

The goal of rehabilitation is to improve the function of the esophageal sphincter through specific exercises (9-13), thereby preventing the return of stomach contents into the esophagus. When performed regularly, the following exercises can help reduce the negative impacts of gastroesophageal reflux on lung function. It is advisable to perform the exercises daily according to the following description or as instructed by a physical therapist.

Figure 1 Lungs

Manual release of the chest and scar

Before exercising, it is advisable to manually release the area of the chest, particularly the lower part and the surrounding scar.

Lie on your back, bend your legs, and support your head to avoid hyperextension. Place your hands at the lower edge of the chest, trying to insert your fingertips under the ribs. Gradually move your hands to the sides, and attempt to “massage” the space beneath the ribs with your fingers.

Perform the massage slowly. Apply gentle pressure to areas with greater resistance, holding it until the tense tissue relaxes. The pressure should not be painful. With a sufficiently long application of pressure (approximately 20-60 seconds), you should feel the resistance gradually release beneath your fingers. For more effective release of tense areas, you can warm them up beforehand, for example, by using heating pads placed on the lower rib area.

Work on the scar according to the instructions from the brochure “Scar Care” that you received after your surgery or as directed by your physical therapist. After the stitches are removed, the primary care for the scar includes gentle S-shaped stretching (in the shape of an S and C). Six weeks after surgery, you can also add longitudinal stretching of the scar. It is also advisable to regularly moisturize the scar with any fatty cream.

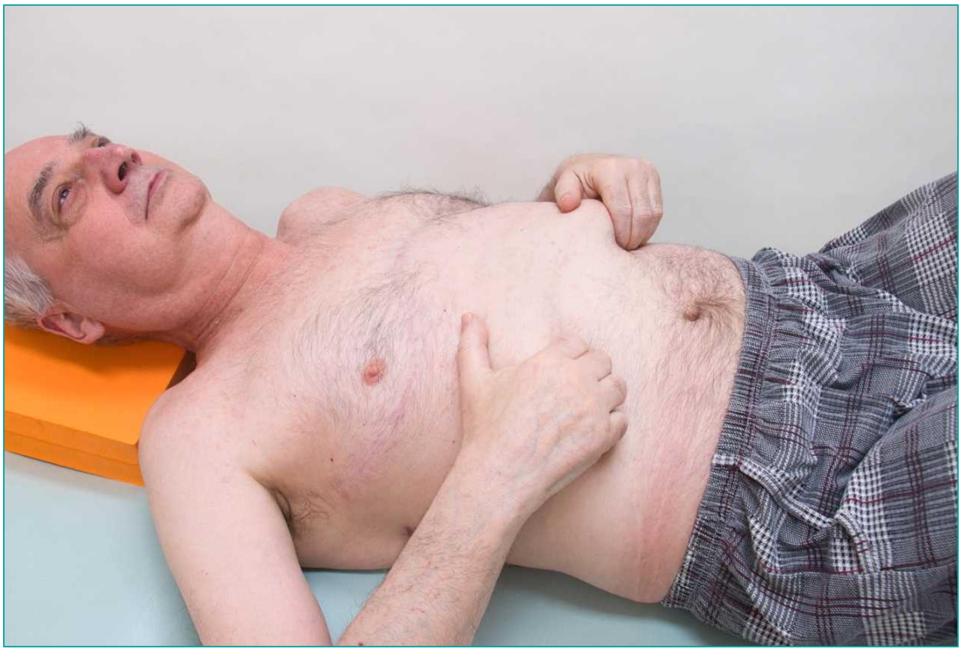

Figure 2 Manual release of the chest and scar

Deepening and calming the breath

This exercise is designed to calm and slow down the breath, positively affecting the function of respiratory muscles. Lie on your back with your legs bent. Place your arms out to the sides. In this position, inhale slowly through your nose and exhale through open lips, ensuring that neither the inhale nor the exhale is audible. Focus on both the inhalation and exhalation phases. Breathe in this slow and smooth manner for at least one minute.

Figure 3 Deepening and calming the breath

Exercise with lower limbs above the mat

Lie on your back near a wall. Place a cushion under your head to keep it from tilting backward. Extend your arms to the sides, with palms facing up and fingers straight; try to press your fingernails lightly into the mat. Position your feet flat against the wall so your hips and knees are bent to approximately a 90-degree angle. Then, gently press your feet against the wall while keeping your fingers extended and fingernails in

contact with the mat. Maintain the pressure against the wall for 5–10 seconds, then release. Remember to breathe freely throughout the exercise; do not hold your breath. You may also try lifting your feet slightly away from the wall for a moment, holding this position for 5–10 seconds while breathing freely. Keep your back from arching, with your lower back firmly pressed against the mat.

Figure 4 Exercise with lower limbs above the mat

Exercise lying on the side

Lie on your side with your legs slightly bent. Place a pillow or an exercise ball (small ball) between your knees. Position the lower elbow bent in front of your body while the upper elbow points toward the ceiling, with the hand resting on the side of your head.

Figure 5 Exercise lying on the side

Gently press the lower elbow and knee into the mat simultaneously. At the same time, try to reach upward with the upper elbow toward the ceiling, as if you're lifting the shoulder blade away from the spine. Keep your hand resting on your head without lifting it. Maintain light pressure from the lower elbow and knee into the mat while reaching with the upper elbow toward the ceiling. Hold this position for about 2 minutes. Breathe deeply during the exercise, and remember not to hold your breath.

Another option is to perform the exercise with your legs resting on a chair. In this case, try to lift your legs slightly, raising them just above the chair. Keep your arms extended to the sides, palms facing up, and fingers extended, keeping contact with the mat. Hold this position for 5–10 seconds, then rest your legs back on the chair. During the exercise, avoid arching your lower back and remember to breathe freely without holding your breath. Repeat the exercise several times.

Figure 6 Another variant of exercise

Trunk stretch in sitting position

Sit on a chair with a backrest. Sit straight and try to lengthen your spine by reaching upward with your head. Place both hands behind your head and bring your elbows together. Lean back slightly over the chair's backrest and gently, rhythmically, rock backward for about 1 minute. Keep your elbows together throughout and continue reaching upward.

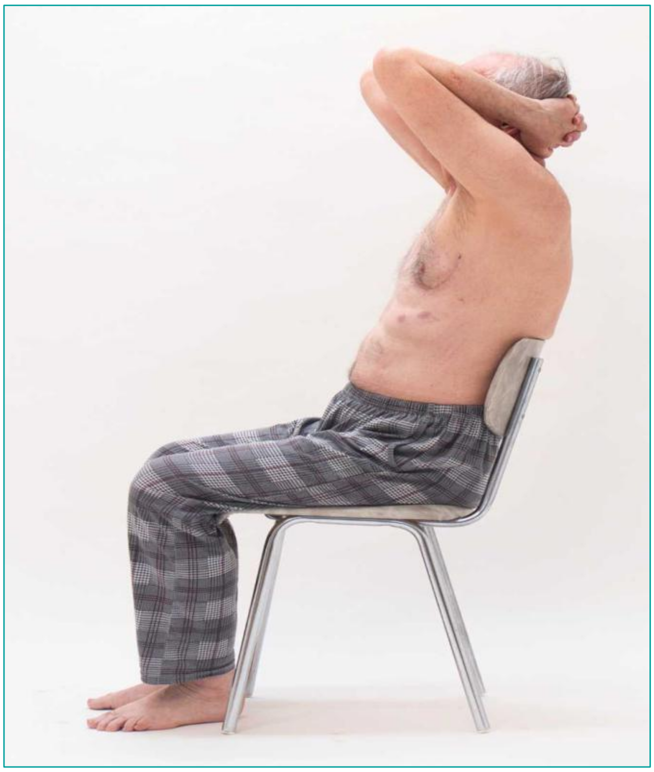

Figure 7 Trunk Stretch in Sitting Position

Exercise with the coach 2 breathing trainer

Incorporate exercises with the coach 2 inspiratory trainer. Sit on a chair without a backrest, or turn the chair around so you can rest your entire back against a wall. Ensure your head is also supported; if resting against the wall tilts your head back, use a cushion to keep it aligned. Keep your head upright and in contact with the wall, and ensure your entire back remains in contact with it. During inhalation, avoid lifting your shoulders.

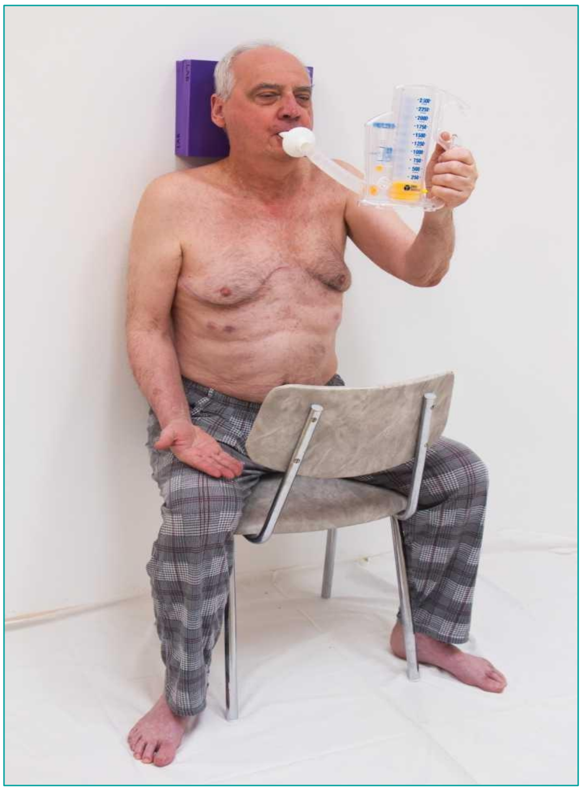

Figure 8 Exercise with the coach 2 breathing trainer

Continue using the Coach 2 trainer following the instructions provided by your physiotherapist, who will recommend the appropriate number of repetitions and depth of inhalation (volume of air). The core of the exercise is a smooth inhalation, during which the small yellow marker on the right should reach the level of the smiling face icon and stay there throughout the entire inhalation. You may also use the trainer in other positions, such as lying on your side or standing with support against a wall.

Figure 9 Exercise with the coach 2 breathing trainer

Seated exercise with support on the table

Sit on a chair at a table, sitting up straight. Place your palms on the table and apply light pressure downwards. Be careful not to lift your shoulders as you do this. While maintaining the pressure of your palms on the table, lift both legs slightly so your feet do not touch the floor. Keep your posture upright without arching your back. Try to hold this position for about 5–10 seconds, and remember to breathe continuously without holding your breath. Then, gently place your feet back on the floor. Repeat the exercise several times.

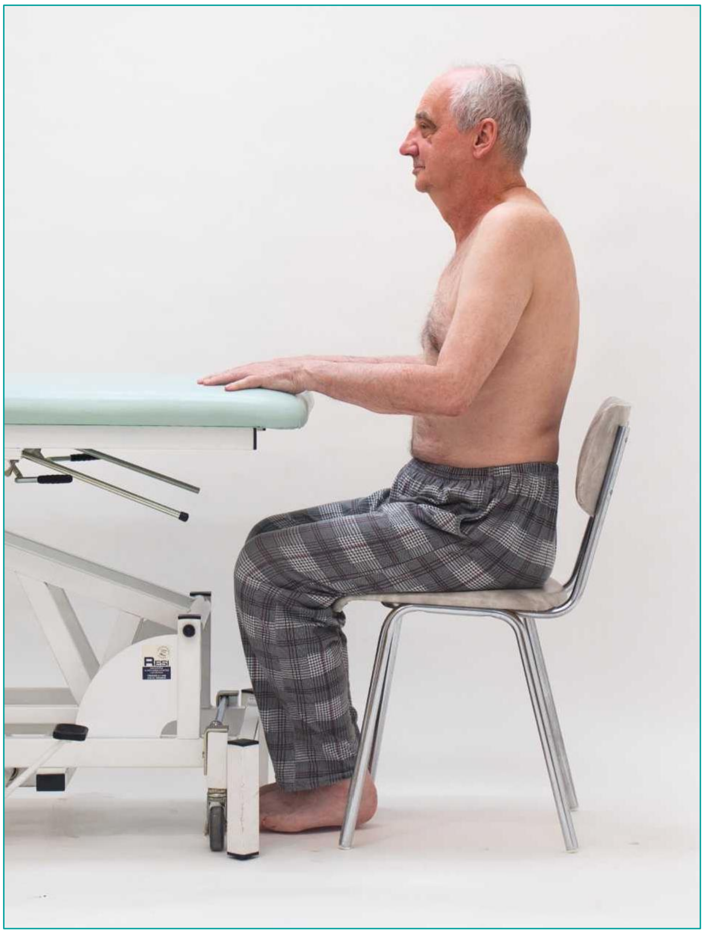

Figure 10 Seated exercise with support on the table

Standing exercise with weights

Take a light dumbbell or another weight, such as a water bottle (0.5 kg is sufficient to start), in each hand. Stand with your back against a wall, slightly bend your knees, press your entire torso and head against the wall. If resting your head against the wall causes it to tilt backward, use a cushion to support it (similar to when lying on your back). Extend both arms forward, holding them in front of you. Hold this position for about 1 minute while slowly straightening your knees. Keep your back and head in contact with the wall at all times. Maintain an upright posture – avoid arching your lower back, hunching forward, or tilting your head back. Breathe deeply and avoid holding your breath during the exercise.

Figure 11 Standing exercise with weights

Manual release of the abdominal area

It is beneficial to relax the abdominal area using specific circular movements. Place your hand on your abdomen and press with the flat of your palm. Maintain a broad, gentle, and painless pressure, and move your hand in a circular motion in the indicated direction, completing two “circles” (refer to the image for guidance).

