Posture, sedentary lifestyle, and musculoskeletal pain in young adults: emerging challenges and physiotherapy-based interventions

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Abstract:
Musculoskeletal pain among young adults has emerged as a growing public health concern associated with prolonged sedentary behaviour, excessive digital-device use, poor postural habits, reduced physical activity, and changing academic and occupational demands. Increasing dependence on smartphones, computers, and online learning has contributed to extended periods of sitting and sustained positioning of the cervical spine, shoulders, and lumbar region, potentially increasing muscular fatigue, movement restrictions, and functional discomfort. This review explores the relationship between posture, sedentary lifestyle, and musculoskeletal pain in young adults, with particular emphasis on the biomechanical, physiological, behavioural, and psychosocial mechanisms underlying neck pain, shoulder discomfort, upper back pain, and low back pain. Recent evidence suggests that prolonged screen exposure, limited movement variability, inadequate muscular endurance, and insufficient physical activity may contribute to musculoskeletal symptoms, although pain development is multifactorial and cannot be attributed to posture alone. The review further highlights physiotherapy-based approaches, including postural and ergonomic education, cervical and scapular stabilization, progressive strengthening, core conditioning, thoracic mobility exercises, aerobic training, motor-control interventions, manual therapy, and pain neuroscience education. Integrated rehabilitation strategies combining individualized exercise prescription, regular movement breaks, workstation modification, and behavioural interventions may improve pain management, functional capacity, physical activity, and long-term musculoskeletal health. Emerging technologies such as wearable activity monitors, mobile health applications, artificial intelligence-based posture monitoring, and tele-physiotherapy may provide additional opportunities for preventive care and rehabilitation. The review emphasizes the importance of shifting from rigid posture-correction approaches toward individualized, movement-oriented, and biopsychosocial physiotherapy management. Early screening, preventive physiotherapy programmes, and sustainable lifestyle modifications in universities and workplaces may help reduce the burden of musculoskeletal pain and promote improved functional independence and quality of life among young adults.

Keywords:
Young adults, musculoskeletal pain, sedentary lifestyle, Postural dysfunction, Digital-device use, Neck pain, Low back pain, Ergonomics, Physiotherapy, Exercise therapy, Physical activity, Rehabilitation.

1. Introduction:
Musculoskeletal pain has become an increasingly important health concern among young adults because of its potential effects on physical functioning, academic performance, occupational productivity, social participation, and quality of life. Young adulthood represents a transitional period characterized by higher educational responsibilities, employment-related demands, independent living, and increasing dependence on digital technologies. These lifestyle changes have substantially modified the way individuals sit, stand, work, study, communicate, and participate in recreational activities. Although technological development has improved accessibility and efficiency, it has also encouraged prolonged screen exposure and reduced

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opportunities for regular movement. Consequently, complaints involving the cervical spine, thoracic region, lumbar spine, shoulders, and other musculoskeletal structures are frequently encountered in younger populations. Traditionally, musculoskeletal disorders were primarily associated with ageing, repetitive occupational loading, traumatic injuries, and degenerative changes. However, contemporary research demonstrates that younger individuals can also experience recurrent musculoskeletal symptoms associated with prolonged static activities, inadequate physical conditioning, repetitive movements, and psychosocial stress. The transition from active school-based routines to sedentary university education and computer-oriented employment may contribute to the development of unfavourable movement habits. Individuals may spend several consecutive hours attending online classes, preparing assignments, working on computers, playing video games, or using smartphones without sufficient movement breaks. Sedentary behaviour is generally defined as waking behaviour characterized by an energy expenditure of 1.5 metabolic equivalents or less while sitting, reclining, or lying down. It should be distinguished from physical inactivity, which refers to insufficient participation in moderate-to-vigorous physical activity. An individual may meet recommended physical activity levels but still accumulate prolonged sedentary time throughout the day. The World Health Organization (WHO, 2020) emphasizes the importance of reducing sedentary behaviour and replacing it with physical activity of any intensity. These recommendations are particularly relevant to young adults whose academic and professional activities increasingly involve extended sitting periods. Postural behaviour represents another important consideration. Forward head positioning, rounded shoulders, increased thoracic flexion, unsupported sitting, and sustained lumbar flexion are commonly observed during smartphone and computer use. Repeated exposure to these positions may increase muscular demands, alter movement strategies, and contribute to regional discomfort in susceptible individuals. Nevertheless, there is no single universally correct posture that must be maintained throughout the day. Contemporary musculoskeletal rehabilitation increasingly recognizes that posture is dynamic and that prolonged immobility may be more relevant than the appearance of a particular sitting position. Recent evidence strengthens the relationship between sedentary behaviour and neck pain. A systematic review and meta-analysis involving 25 studies and 43,184 participants reported a significant association between sedentary behaviour and neck pain, with an overall odds ratio of 1.46. The association was particularly notable for mobile phone use and prolonged screen-based sedentary activities (The associations between sedentary behavior and neck pain, 2025). Similarly, Alaca et al. (2025) identified relationships between sitting time, sitting posture, and sitting behaviour and low back pain among office workers, highlighting the importance of movement patterns and opportunities for postural variation. The emerging challenge is therefore not simply to correct an individual's posture but to understand the combined influence of physical loading, movement behaviour, muscle capacity, psychological factors, and environmental conditions. Physiotherapy offers an effective framework for addressing these interacting factors through individualized assessment, therapeutic exercise, ergonomic education, movement retraining, and long-term self-management. Fig. 1 illustrates the proposed relationship between modern lifestyle exposures, biomechanical and behavioural mechanisms, and musculoskeletal symptoms in young adults.