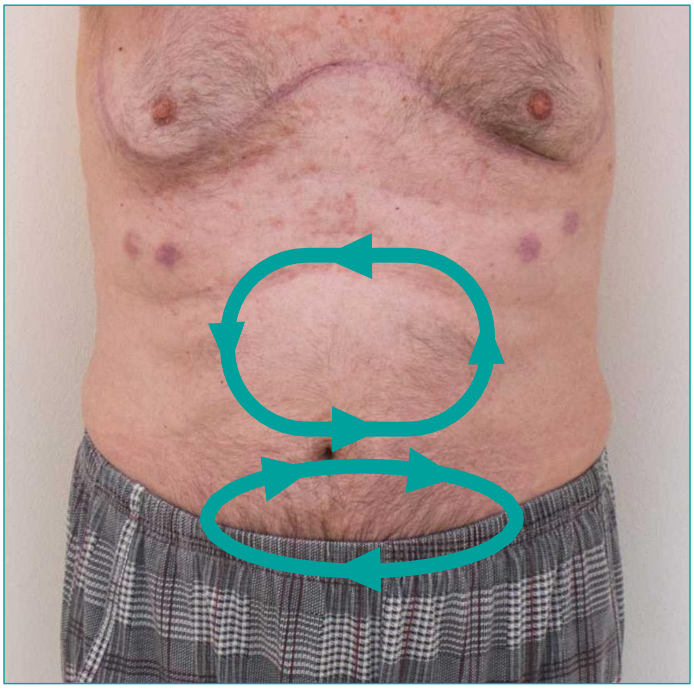

Figure 12 Manual release of the abdominal area

Begin the first “circle” in the upper part of the abdomen, starting on the left just below the ribs, and move counterclockwise. Glide your hand under the ribs and return to the left side slightly below the navel.

For the second “circle”, move clockwise. Start in the lower right abdomen below the navel area and move upward above the navel, gradually circling to the left side. Repeat each “circle” slowly at least 10 times. Maintain consistent downward pressure with the palm into the abdominal cavity, ensuring the pressure is firm but not painful.

Figure 13 Exercise with the acapella exhalation trainer

Finish your session with the Acapella exhalation trainer. The basic position is seated against a wall with your head also supported (and cushioned if needed), similar to the position for the Coach 2 inspiratory trainer. Maintain this position throughout both inhalation and exhalation. You can also practice with Acapella in other positions, such as lying on your side or standing with support against a wall. Follow the instructions provided by your physiotherapist, who will tailor the exercise parameters (repetitions, duration, and strength of exhalation) to suit your needs. The key to this exercise is a longer, smooth exhalation, during which you should hear the Acapella device "vibrate."

Figure 14 Exercise with the acapella exhalation trainer

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Chapter 7

Recommended preparation for selected physical activities. Using the methodology of dynamic neuromuscular stabilization

Introduction

Lack of physical activity, or being sedentary, significantly increased during the COVID-19 pandemic, and a portion of the population has yet to return to sufficient levels of physical activity since then (1–3). This trend contributes to the global rise in health risks, making it essential to emphasize the importance of ensuring adequate physical activity in the general population across all age groups (4).

Movement is life

It is time to change sedentary lifestyles. Physical activity helps maintain optimal body weight, improves cardiovascular fitness, and reduces the risk of lifestyle-related diseases. It also has a positive impact on mental health (5–7).

But how do we approach it correctly?

Figure 1 Exercise as life

Recommendations are frequently given to move regularly and incorporate adequate physical activity into daily life. However, simply deciding to start exercising is not enough. Moving mindfully and preparing your body for the upcoming physical demands is crucial. Sudden transitions from inactivity to intensive exercise without sufficient preparation increase the risk of injury. Focusing on the quality of movement is essential to avoid pain and overloading joints or muscles.

What does quality movement look like?

Optimal movement begins with proper preparation, more specifically, the correct functioning of the postural system, which is responsible for maintaining a stable body position during any activity.

What is postural system and postural training?

It is the way we stand, sit, or move. Postural function has a crucial impact on joint load and muscle function and, thus, on the risk of injury (8,9). If the trunk stabilizing system is dysfunctional (for example, due to weakened or overloaded muscles), it can lead to excessive strain on certain joints, ligaments, and muscles, resulting in pain and degenerative changes (10). Every athlete, whether professional or amateur, should remember that trunk stabilization is the foundation of functional limb movement. For example, in running, it is essential that the legs and arms not only perform the movement correctly but that the trunk remains stable, enabling efficient and economical athletic performance. At the same time, good stability protects joints against excessive impacts and shocks. In the case of an unstable trunk, pressure on the lower limb joints increases, which can lead to the overload of the knees, hips, or ankles.

Postural training

Postural training focuses on improving movement patterns and preventing hypokinesis, i.e., a lack of active movement. The current trend of a sedentary lifestyle is a common cause of chronic pain (11), which can then cause difficulties even in performing daily activities, such as limiting household tasks. The objective of postural training is to restore body stability and strengthen key parts of the body, such as the pelvis, torso, and neck, which work together in every movement. During training, the focus is on the ideal postural stabilization technique, gradually shifting from static to dynamic stability. Training principles include, among others, avoiding exercises to the point of extreme fatigue and controlling breathing. Through postural training, we aim to build automatic movement patterns that can be used in everyday activities and sports. Postural training is not just about strengthening the body but also about the experience of movement and its return to natural form, which improves physical endurance and the range of movements we can perform. Ultimately, quality postural training enhances both the quality of life and athletic performance.

Essential parameters of movement: quality, frequency, intensity, and additional recommendations

To exercise effectively, we must be able to "read our body," meaning we need to perceive movement and be able to correct mistakes during physical activity. At the same time, it is essential to maintain regularity and an appropriate level of physical activity. According to experts, adults should engage in at least 150 minutes of moderate-intensity physical activity per week, such as 30 minutes five times a week. Cardiovascular training, often referred to as "cardio," is a form of exercise aimed at improving endurance and strengthening the cardiovascular system, including the heart, blood vessels, and lungs (12). Cardio training increases heart rate and promotes better blood circulation, contributing to more effective oxygen delivery to muscles. Cardiovascular training improves physical fitness, helps burn fat, and positively impacts overall health. Typical forms of cardio training include running, cycling, swimming, brisk walking, rowing, or aerobic exercises. Cardio training should be combined with strength training. Strength training is a form of exercise aimed at developing muscle strength, size, and endurance through resistance, which can be body weight, various weights (dumbbells, kettlebells), resistance machines, or elastic bands (13). Strength training aims to gradually increase resistance or load, stimulating muscle fiber growth and strengthening skeletal muscles. Strength training brings many benefits, such as increased muscle mass, accelerated metabolism, improved bone density (which helps prevent osteoporosis), and better stability and coordination. Training may include various exercises such as squats, deadlifts, bench presses, or pull-ups and can be adapted to the individual needs and abilities of the exerciser. For all types of exercise, movement quality is crucial. Exercising less often but correctly is better than overloading the body with uncontrolled, intense activity. Attention should be given to exercise technique, proper breathing, and engaging stabilizing muscles. These principles should always be part of the training plan. Before any physical activity, preparing the body with dynamic warm-ups that activate muscles and joints is advisable. Don’t forget to stretch at the end of the physical activity, which helps with recovery. Regular exercise, following the principles of quality postural stabilization, can improve athletic performance and extend the time we can engage in sports without an increased risk of injury. The following text outlines the principles of proper preparation for the most common physical activities of the general population.

Running and walking

One of the first options to improve fitness and muscle mass can be brisk walking and various forms of running, depending on the individual's performance level. Those familiar with running in their youth and now, in middle or older, want to start with physical activity again. It will be easier to begin with this activity since the body “remembers” running. We recommend suitable footwear, such as running shoes. Modern Barefoot shoes are recommended only for more experienced athletes or after consulting a specialist. Especially after a long period without exercise, it is important to start gradually and allow a day of rest after training, at least for the first few weeks, so the body has time to adapt. You can vary the pace during the activity, alternating between fast and slow intervals. It’s also good to include walking and running on varied terrain. Run faster uphill within your capacity, and slow down and rest when running downhill. Even if the activity is very strenuous, breathe only through your nose. Since walking and running primarily stress the lower half of the body, it is essential to include gradual warm-ups and specific preparation for these activities. Perform exercises slowly, doing 5 repetitions with a 3–10 second hold in each position. Do not exercise through pain. You may feel a stretch or activation in the targeted muscle group and pressure in the body’s support segments. Here are some suitable exercises for preparation before everyday physical activities such as walking, running, cycling, and swimming. A green checkmark next to the image demonstrates correct execution, while a red cross indicates incorrect execution

Stretching and activation of the pelvic girdle muscles

Stretching and activating muscles around the hips and pelvis is vital for proper function during walking and running. Press your right knee into the ground during the exercise as if preparing to push forward. Keep your spine straight, with your head extending out from your shoulders, forming a straight line with your spine. You should feel activation and a stretch in the front thigh and gluteal muscles of the front leg (right in the image), as well as activation in the abdominal muscles. Achieve this by shifting your weight onto both hands and the loaded (right) knee, initiating movement as if preparing to push forward. You are not actually moving forward; you are lengthening your body in a forward direction. Hold this activated position for 5–10 seconds. Then relax and repeat the exercise 3–5 times. Next, switch sides and train activation by supporting yourself on the left knee. Be sure to support yourself with the entire palms and all fingers pointing forward, ensuring your elbows are not bent but not fully extended ("locked"). Breathe evenly into your whole trunk and abdomen. Imagine you have an elastic band stretched around your chest and abdomen. As you inhale, you feel it expand in all directions. As you exhale, hold it in place so it does not collapse.

Figure 2 Stretching and activation of the pelvic girdle muscles

Stretching the groin and calf

In this exercise, start from the same initial position and follow the same principles as the previous exercise. Try to straighten the knee of the back leg. The back leg should rest on the toes, with the knee pressing upward. You should feel a stretch around the groin and calf of the back leg. Ensure your back does not arch and the pelvis does not tilt forward.

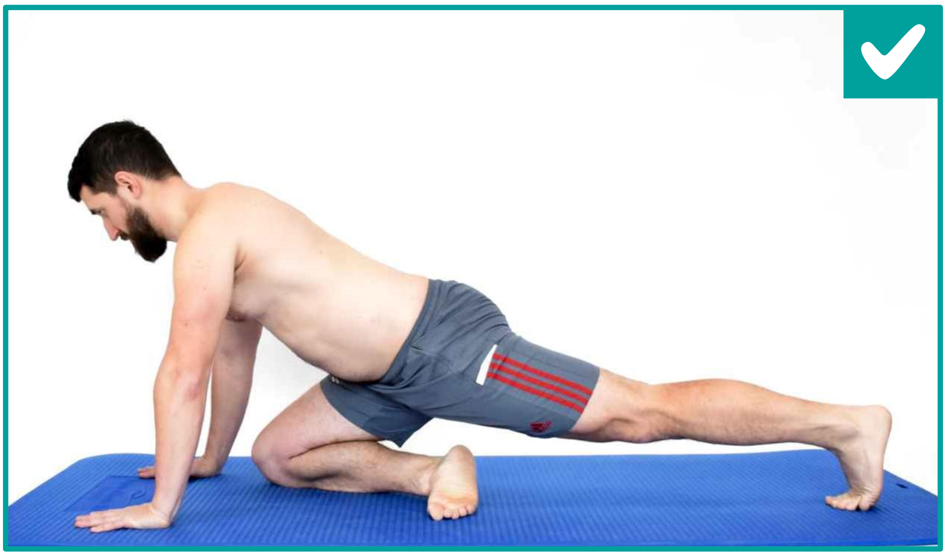

Figure 3 Stretching and activation of the pelvic girdle muscles

Stretching the back of the lower limbs

Lie on your back without excessive arching in the lower back. The spine should remain in contact with the surface. Direct your breath into your abdomen in all directions. Imagine a stretchable band wrapped around your lower chest and abdomen, expanding evenly in all directions as you inhale. The right hip should be bent at approximately a 90-degree angle. Visualize pressing the heel of the raised leg (in the illustration, the right leg) toward the ceiling. You should feel a stretch in the right calf and the back of the thigh. Maintain the 90-degree angle at the hip joint while pressing the leg upward. Avoid errors such as straightening the knee without maintaining the 90-degree angle at the hip, lifting your lower back off the surface, or tilting your head back. Hold the position for 5–10 seconds, then relax for 5–10 seconds. Repeat the exercise 3–5 times and switch legs.

Figure 4 Stretching the back of the lower limbs

Stretching and activation of hip joint internal and external rotators

The weight is primarily on the front leg. The sole of the front foot should be fully grounded. With a straight back, rotate the entire torso and rear leg around the hip of the front leg (in the illustration, the right hip) — the rear leg pivots on the toes. During forward pelvic rotation, you should feel a stretch in the gluteal muscles on the right side. During backward rotation, you should feel a stretch on the inner side of the right thigh. The torso remains upright without tilting to either side. Imagine the pelvis and torso rotating above the right hip as if on a pivot. Hold each end position, i.e., the phase of maximum forward and backward rotation, for at least 5 seconds, preferably 10. Repeat the forward and backward rotations 3–5 times, then switch legs.

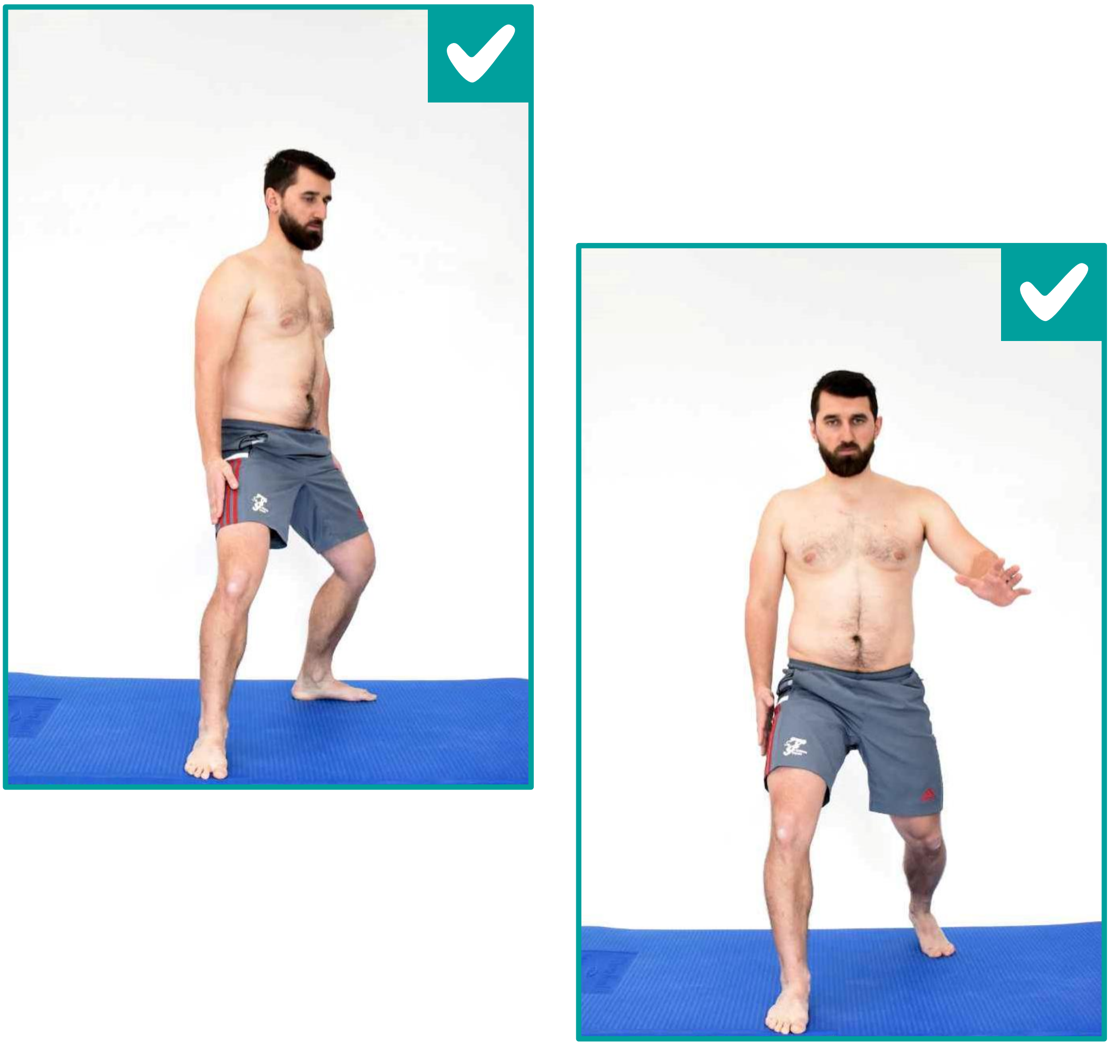

Figure 5 Stretching and activation of hip joint internal and external rotators

An error occurs if the lumbar spine arches excessively during rotation, the front knee moves side to side, or the sole of the front foot is not fully grounded.

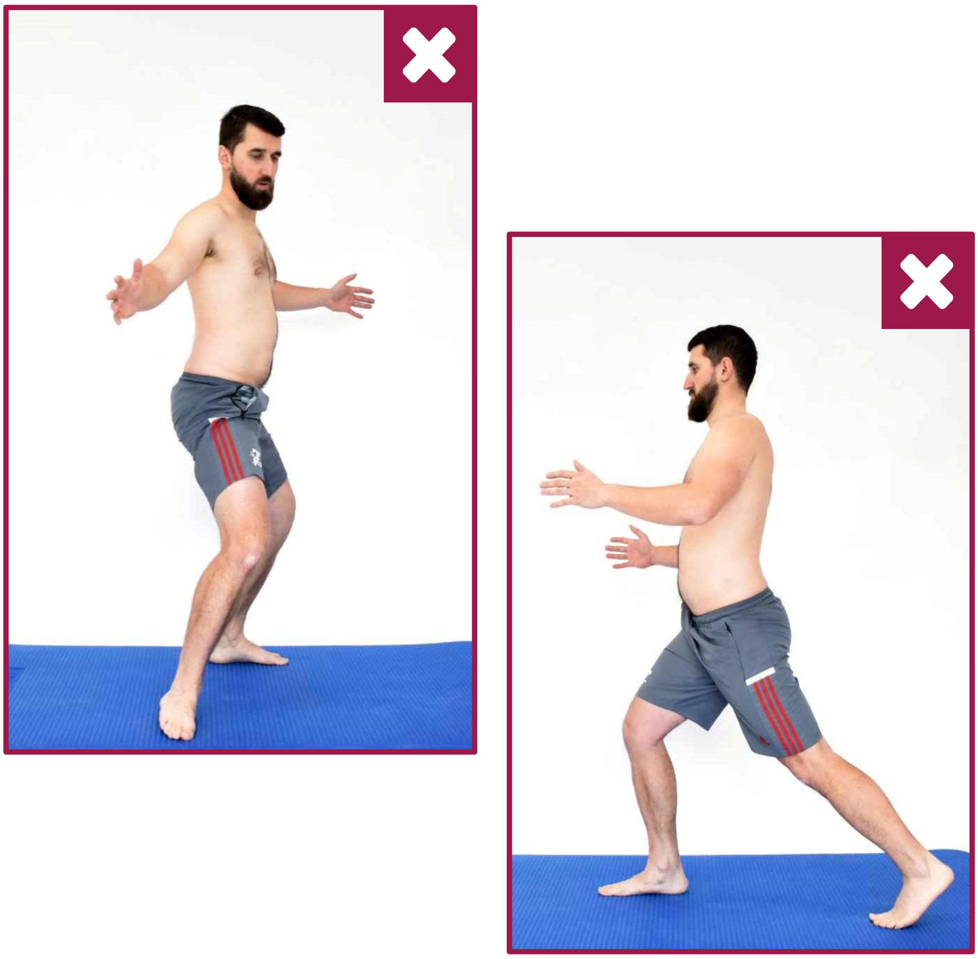

Figure 6 Errors of stretching and activation of hip joint internal and external rotators

Cycling

Cycling or using a stationary bike is another suitable activity (14). The movement is simple and controlled, without jolts or abrupt changes in direction. It is well tolerated even by individuals with degenerative changes, injuries, or postsurgical recovery who need to regain muscle strength. If you choose a suitable route without steep hills or an appropriate program on a stationary bike, cycling can also be suitable for individuals with various cardiovascular or respiratory conditions. During cycling, try to breathe through your nose with your mouth gently closed if the intensity allows. The sole of your foot should be positioned on the pedal so that the ball of the foot, not the toes, bears the weight. Adjust the saddle so the leg remains slightly bent at the knee (approximately 20 degrees) when the pedal is at the bottom and is flat. To avoid improper extension of the cervical spine and excessive hip flexion, commonly strained areas in cyclists, it is advisable to have the handlebars higher and closer to the saddle (a shorter and raised stem). While this is less aerodynamic, it allows the spine to stay upright, which prevents back and hip pain. The pedaling cadence should be at least 60 revolutions per minute (60–90).

Cycling is highly recommended, but since it is performed in a seated position—a posture much of the population spends most of their day in—it is essential to compensate for this position appropriately. Focus on stretching the hips, improving thoracic mobility, and loosening the shoulders. If you have any medical conditions or musculoskeletal issues, it is always advisable to consult a specialist. Before cycling (or using a stationary bike), gradual warm-ups and exercises targeting specific body areas are essential. Perform exercises slowly, in a controlled manner, without excessive force. Hold each exercise for 10 seconds and repeat 3–5 times. Never exercise through pain. During workouts, you may feel stretching, muscle activity, and loading of the body's support segments, but no pain.

Exercise on all fours: arching and stretching

In this exercise, arch your back as much as possible, then try to straighten your chest area downward and forward while stretching your arms out in front of you. You should feel pressure and stretching between the shoulder blades, stretching around the shoulders, and stretching of the chest muscles. Stretch your back into a "plank" position, feeling the spine straighten. Extend your head forward. The lumbar and cervical spine should not arch, and the head should not tilt back.

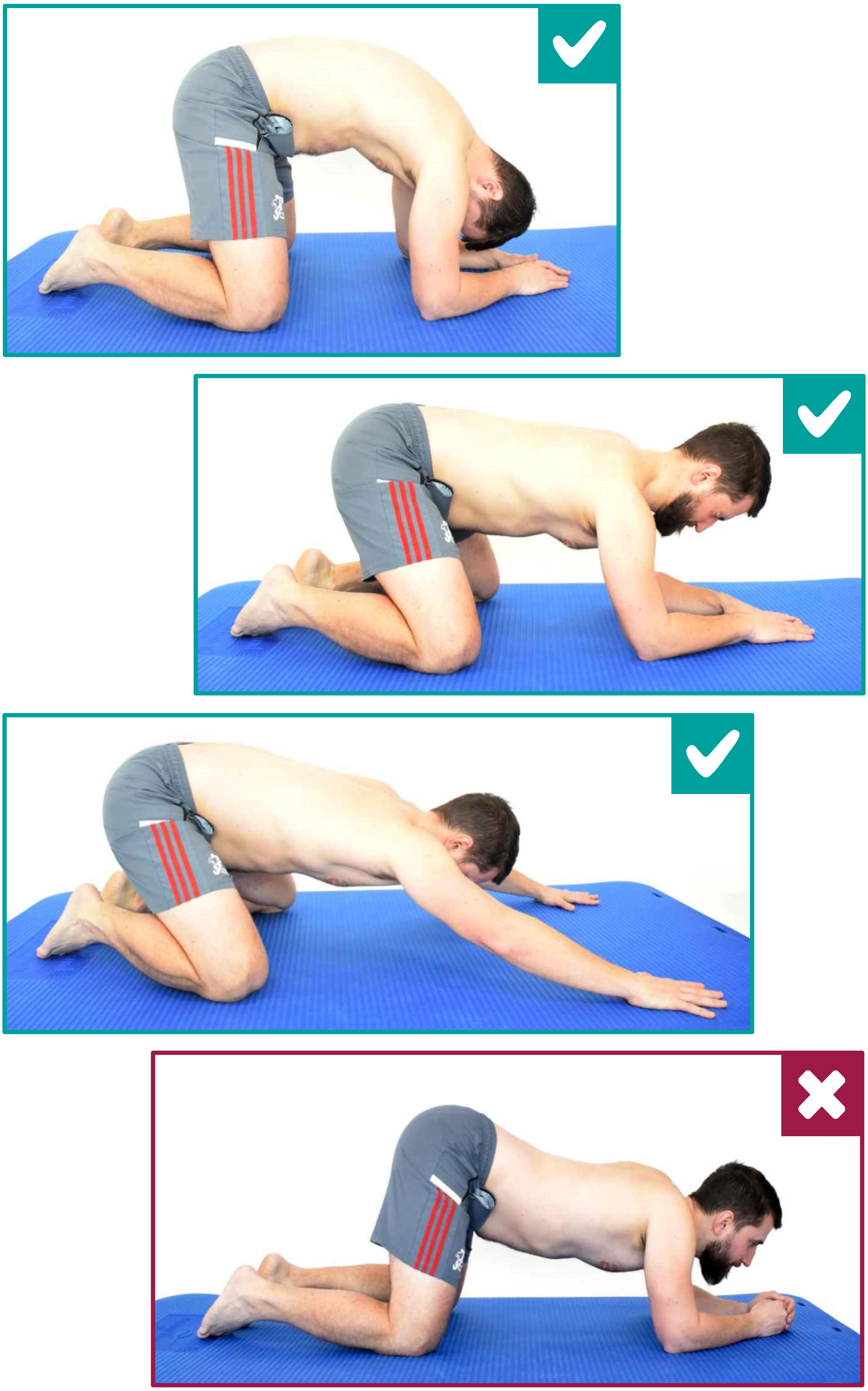

Figure 7 Exercise on all fours: arching and stretching

Exercise in all-four position: forward rocking

From the all-fours position, shift your pelvis and torso forward until your spine and thighs form a straight line. You should feel abdominal muscle activation and a stretch around the groin area. Support yourself on your entire palms and all fingers pointing forward, pressing your hands into the surface. Hold the final position for at least 5 seconds, preferably 10, and breathe deeply into your chest and abdomen as if expanding a stretchable band wrapped around your torso in all directions (360 degrees). Direct your breath into the "lower abdomen," above the groin, as well as backward and to the sides, into the area of the lower ribs. Avoid arching your lower back or tilting your head backward during the exercise.

Figure 8 Exercise on all fours

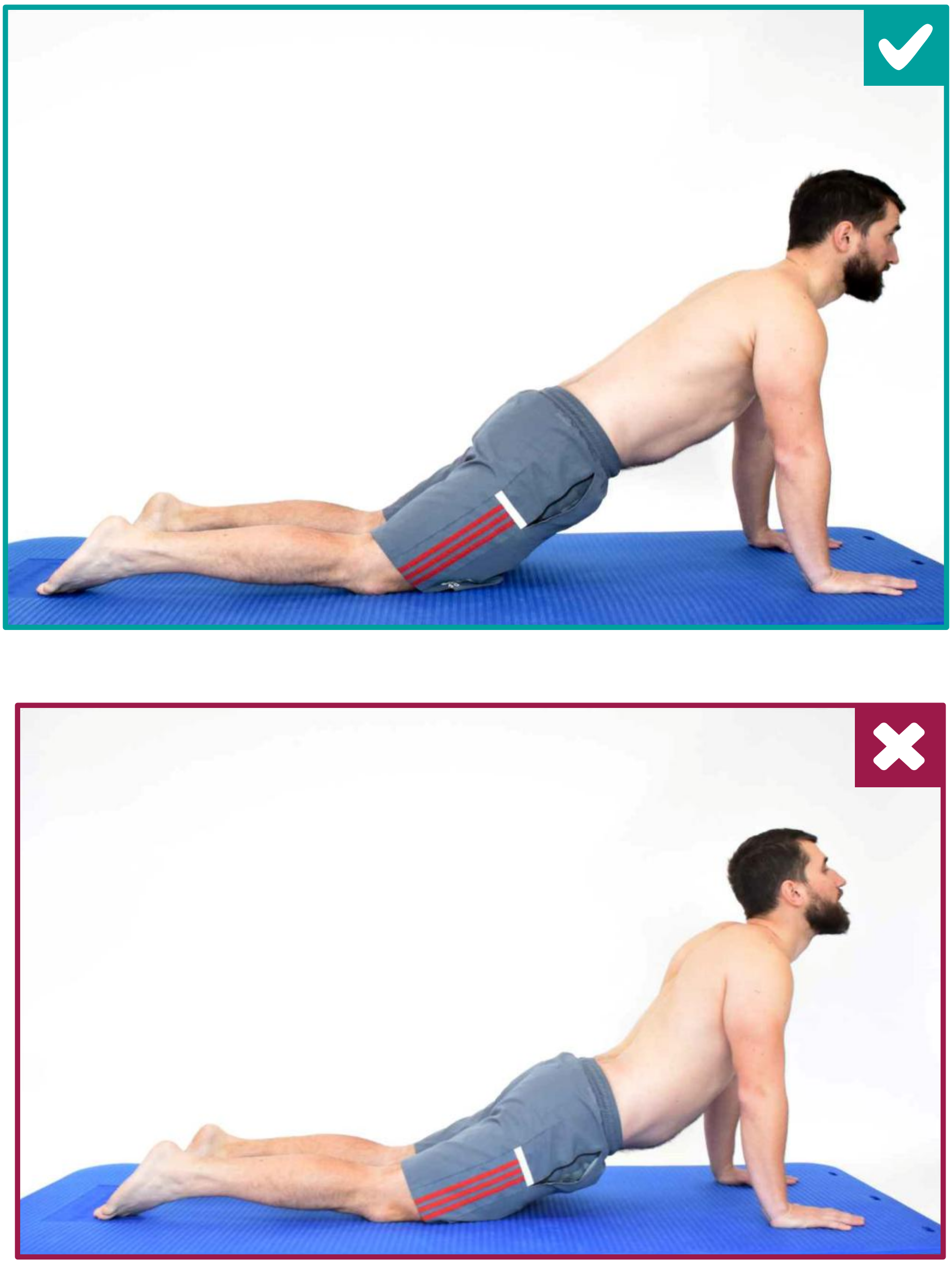

Figure 9 Exercise in all-four position: forward rocking

Oblique sitting

Support yourself on the outer side of your thigh and glute (in the illustration, the right lower limb) and on your hand (right hand), positioned in line with the supporting hip joint. During this exercise, try to rotate your torso forward as much as possible until you are also supported by your other hand. Lengthen your neck, pulling your head away from your shoulders. Keep your back straight in the initial position and throughout the entire phase of trunk rotation. Draw your shoulders down away from your ears. Actively press the front knee into the surface. You should feel pressure and stretch in the thoracic spine and the gluteal area of the supporting (right) leg. In the final position, with support on both hands, hold for 5–10 seconds, then slowly and in a controlled manner, return to the starting position. Repeat the exercise 3–5 times, then switch sides.

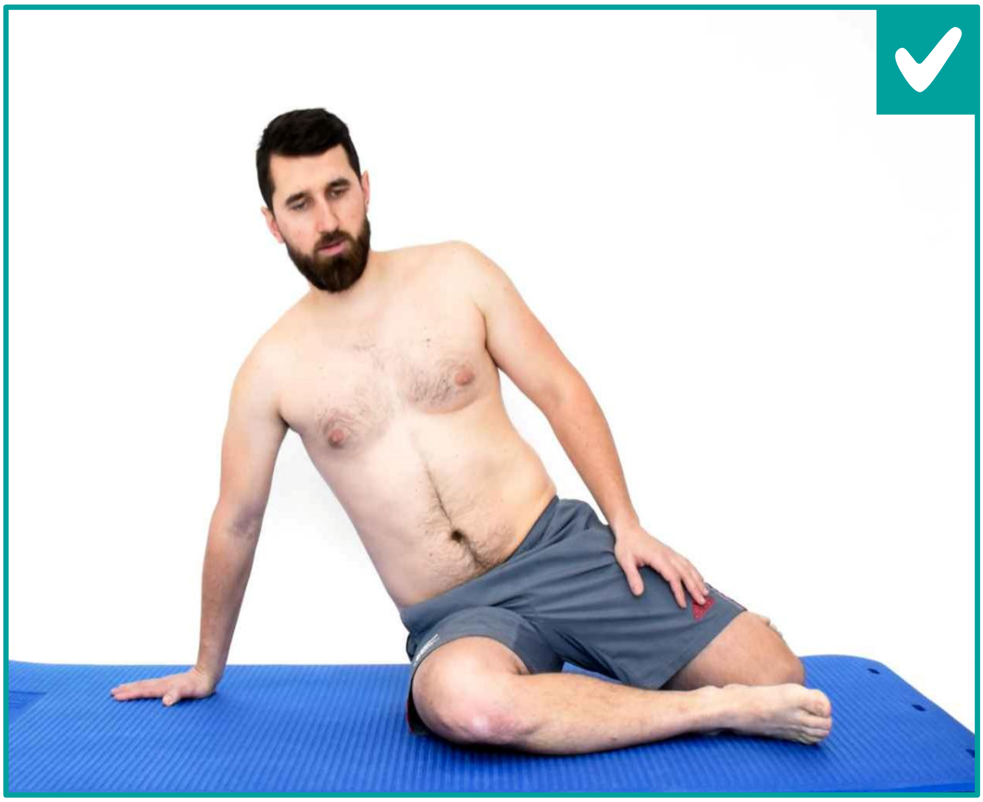

Figure 10 Oblique sitting

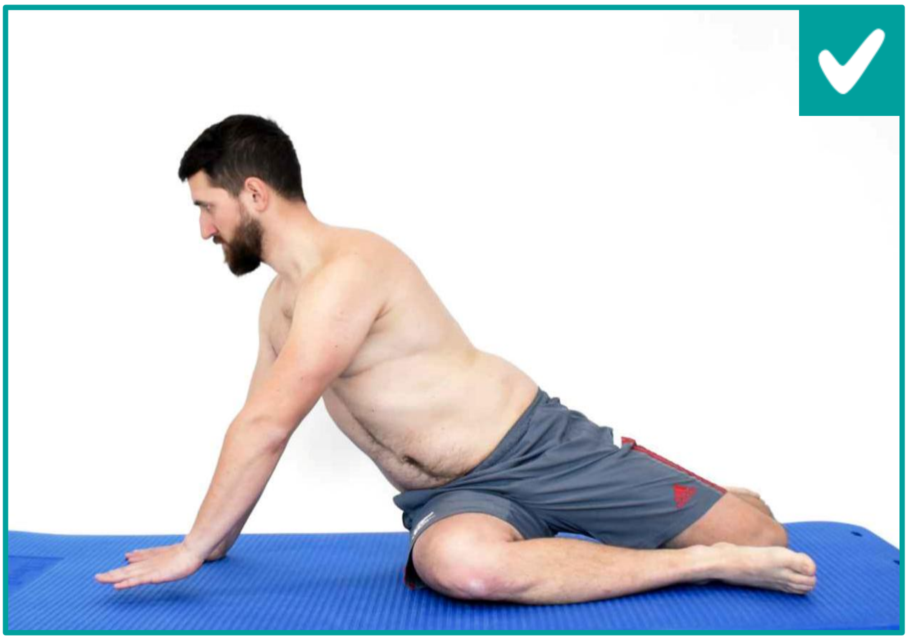

Figure 11 Errors of oblique sitting

Bear position

In the bear position, aim to straighten your thoracic spine and align the entire spine. Extend your head away from your shoulders and alternately extend each leg backward as far as possible toward the ceiling. Keep your back straight throughout the movement. You should feel pressure around the thoracic spine, a stretch in the groin of the extending leg, and activation of the abdomen, glutes, and upper limbs bilaterally. Support yourself with your entire palms and fingers pointing forward. Draw your shoulders down away from your ears. Breathe deeply into your chest and abdomen. While extending your leg, be mindful not to tilt your entire body to the side. Your back must remain straight, "like a plank," throughout the exercise.

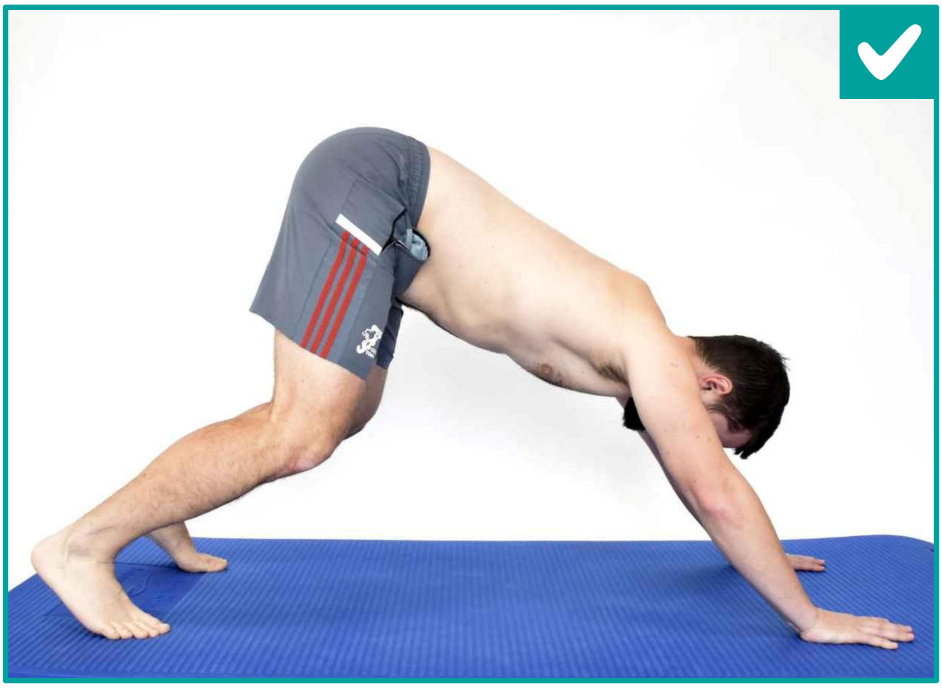

Figure 12 Bear exercise

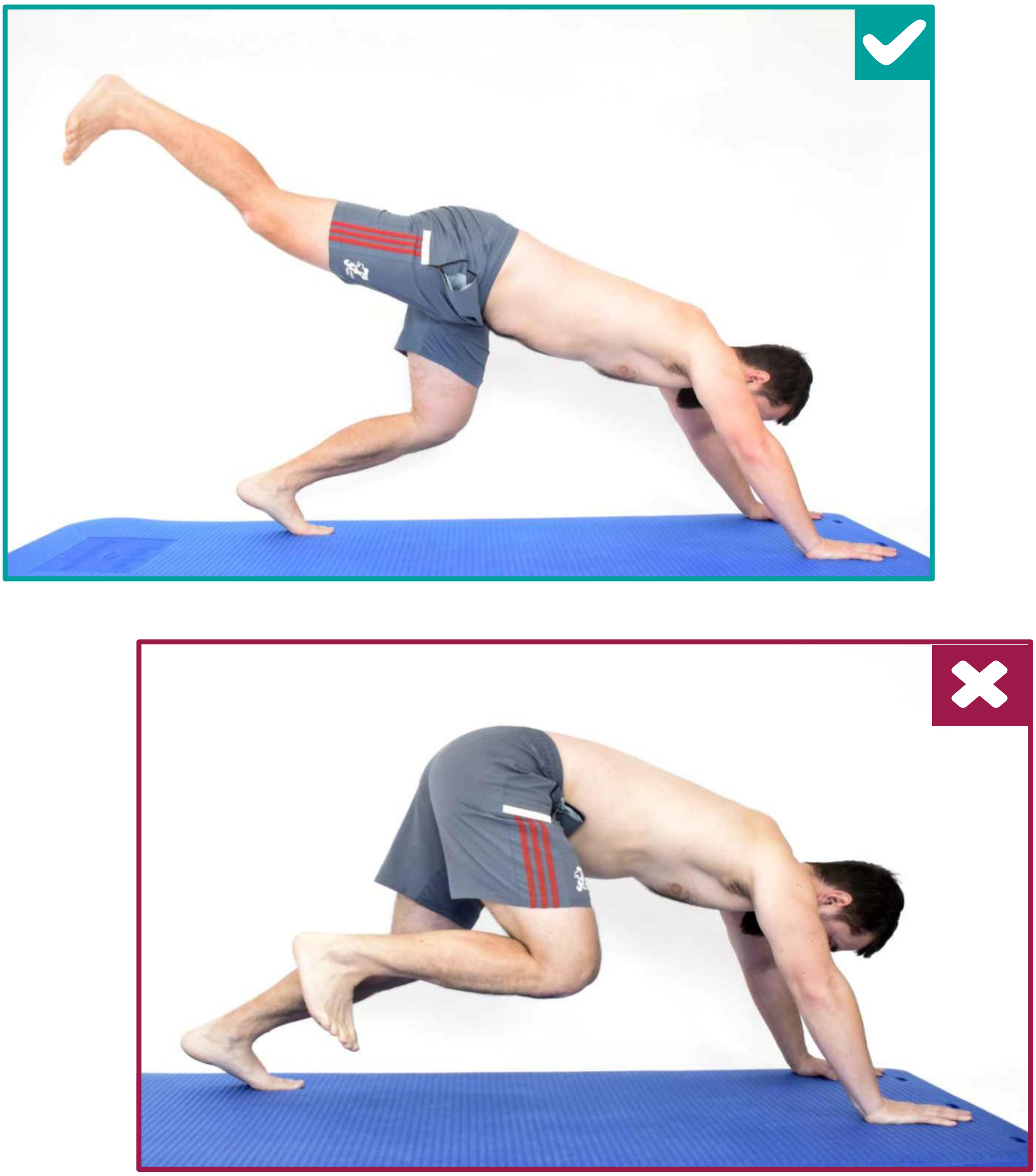

Figure 13 Errors of bear exercise

Hang

The hang is a suitable compensatory activity. It stretches the entire spine and provides decompression. A supported hang using the lower limbs is easier. Grab a sturdy bar with your hands and hang downward into a deep squat. The soles of your feet should be fully grounded. Draw your shoulders downward and keep your shoulder blades wide and flat against your ribcage (not protruding). Extend your head away from your shoulders as if preparing to do a pull-up. Breathe proportionally into your lower ribcage and abdomen (360 degrees).

If you have sufficient strength and mobility in your shoulder joints, you can perform a hang without leg support while adhering to the same principles.

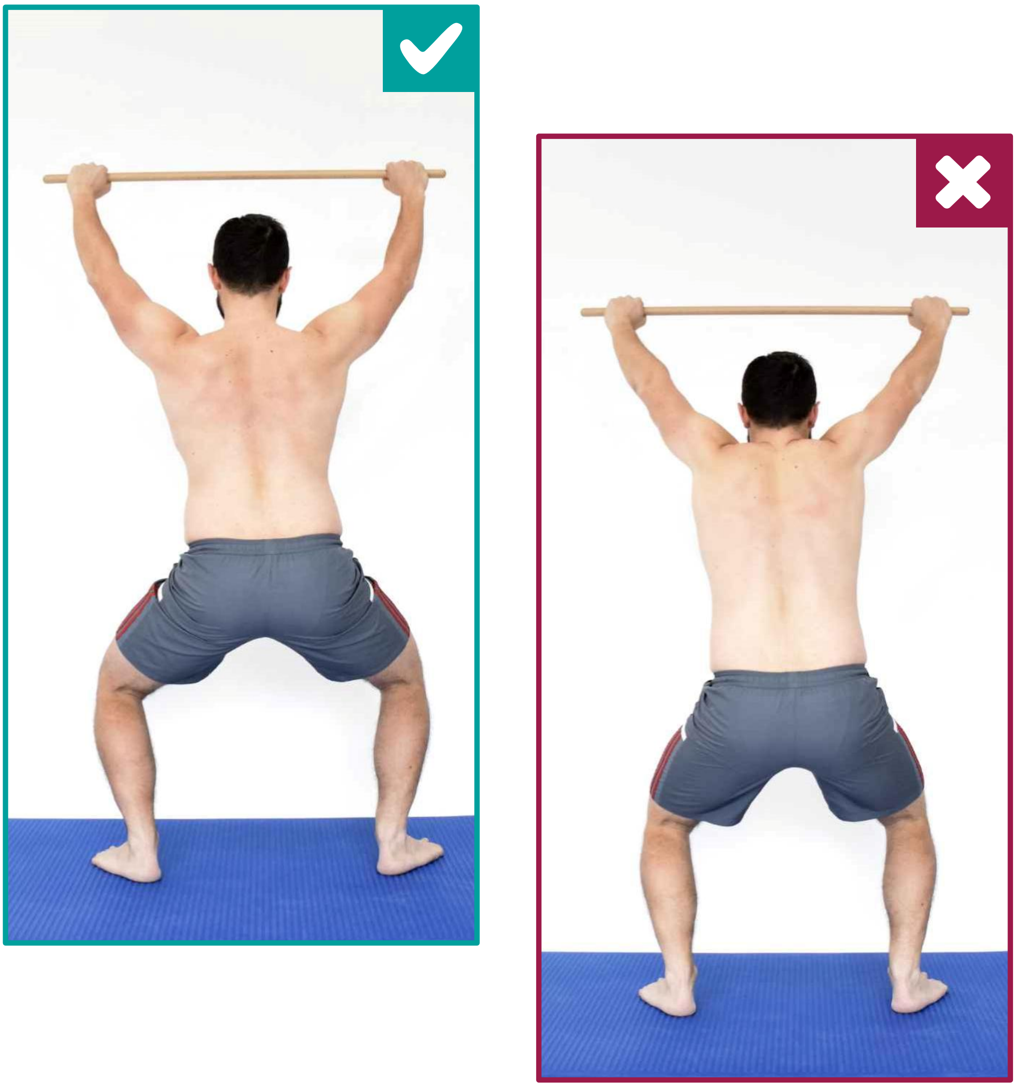

Figure 14 Proper technique

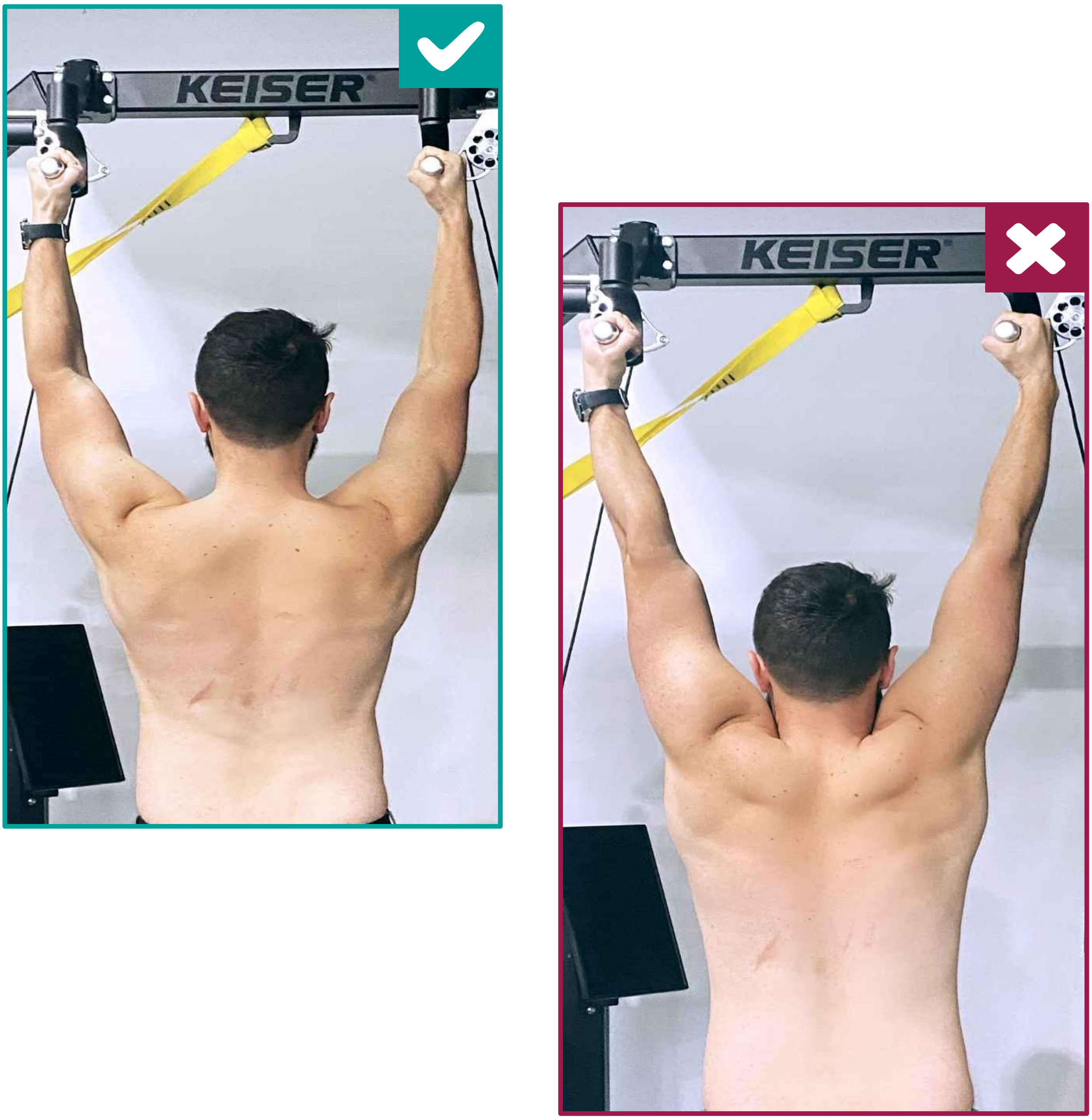

Figure 15 Hang exercises

Cycling posture

While cycling, extend your head away from your shoulders to align it with your spine. Avoid tilting your head backward. Pressing into the handlebars, draw your shoulders away from your ears, and keep your back straight or slightly and smoothly curved. During the ride, the pelvis and torso should not sway excessively from side to side. Keep your shoulders and neck relaxed, and direct your breath into your abdomen and lower ribcage.

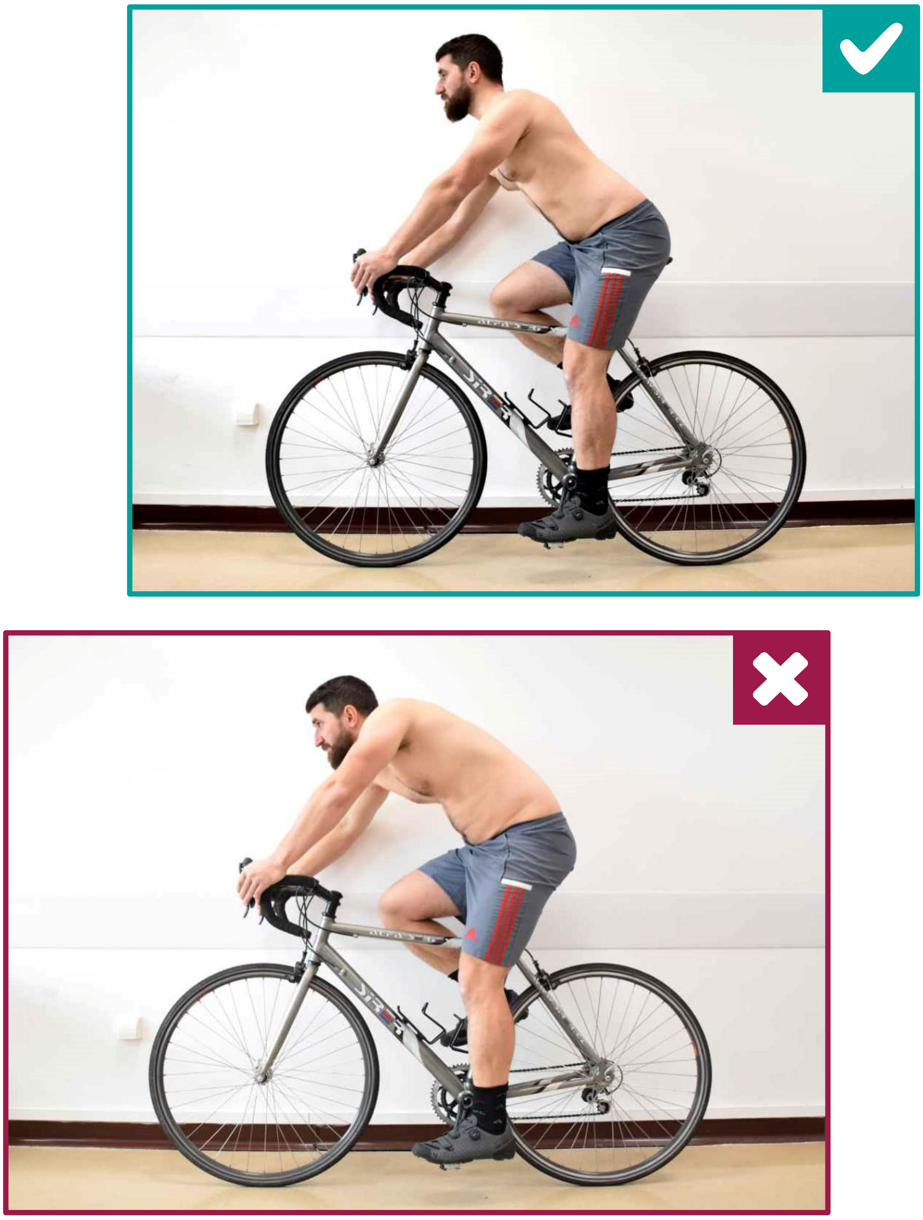

Figure 16 Cycling

Swimming

Swimming is a physical activity that engages the entire body while being buoyant in water. It eliminates impact, making it joint-friendly and suitable after injuries or for individuals with degenerative changes in the musculoskeletal system. However, swimming can be demanding regarding range of motion, particularly in the hip and shoulder joints. The breaststroke style requires good hip joint mobility, while freestyle and backstroke demand sufficient mobility in the shoulder joints. The breaststroke technique can easily strain the cervical and lumbar spine areas. Alternating styles is recommended. As with any physical activity, proper preparation for swimming is important to mitigate potential negative impacts. Focus mainly on thoracic, hip, and shoulder mobility. Patients with any medical conditions or musculoskeletal issues should always consult a specialist. Preparation should include gradual warmups and exercises targeting specific body parts. Perform the exercises slowly and in a controlled manner. Repeat each exercise 3–5 times, holding the position for 5–10 seconds. You should feel stretching, pressure, or muscle activation during the exercises but no pain.

Exercise in a prone position

Support yourself on your forearms and the pubic area. Extend your head forward and away, keeping your neck neutral without tilting it backward. Raise your head just enough to align it with your spine. Rest on your pelvis (pubic bone), not your navel. Direct your breath proportionally into your abdomen and lower ribcage and draw your shoulders away from your ears. Avoid excessive arching in the lower back and cervical spine. Instead, aim to straighten the thoracic region, activating the muscles between the shoulder blades and the abdominal muscles.

Figure 17 Exercise in prone position

Exercise in the supine position

Lie on your back without arching your lower back. Your spine should remain in contact with the surface but not press forcefully into it. Bend your hips and knees to approximately a 90-degree angle. Raise your arms as far as possible overhead without arching your back or losing contact with the surface. Draw your shoulders away from your ears. You should feel a stretch in your shoulders, chest muscles, and thoracic spine while engaging your abdominal muscles.

Figure 18 Exercise in supine position

High ½ kneeling

In this position, distribute your weight evenly on both legs. Push your pelvis forward while raising your arms overhead. Extend your head away from your shoulders without tilting it backward. Focus on pushing the groin of the kneeling leg forward, not the navel. Avoid arching your lower back; keep your spine straight. You should feel a stretch in the groin of the kneeling leg, shoulder joints, and chest muscles. Hold the position for 5–10 seconds, then relax. Repeat the exercise at least two more times. Afterward, switch legs and perform the same exercise with support on the opposite knee and leg

Figure 19 High ½ kneeling

Figure 20 High ½ kneeling incorrect movement technique

Thoracic spine mobilization

For thoracic spine mobilization, you can use a foam roller. Place it under the mid-thoracic spine and symmetrically support yourself with both soles flat on the ground. Keep your pelvis lifted above the surface. Hold this position for a few seconds, then slightly move the roller up or down, gradually stretching the entire thoracic spine. Focus on ensuring the extension comes from the thoracic spine, not the lumbar spine. Keep your abdominal muscles engaged and your pelvis elevated throughout the exercise to achieve this. You should feel a stretch or pressure in the chest area and a stretch around the shoulders and chest muscles.

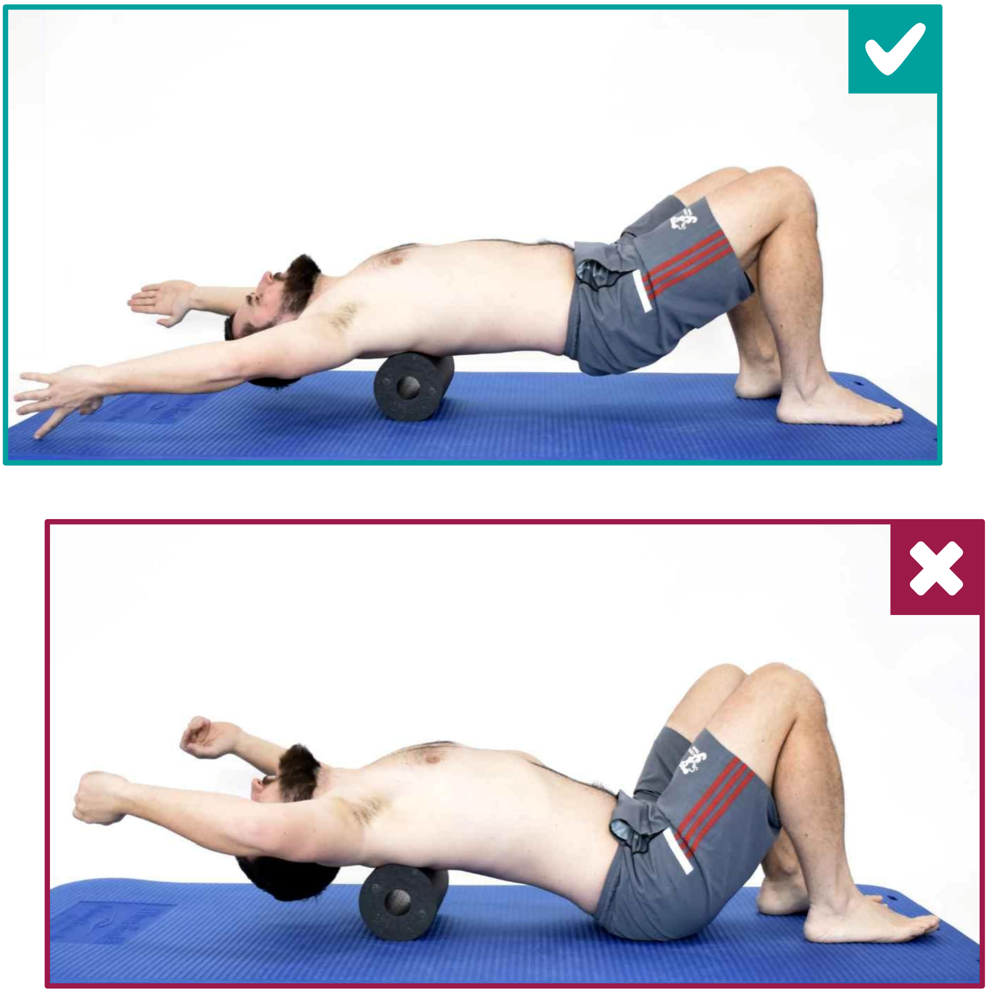

Figure 21 Thoracic spine mobilization

Functional capacity

During sports activities, we sometimes exceed our functional threshold, a state in which we can no longer maintain an ideal posture and quality of movement, and our joints lose optimal muscular control. Poor postural control can cause pain and dysfunction in the musculoskeletal system, leading to the situation where "the more we exercise, the more it hurts."

When the muscular system, guided by the central nervous system, fails to keep the joints in optimal positions under load, repetitive improper movement can overburden passive structures such as ligaments, discs, cartilage, menisci, and other tissues, leading to irreversible degenerative changes. Training for optimal motor control is crucial for maintaining the longevity of the musculoskeletal system (15–17). It is not just about how much we exercise but also about the quality of exercise—whether we can control our movements, identify errors, and correct them ourselves. Warm-ups or specific preparations for a particular sport are designed for this purpose. Above, we provide examples of suitable exercises before walking, running, cycling, and swimming. Similarly, customized exercise routines can be created for other types of physical activities. Maintaining ideal muscle function during sports is much more challenging, as muscles must facilitate movement and protect the joints through balanced activity. Sports often demand maximum range of motion, speed, strength, or endurance.

When demands become too high, we exceed our functional threshold and adopt suboptimal stabilization strategies. Some muscles become overactive, others underactive, and joints move into positions where they are overburdened. Each individual has a unique functional capacity zone, where movement quality is sufficient and the risk of overload or injury is low. Above the functional capacity zone is the overload zone, where movements can still be performed but with poor quality, risking degenerative changes and making injuries more likely. Beyond the overload zone lies the threshold of absolute exhaustion, at which point the body can no longer perform the movement and must stop the activity. Functional capacity varies significantly between individuals. A trained athlete has different abilities than someone who trains recreationally or has not exercised for a long time. Three main factors push us beyond our functional capacity during sports: excessive demands on strength, endurance, and speed. In professional sports, athletes often exceed their functional threshold to achieve maximum performance "at all costs." However, during rehabilitation or training for the general population, this should be avoided or minimized. It is crucial to recognize the moment when movement quality begins to fail. At that point, we should stop, rest, correct errors, and resume with total control. Regular physical activity improves control over time, enabling us to exercise longer and more effectively. The musculoskeletal system positively adapts to the activity, expanding our functional capacity zone.

Control of movement requires full awareness. Therefore, focusing entirely on the movement and eliminating distractions, such as listening to music, spoken word, or watching videos while exercising, is essential, especially in the beginning. Activities like listening to audiobooks or watching movies during exercise should only be done once the movement becomes sufficiently automated.

It is always advisable to consult a professional (e.g., a sports coach or physiotherapist) to identify significant errors, learn to recognize them and correct them effectively.

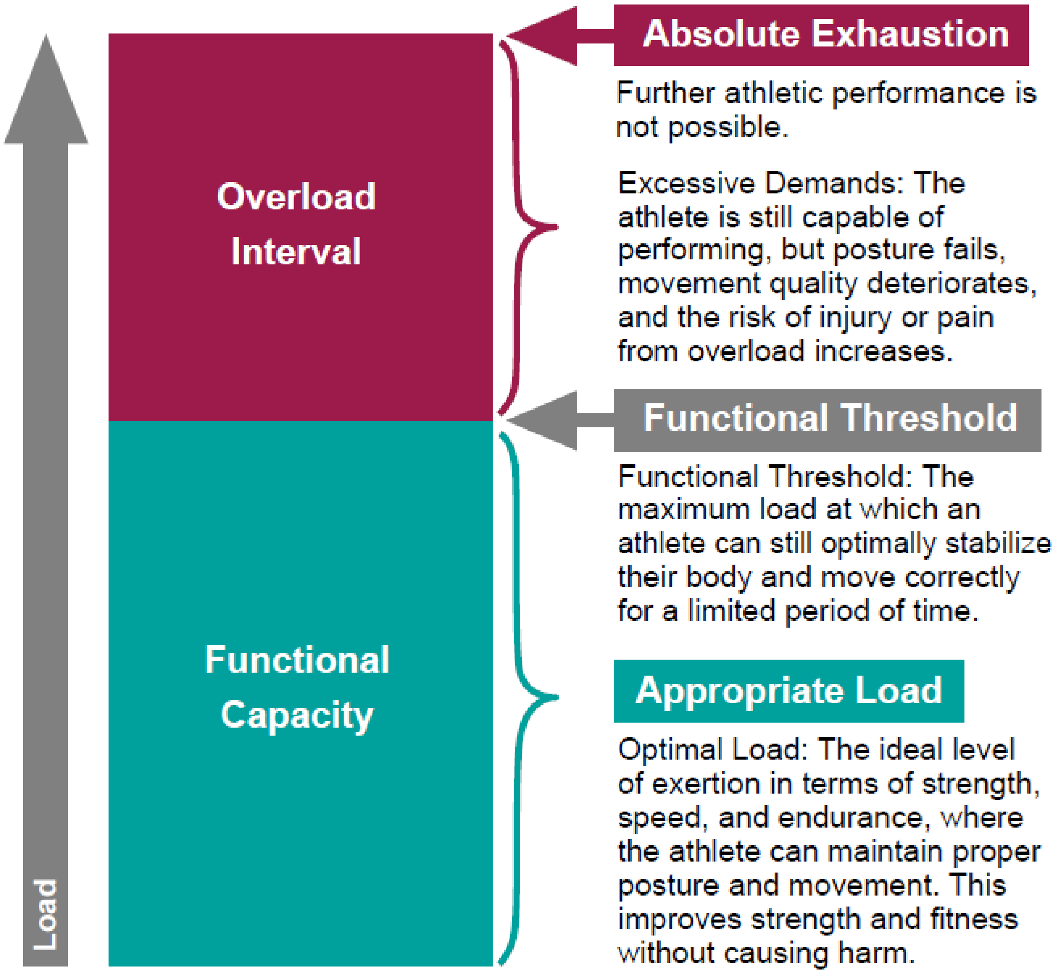

Figure 22 Loading and functional capacity

We quickly reach the functional threshold.

When the functional threshold is exceeded, we lose quality.

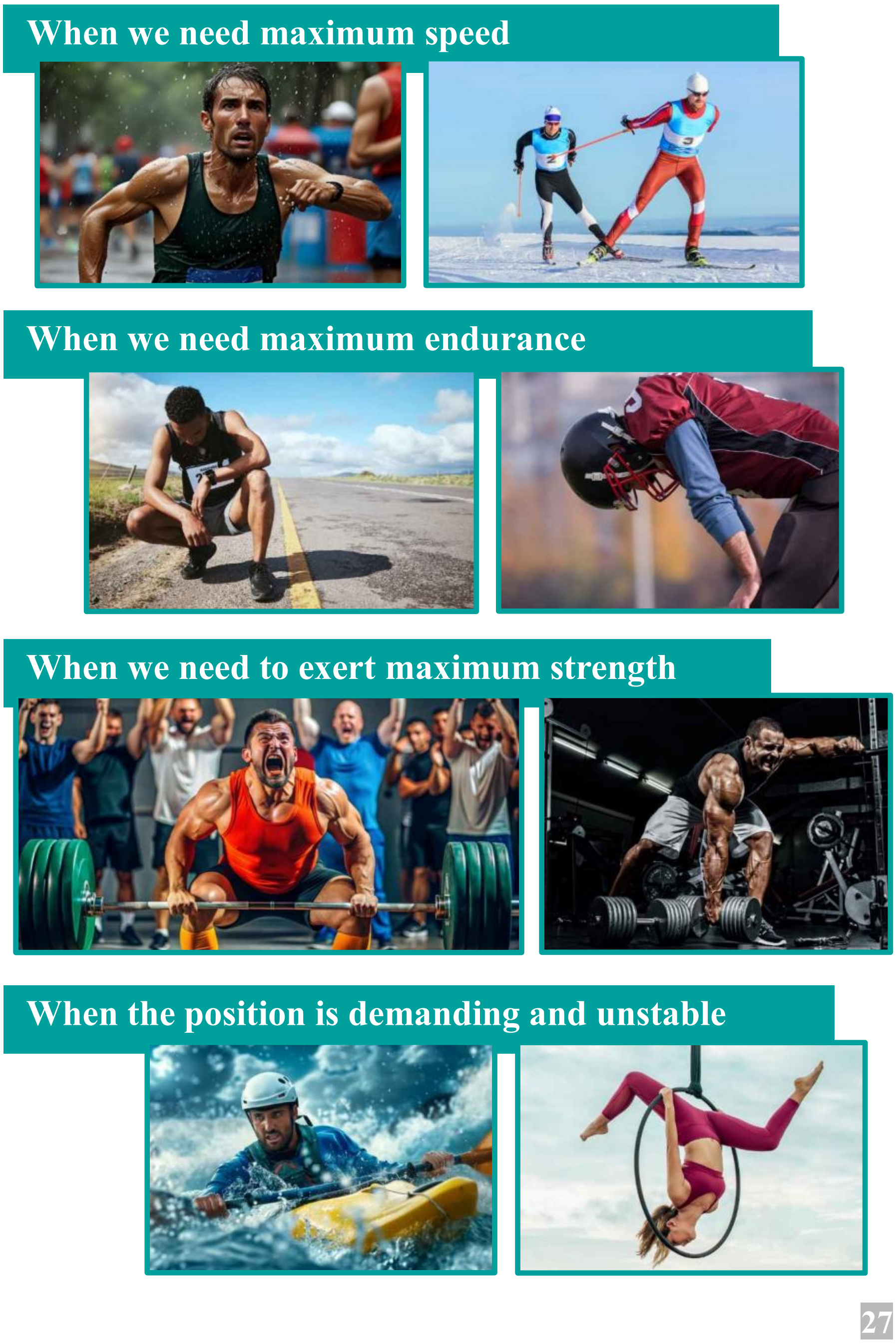

Figure 23 Functional threshold and quality of exercise

Increasing the functional threshold the goal of regular training

Training focused on increasing functional capacity is essential for injury prevention and maintaining performance.

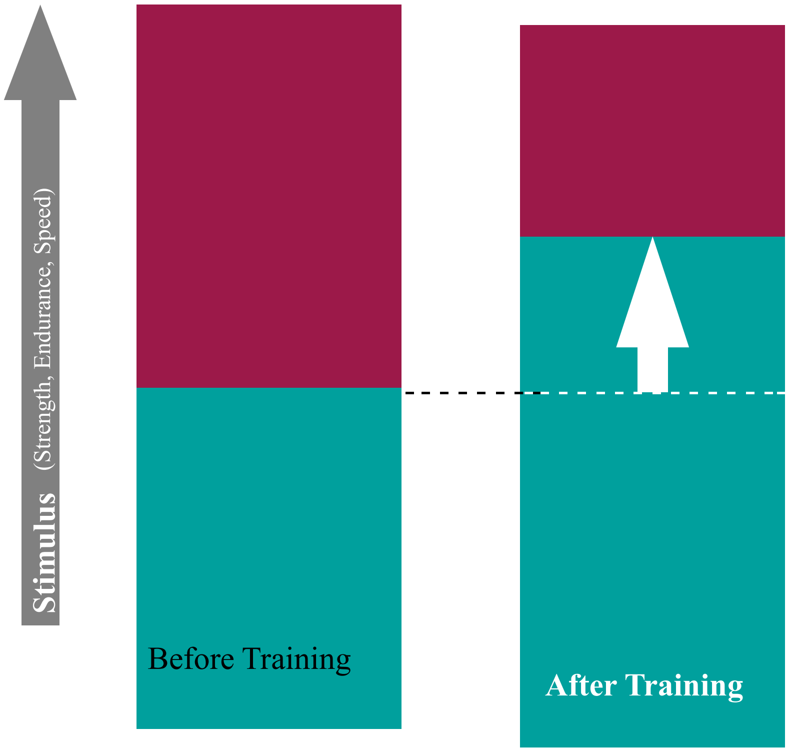

Figure 24 Increasing functional capacity

Increasing the functional threshold means the athlete must train in the functional threshold zone, stimulating the movement system to adapt. This will allow the athlete to move correctly even under higher loads.

The exercises mentioned above serve as preparation for selected physical activities. A proper warm-up also helps to increase the functional threshold, improve and enhance athletic performance, and reduce the risk of overuse and injury. Especially after the COVID-19 pandemic, when a portion of the population experienced decreased physical activity and increased hypomobility, it is important to emphasize proper body preparation for movement to minimize the risks associated with returning to an active lifestyle (18–20).

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Chapter 8

Enhancing physical activity and postural health: lessons from the COVIDMOVE project

Introduction

Hypoactivity, often referred to as physical inactivity or sedentary behavior, is defined as a lack of sufficient physical movement required to maintain optimal health. It is characterized by prolonged periods of minimal energy expenditure, such as sitting, lying down, or engaging in passive activities, without incorporating adequate moderate-to-vigorous physical exercise into daily life. According to the World Health Organization (WHO), adults should engage in at least 150–300 minutes of moderate-intensity aerobic activity or 75-150 minutes of vigorous-intensity aerobic activity per week (1) to mitigate the risks associated with hypoactivity, yet a significant portion of the global population fails to meet these guidelines. García-Hermoso et al. report that only 17–20% of adults and adolescents meet the WHO guidelines for both aerobic and muscle-strengthening activities (2). Factors associated with low physical activity include female sex, older age, higher education and wealth, unemployment, and urban settings (3) This lack of adherence to physical activity guidelines increases with age, particularly among older adults (4). The prevalence of physical inactivity varies across studies and countries, partly due to differences in measurement methods (5). Addressing this global issue requires multi-level interventions and strategies to promote physical activity across diverse populations. Recent findings from a study conducted as part of the Erasmus+ project (project entitled: Movement Activity Enhancement After the COVID-19 Pandemic; project number: 2021-1-SK01-KA220-HED-000023008; acronym "COVIDMOVE") on university students in Poland, Slovakia, and the Czech Republic reveal the lasting effects of the COVID-19 pandemic on physical activity (PA) levels (6). Using the International Physical Activity Questionnaire Short Form (IPAQ-SF), the COVIDMOVE study found significant differences between the countries, with Slovak students exhibiting the highest median PA levels and Polish students the lowest. Despite meeting WHO recommendations for health benefits, overall PA levels have not returned to pre-pandemic levels, indicating persistent effects of the pandemic. These findings emphasize the need for targeted educational programs and initiatives to promote PA, particularly among women and populations at risk of adopting inactive lifestyles, to address the long-term consequences of reduced activity.

The health impacts of hypoactivity are profound and wide-ranging, affecting nearly every system in the body. It weakens the cardiovascular system by reducing heart efficiency and vascular elasticity, thereby increasing the risk of conditions such as hypertension (7), atherosclerosis, and coronary artery disease (8). Insufficient physical activity disrupts energy balance, impairs lipid metabolism, and promotes chronic low-grade inflammation, making it a key factor in the development of obesity, insulin resistance, and type 2 diabetes (9). Additionally, hypoactivity leads to musculoskeletal decline, including loss of muscle mass and strength (sarcopenia) (10) and decreased bone density (osteopenia or osteoporosis), which raises the risk of fractures and mobility impairments (11). A sedentary lifestyle can also weaken respiratory muscles and reduce lung capacity, potentially exacerbating conditions like chronic obstructive pulmonary disease (COPD) or postural respiratory dysfunction (12).

Beyond physical effects, hypoactivity is associated with an increased risk of mental health challenges such as depression, anxiety, and cognitive decline, as regular movement promotes the release of endorphins and supports neuroplasticity, both essential for mental well-being (13). Furthermore, physical inactivity is a leading modifiable risk factor for global mortality, contributing significantly to non-communicable diseases that account for the majority of deaths worldwide. These extensive impacts highlight the critical need to address hypoactivity as a significant public health issue by promoting regular physical activity and reducing sedentary behaviors across all age groups and populations.

Cardiovascular diseases and hypoactivity

The cardiovascular system delivers oxygen and nutrients to tissues and removes waste products. It includes the heart, blood vessels, and blood. Key functions are cardiac output (blood flow regulated by heart rate and stroke volume), vascular resistance (blood pressure control by artery tone), and endothelial function (vasodilation, coagulation, inflammatory regulation, oxidative stress regulation, and angiogenesis).

Cardiovascular diseases (CVD) are a leading cause of morbidity and mortality worldwide, encompassing conditions such as coronary artery disease (CAD), hypertension, heart failure, and arrhythmias. Among the various risk factors, physical inactivity or hypoactivity has emerged as a critical determinant of CVD development and progression. Gene-environment interactions play a crucial role in CVD development, with factors like smoking, physical activity, and diet modifying genetic risks (14). Network and systems approaches are being developed to elucidate the complex mechanisms underlying CVD (15). Hypoactivity increases oxidative stress, promotes endothelial damage, and contributes to dyslipidemia, with increased LDL and decreased HDL levels fostering plaque formation (16). Pro-inflammatory cytokines such as TNF-α and IL-6 exacerbate plaque instability. It also decreases arterial compliance, elevates blood pressure, and enhances sympathetic nervous system activation, contributing to sustained vasoconstriction. Prolonged hypoactivity leads to maladaptive changes such as left ventricular hypertrophy and reduced contractility while impairing energy metabolism in myocardial cells (17). Hypoactivity amplifies systemic inflammation, promoting vascular dysfunction, and induces insulin resistance, hyperglycemia, and dyslipidemia, which are major risk factors for CVD (18). It is strongly linked to weight gain, increasing mechanical and metabolic strain on the cardiovascular system (18).

The prevalence of CVD among inactive individuals is significantly higher compared to their physically active counterparts (19, 20). Regular physical activity has been shown to reduce the risk of CVD, coronary heart disease, and all-cause mortality (20). Even modest increases in physical activity can provide protective health benefits, with greater benefits observed at higher activity levels (21). Despite this evidence, a substantial portion of the population remains physically inactive (22). The economic burden of CVD associated with inactivity is significant, highlighting the need for increased efforts to promote physical activity (23). Demographic and socioeconomic factors play a role in predicting physical inactivity among CVD patients (22). Promoting physical activity across all age groups and ethnicities is crucial for improving cardiovascular health and reducing mortality rates (20).

Regular physical activity significantly reduces the risk of cardiovascular diseases (CVD) and associated mortality by 30-50% (24, 25). Exercise improves cardiovascular health through multiple mechanisms, including enhanced endothelial function, increased nitric oxide production, reduced oxidative stress, and decreased inflammation (26, 27). It also optimizes lipid profiles, improves insulin sensitivity, and lowers blood. These benefits can be achieved with as little as 30 minutes of moderate-intensity activity daily (25). Exercise-induced cardiovascular improvements are attributed to various physiological adaptations, such as enhanced fibrinolysis, improved endothelial function, and decreased sympathetic tone (28). While moderate exercise is generally recommended personalized exercise programs based on individual health status and fitness levels are becoming increasingly important for maximizing cardiovascular benefits (29).

Metabolic diseases and hypoactivity

Disorders in lipid and carbohydrate metabolism are central to the pathophysiology of chronic diseases like type 2 diabetes and cardiovascular disease. Dyslipidemia, characterized by elevated triglycerides, low HDL cholesterol, and increased LDL cholesterol, disrupts vascular function and promotes atherogenesis (30). Insulin resistance and physical inactivity are key factors in metabolic dysfunction, leading to impaired glucose uptake, hyperglycemia, and systemic inflammation (31). Type 2 diabetes mellitus (T2DM), metabolic syndrome, and obesity form an interconnected triad of metabolic disorders characterized by chronic inflammation, oxidative stress, and insulin resistance (32). These conditions share common pathophysiological mechanisms, including adipose tissue dysfunction, mitochondrial impairment, and hyperinsulinemia (33). The interplay between oxidative stress and inflammation creates a feed-forward cycle that initiates and advances disease progression, leading to complications such as cardiovascular disease and non-alcoholic fatty liver disease (34). Sedentary lifestyles and poor dietary habits are significant contributors to the development of these disorders (35). The complex relationship between these conditions is often referred to as the "Cardiovascular Metabolic Syndrome," emphasizing the need for a multi-pronged approach to prevention and treatment (36). The global prevalence of these interrelated disorders has reached epidemic proportions, posing significant challenges to public health systems worldwide (37).

Early lifestyle interventions targeting weight management, physical activity, and dietary improvements are critical for prevention and management. Also, a sedentary lifestyle and associated metabolic disorders significantly reduce quality of life and increase the risk of developing other chronic diseases. Individuals with obesity, type 2 diabetes, and metabolic syndrome often face significant physical limitations, fatigue, and psychological distress, including anxiety and depression, which adversely affect their health-related quality of life (HR-QoL) (38). Besides cardiovascular diseases, these conditions are linked to an increased risk of comorbidities such as certain cancers and musculoskeletal disorders (39). The cumulative burden of these diseases exacerbates functional impairments and elevates healthcare costs, ultimately shortening life expectancy (40, 41). Addressing physical inactivity and promoting healthier lifestyles are crucial for breaking this cycle (42). Furthermore, managing mental health issues like depression and diabetes distress is essential for improving disease management and overall well-being (43). Effective interventions can enhance quality of life and longevity for affected individuals (39).

Respiratory diseases caused by hypoactivity

Physical inactivity significantly contributes to the pathophysiology of respiratory diseases, particularly chronic obstructive pulmonary disease (COPD). It leads to reduced lung ventilation, impaired gas exchange, and loss of respiratory muscle mass and strength (44, 45). Inactivity is both a consequence and a potential cause of COPD, with low activity levels linked to faster lung function decline and increased COPD incidence. In COPD patients, physical inactivity is associated with disease progression, impaired health status, increased healthcare utilization, and higher mortality risk (46).

Similarly, recent studies suggest a complex relationship between physical activity and lung cancer risk. Leisure-time physical activity is generally associated with reduced lung cancer risk, particularly among current and former smokers (47). The protective effect of leisure-time activity appears dose-dependent, with higher levels offering greater risk reduction (48). This association is observed across various lung cancer subtypes (47). Proposed mechanisms include improved pulmonary function, enhanced immune function, and reduced inflammation (48). And finally, some studies indicate that individuals with asthma are less physically active than those without (49, 50). Factors influencing physical activity levels in asthmatic individuals include disease severity, parental beliefs, and body mass index (51, 52). A meta-analysis suggests that higher physical activity levels may be protective against asthma development (53). However, asthma is often perceived as a barrier to exercise by both children and parents (50). Some research indicates that children with asthma have higher rates of obesity and lower physical activity levels compared to those with other medical conditions (50).

These findings highlight the importance of physical activity and proper management of respiratory conditions in lung cancer prevention. The connections between hypokinesia and respiratory diseases, and the effects of COVID-19 on respiratory health have already been discussed in detail in this book within the chapter Impact of Physical Activity on Respiratory diseases, providing a comprehensive analysis of these topics.

Building upon the discussion of hypoactivity's impact on respiratory function, the findings from the Erasmus+ project further highlight the interplay between respiratory and postural functions and their implications for rehabilitation strategies. The studies conducted under the COVIDMOVE project collectively illuminate the intricate relationship between postural stability and respiratory function, emphasizing their relevance in rehabilitation science (54–56). A study reported by Sembera et al (55) examined the impact of abdominal bracing during load-lifting tasks on respiratory and postural function. The findings revealed that abdominal bracing increases diaphragmatic motion but reduces lung volumes, illustrating a trade-off between enhancing spinal stability and maintaining respiratory efficiency. Strong correlations were observed between diaphragmatic excursions and lung volumes, confirming the diaphragm's pivotal role in respiration even under heightened postural demands. These results are particularly relevant for individuals with respiratory limitations, such as those experiencing dyspnea, as the reduced lung volumes associated with bracing could potentially exacerbate breathing difficulties. This study highlights the importance of balancing postural and respiratory considerations in rehabilitation protocols, particularly for patients recovering from conditions that impair both systems. The same group of authors also investigated the postural-respiratory function of the diaphragm during load-lifting tasks using M-mode ultrasonography, spirometry, and abdominal wall tension (AWT) measurements (56). It demonstrated that load-lifting induced significant caudal displacement and increased diaphragmatic excursions, with greater AWT compared to tidal breathing. Importantly, the diaphragm's postural function remained independent of its respiratory activity, as breath-holding scenarios showed stable diaphragm behavior. The study also found that voluntary contraction of the abdominal muscles doubled AWT without reducing diaphragm motion, suggesting that diaphragmatic and abdominal muscle activity synergize to maintain adequate intra-abdominal pressure (IAP) and ventilation. These findings contribute to understanding the diaphragm's dual role in postural stabilization and respiration, with implications for rehabilitation and strength training strategies. The third study under the COVIDMOVE project assessed the inter-rater reliability of Dynamic Neuromuscular Stabilization diaphragm and intra-abdominal pressure regulation tests among patients with non-specific low back and neck pain (54). It found moderate reliability between experienced and novice DNS clinicians, with higher reliability noted in patients reporting greater pain intensity. These tests, which evaluate the diaphragm's dual role in postural stabilization and respiratory function, offer a practical and accessible method for clinical settings, addressing the need for reliable assessments of postural-respiratory dysfunction. This work, alongside the other studies in the COVIDMOVE project, highlights the diaphragm's critical role in postural stabilization and respiratory function, which are often compromised due to hypoactivity. Reduced physical activity can exacerbate dysfunction in these systems, emphasizing the importance of interventions that promote movement and restore postural-respiratory balance. Together, these findings provide a robust foundation for integrating respiratory and postural evaluations into rehabilitation protocols to mitigate the effects of hypoactivity and improve patient outcomes.

Recommendations and interventions

To mitigate the adverse effects of inactivity and enhance overall well-being, promoting physical activity across all age groups is essential. Prevention plays a pivotal role, with targeted strategies to encourage movement and reduce sedentary lifestyles. Recommended physical activities include aerobic exercises to improve cardiovascular health, strength training for muscle and bone health, and breathing exercises to enhance respiratory function. Programs and policies at both national and global levels should focus on creating accessible, inclusive opportunities for movement, such as community fitness initiatives and public awareness campaigns. A multidisciplinary approach is crucial for success, requiring collaboration among healthcare providers, physiotherapists, public institutions, and policymakers to ensure that interventions are comprehensive, equitable, and effective.

Exercise guidelines (1) for addressing hypoactivity focus on a range of objectives, including improving muscle strength and endurance to counteract the loss of muscle mass and functionality, and enhancing cardiovascular fitness to boost oxygen delivery, energy levels, and overall stamina. Mobility and flexibility exercises are emphasized to prevent stiffness and improve functional independence, while activities targeting neuromuscular coordination help reduce the risk of falls by enhancing balance and motor control. Regular physical activity is also highlighted for its role in reducing systemic inflammation and improving metabolic health by enhancing insulin sensitivity and lipid profiles, thereby addressing conditions like obesity and dyslipidemia. Additionally, the guidelines prioritize mental well-being, as physical activity is known to alleviate mood disorders such as depression and anxiety by boosting endorphin levels and improving sleep quality. A key focus is on fostering long-term behavioral change, encouraging individuals to integrate physical activity into daily routines and reduce sedentary behaviors to achieve sustainable health benefits across physical, metabolic, and psychological domains. However, one aspect that is not as often analyzed and emphasized within guidelines is the quality of posture during exercise as well as everyday activities.

As part of this strategy, the Erasmus+ COVIDMOVE was awarded to support initiatives promoting physical activity and recovery following the pandemic's impact. This collaborative project involved multiple institutions, including universities, research centers, and public health organizations from Slovakia, the Czech Republic, and Poland. The project's key outcomes include the development of comprehensive guidelines for physical activity programs tailored to post-pandemic recovery, the establishment of cross-border conferences for healthcare professionals, and the launch of public campaigns emphasizing the importance of regular movement. These efforts have effectively raised awareness about strategies to increase physical activity in both the general population and individuals with specific conditions, such as sarcopenia, mental health issues, pelvic floor dysfunction, breathing disorders, or digestive complications associated with respiratory disorders and lung transplantation.

The importance of posture in exercise: The Dynamic Neuromuscular Stabilization (DNS) concept

Proper posture is crucial for optimal body function and movement efficiency. It involves the alignment of body segments and maintenance of spinal curvatures (57). Poor posture can lead to musculoskeletal imbalances, pain, and reduced physical function (58). Exercise is widely recommended for preventing and correcting postural deviations by strengthening weak muscles and stretching tight ones (59). Various types of exercises, including strengthening, stretching, and specific postural exercises, have shown effectiveness in improving postural dysfunctions (58). However, the intensity, volume, and duration of exercise programs must be considered (58). While some studies suggest that exercise can correct postural deviations, there is a lack of reliable data to support this claim conclusively (59). Nonetheless, physical activity remains essential for maintaining good posture and overall health, particularly for sedentary individuals. One functional diagnostic and therapeutic concept that directly focuses on the analysis and training of posture is Dynamic Neuromuscular Stabilization (DNS) (60–62). DNS is a therapeutic approach rooted in developmental kinesiology, emphasizing the intricate relationship between posture and movement quality (60, 63, 64). DNS carefully analyzes posture by examining the alignment and function of the musculoskeletal system, focusing on how it supports optimal motor control during both static positions and dynamic activities. The concept is focused on core stability and optimal diaphragm function (54, 61, 65, 65, 66). Posture assessment within DNS involves a detailed evaluation of body alignment, respiratory patterns, muscle activation, and functional movement patterns (54, 61, 65, 67). Practitioners observe how the body maintains stability and compensates for dysfunctions, often identifying common examples of poor posture, such as forward head position, excessive lumbar lordosis, rigid thoracic kyphosis, or pelvic tilts. These postural imbalances frequently lead to inefficient movement patterns, increased strain on joints and muscles, and heightened risk of injury or chronic pain.

In DNS, the quality of movement is intrinsically tied to the quality of posture, as poor alignment disrupts the natural coordination of muscle groups and hinders the body's ability to generate efficient and balanced movements. For instance, improper posture can alter the activation of core stabilizing muscles, compromising stability and mobility during physical activities. DNS employs specific exercises that mimic developmental stages in early human motor development, such as rolling, crawling, or squatting, to retrain the neuromuscular system and restore functional movement (67). These exercises are designed to re-establish proper postural alignment and breathing mechanics while progressively challenging the body's ability to maintain stability under dynamic conditions.

The approach is strongly evidence-based, supported by research in biomechanics, neurophysiology, and motor control. Studies highlight its effectiveness in addressing musculoskeletal pain (68–73), improving athletic performance (74, 75), and enhancing rehabilitation outcomes by targeting the root causes of movement dysfunction. DNS is an effective approach for improving functional movements (76), postural control, and core stability (77). Studies have shown that DNS exercises can enhance chest mobility, upright sitting height, and quality of life in obese individuals (78). DNS has also demonstrated positive effects on core strength (79) and the functionality of the locomotor system (80). DNS exercises have shown promising results in treating various musculoskeletal and neurological conditions such as enhancing the performance and quality of life in stroke patients (81–83) or improving balance, gait, and gross motor function in cerebral palsy patients (84). Additionally, holistic therapy approach, including Dynamic Neuromuscular Stabilization (DNS), have demonstrated positive effects on fecal incontinence and quality of life in patients with multiple sclerosis (85). In sedentary female workers with mechanical neck pain, DNS training improved neck pain, cervical position angle, and muscle strength (86). For flatwater kayakers, DNS integration with traditional training increased maximum paddling force (74).

DNS provides a systematic, individualized framework for improving posture and movement quality, empowering individuals to achieve long-term health and functional resilience. By integrating principles of developmental kinesiology with rigorous scientific validation, DNS offers a holistic and precise method for addressing posture-related challenges in both therapeutic and everyday contexts. Overall, DNS appears to be an effective approach for promoting spinal stability, reducing pain, and enhancing functional performance across various populations (77, 79, 80).

Integration of DNS in the brochures: outcomes of the COVIDMOVE project

DNS is a core focus of the brochures developed for the Erasmus+ COVIDMOVE project. These materials emphasize the critical role of posture and movement quality in rehabilitation and overall physical health. Through these educational brochures, DNS incorporates the principles of developmental kinesiology, guiding individuals to achieve optimal body positions and movement patterns rooted in natural motor control. The brochures highlight DNS's focus on a self-treatment approach, empowering individuals to take an active role in their recovery and health management. This is achieved through education on proper posture and movement, helping patients improve their functional capabilities while preventing injuries and promoting long-term wellness.

A brochure entitled "Recommended Preparation for Selected Physical Activities, using the methodology of Dynamic Neuromuscular Stabilization (DNS)"(87) developed as part of the COVIDMOVE grant project, provides a comprehensive guide to integrating physical activity into daily life based on DNS principles. It emphasizes the importance of mindful movement and proper preparation to reduce the risk of injury and improve overall health. The document outlines key components of physical activity, including postural training, strength and cardiovascular exercises, and specific movement preparation for activities such as running, cycling, and swimming. It also highlights the need for gradual adaptation, quality of movement, and proper breathing techniques. The brochure serves as a resource for both individuals and professionals aiming to enhance functional capacity and promote long-term musculoskeletal health, particularly in the context of a global decline in physical activity post-COVID-19.

Another brochure entitled "Exercises for people with breathing disorders using DNS methodology" (88) provides a detailed guide to improving breathing patterns and strengthening respiratory muscles, particularly for individuals with breathing disorders or post-COVID-19 complications. It emphasizes the importance of proper breathing mechanics, the role of the diaphragm, and techniques to optimize respiratory function. Using the DNS methodology, the brochure offers exercises based on natural developmental positions, which enhance breathing capacity, trunk stability, and overall coordination. It highlights the need for gradual, mindful practice tailored to individual needs and encourages consulting professionals for personalized plans to achieve optimal results.

There is a clear link between hypoactivity (insufficient physical activity) and pelvic floor dysfunction (PFD), as the pelvic floor muscles (PFMs) play a crucial role in supporting pelvic organs, maintaining continence, and contributing to core stability. Hypoactivity can lead to weakened or poorly coordinated PFMs, increasing the risk of conditions such as urinary or fecal incontinence and pelvic organ prolapse. A sedentary lifestyle often results in muscle atrophy, poor core strength, and impaired blood flow, all of which hinder the ability of PFMs to function effectively. Additionally, physical inactivity can lead to weight gain, placing greater pressure on the pelvic floor and causing further muscle strain. Hypoactivity also disrupts the natural synergy between the PFMs and the diaphragm, essential for effective breathing mechanics and muscle coordination. A comprehensive overview of pelvic floor issues caused by hypoactivity, including the types and forms of urinary incontinence, its prevalence, and contributing factors such as age, childbirth, and physical activity levels, is provided in the chapter titled "Physical Activity in Incontinence Problems." It emphasizes the importance of proper diagnosis and assessment, including physical examinations, questionnaires, and advanced diagnostic tools. Furthermore, the chapter highlights various management strategies, from conservative treatments like pelvic floor muscle training and hypopressive exercises to pharmacological and

minimally invasive approaches. Stressing the socio-economic and psychological impacts of incontinence, it advocates for tailored interventions to enhance quality of life and long-term management. Regular physical activity, including core and pelvic floor-specific exercises, is vital for maintaining PFM strength and reducing the risk of PFD. Therefore, another brochure produced as part of the COVIDMOVE project, entitled "Exercise for People with Pelvic Floor Dysfunction: Exercise Instructions" (89) focuses on addressing pelvic floor dysfunction by educating individuals on self-treatment techniques.
The COVID-19 pandemic has significantly impacted lung transplantation practices, with a notable increase in transplants performed for patients suffering from severe, irreversible lung damage due to the virus. A study published in JAMA Surgery in August 2023 analyzed data from the United Network for Organ Sharing (UNOS) database, identifying 385 patients who underwent lung transplants for COVID-19–related acute respiratory distress syndrome (ARDS) or pulmonary fibrosis between March 2020 and August 2022. The study found that the 1-, 6-, and 12-month overall survival rates for these patients were comparable to those of non–COVID-19 lung transplant recipients, indicating that lung transplantation can be a viable treatment option for patients with irreversible respiratory failure due to COVID-19 (90). Further supporting these findings, an analysis by the Smidt Heart Institute at Cedars-Sinai, published in The New England Journal of Medicine in January 2022, examined over 3,000 lung transplants performed in the U.S. between August 2020 and September 2021. The study reported that approximately 7% of these transplants were conducted to treat severe, irreversible lung damage caused by COVID-19, with a three-month survival rate of 95.6% among these patients (91). These studies underscore the evolving role of lung transplantation in managing severe COVID-19-related lung injuries, demonstrating that, with careful patient selection and management, lung transplantation can offer favorable outcomes for those with life-threatening pulmonary complications from the virus.

One of the potential causes of transplanted lung failure is gastroesophageal reflux disease (GERD). Addressing GERD in patients after lung transplantation is critical, as it can lead to pulmonary complications, impair lung function, increase the risk of both acute and chronic rejection episodes, and reduce survival rates in lung transplant recipients (92, 93). The prevalence of GERD is high among lung transplant patients, with over 50% affected (94). Early diagnosis and aggressive management of GERD, including antireflux surgery, have been shown to improve lung function and reduce complications in both pre- and post-transplant patients (95). Given the strong association between GERD and poor transplant outcomes, experts recommend thorough pre-transplant GERD testing and prompt intervention to potentially improve allograft function and survival (96, 97). Rehabilitation can have a positive effect on GERD in patients after lung transplantation by addressing several contributing factors. Firstly, targeted physical therapy can improve diaphragmatic strength and function, which plays a crucial role in preventing acid reflux by maintaining pressure in the lower esophageal sphincter (LES)(98–100). Secondly, structured exercise programs help with weight management, reducing abdominal pressure on the stomach, which is a known risk factor for GERD. Additionally, breathing exercises, often incorporated into rehabilitation, enhance coordination between respiratory and abdominal muscles, further supporting the LES's ability to prevent reflux (100). Overall, a comprehensive rehabilitation plan not only improves physical conditioning but also directly addresses the mechanical and functional aspects that contribute to GERD, benefiting patients post-lung transplantation. Therefore, a brochure was created as part of the COVIDMOVE project to educate post-transplant patients on postural and respiratory exercises aimed at preventing GERD. The brochure "Rehabilitation for Patients After Lung Transplantation with Gastroesophageal Reflux Using the Methodology of DNS" (101) provides a comprehensive guide for managing GERD in lung transplant patients. It highlights the risks GERD poses to lung health and offers targeted exercises to improve esophageal sphincter function, reducing reflux and its impact on lung function. Utilizing the principles of DNS, the guide emphasizes manual release techniques, breathing exercises, and postural adjustments to support respiratory health and mitigate complications. It also introduces tools like the Coach 2 and Acapella trainers for inspiratory and expiratory muscle training, enhancing lung capacity and function. These exercises are designed for regular practice and can be tailored to individual needs under the supervision of a physiotherapist.

Conclusion

The COVIDMOVE project highlights the vital role of physical activity and posture in addressing the widespread consequences of hypoactivity, particularly in the aftermath of the COVID-19 pandemic. Leveraging the principles of Dynamic Neuromuscular Stabilization (DNS), the project developed educational materials aimed at enhancing physical health through proper movement, breathing mechanics, and postural alignment. These materials, including brochures targeting breathing disorders, pelvic floor dysfunction, and GERD in lung transplant patients, integrate evidence-based strategies to empower individuals in their recovery and health maintenance. Feedback from physiotherapy students underscores the clarity, feasibility, and professional applicability of the materials, while also identifying opportunities for improvement, such as simplifying language and clarifying exercise instructions. By emphasizing the interplay between posture, movement, and overall health, the project provides a comprehensive approach to improving physical activity levels and mitigating the health risks associated with sedentary behaviors, ensuring its relevance and utility for both patients and healthcare professionals.

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