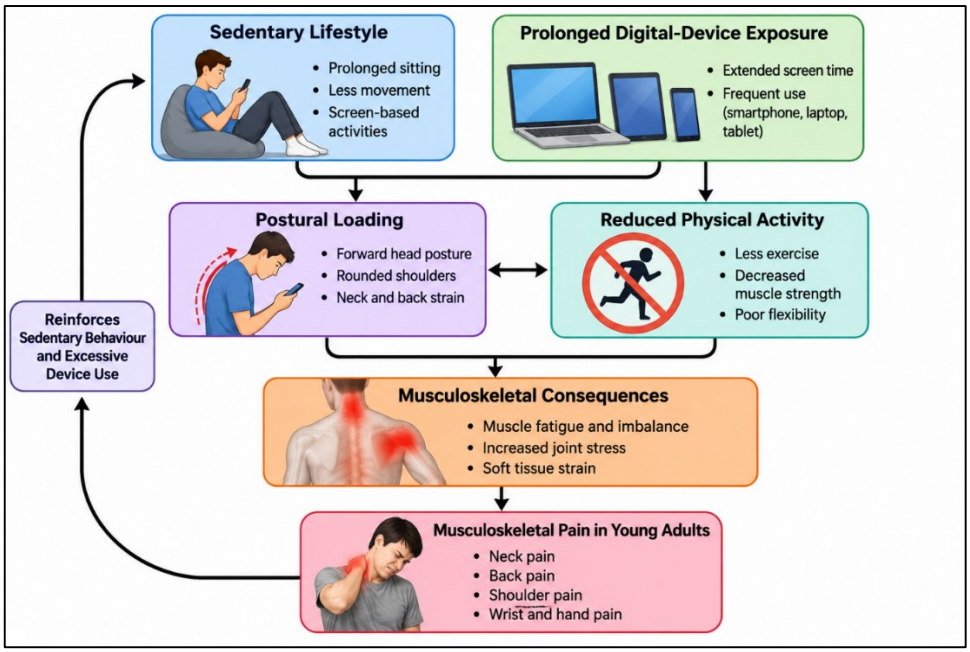


Figure. 1: Conceptual framework illustrating the relationship between sedentary lifestyle, prolonged digital-device exposure, postural loading, reduced physical activity, and the development of musculoskeletal pain in young adults

2. Changing lifestyle patterns and musculoskeletal health in young adults:

2.1. Increasing dependence on digital technology:

Digital technology has become an essential component of contemporary education, communication, employment, and entertainment. Smartphones, laptops, tablets, and desktop computers are routinely used for academic assignments, online meetings, social networking, gaming, and professional activities. Although these devices provide substantial advantages, their frequent use may encourage prolonged sitting and sustained positioning of the head, neck, upper limbs, and trunk. Smartphone activities commonly involve looking downward toward a relatively small screen while maintaining the device below eye level. This behaviour may increase cervical flexion and encourage static activation of cervical and shoulder musculature. Similarly, laptop users may adopt forward head positioning because of screen height, keyboard placement, and inadequate workstation arrangements. Repetitive typing and mouse use may also increase demands on the upper extremities. A systematic review and meta-analysis by Chen et al. (2025) investigated the association between smartphone overuse and neck pain, highlighting the importance of excessive device exposure as a potential contributor to cervical musculoskeletal complaints. However, the relationship should not be interpreted as proof that smartphone use independently causes neck pain. Device duration, posture, movement variability, individual physical capacity, and psychosocial factors may interact to influence symptoms.

2.2. Sedentary academic activities:

University students and other young adults in educational settings may spend considerable time attending lectures, reading, preparing examinations, completing computer-based assignments, and participating in online learning. These activities frequently involve uninterrupted sitting, especially during examination periods and intensive academic schedules. The use of poorly designed classroom furniture, inadequate desk height, limited legroom, and insufficient back support may further influence sitting behaviour. Students who study using beds, sofas, or low tables may repeatedly adopt unsupported trunk positions. Such arrangements can increase muscular demands and contribute to discomfort in the neck, shoulders, and lower back. Sedentary academic behaviour may also reduce opportunities for outdoor recreation, sports, and other physical activities. The cumulative effect of these lifestyle changes may negatively influence physical conditioning and the ability to tolerate prolonged functional activities.

2.3. Remote working and occupational sitting:

The expansion of remote employment and computer-based occupations has introduced additional challenges for musculoskeletal health. Young professionals may work from home using dining tables, beds, or temporary workstations that do not provide adequate ergonomic support. Unlike traditional offices, home environments may lack adjustable chairs, external monitors, dedicated workspaces, and structured movement breaks. Alencar et al. (2025), in a systematic review comparing office workers and teleworkers, examined the musculoskeletal complaints and associated risk factors occurring in different working environments. The findings reinforce the importance of considering the physical and behavioural characteristics of work settings when evaluating musculoskeletal health. A recent scoping review by Alaca et al. (2025), including 22 studies and 7,814 participants, found that sitting behaviour, fewer breaks, and prolonged static positioning were important themes associated with low back pain. These findings suggest that occupational rehabilitation should address the complete pattern of sitting behaviour rather than concentrating exclusively on workstation appearance.

2.4. Reduced participation in physical activity:

Physical activity is essential for maintaining muscular strength, endurance, cardiovascular fitness, joint mobility, and functional capacity. However, many young adults experience declining physical activity because of academic pressures, occupational responsibilities, commuting demands, and increasing recreational screen time. Reduced participation in exercise may decrease the physical capacity required to tolerate everyday activities. Individuals with limited muscular endurance may experience fatigue during prolonged sitting, standing, or computer work. Poor general conditioning may also influence recovery following repetitive or unfamiliar physical activities. Importantly, physical inactivity and sedentary behaviour are separate but interacting constructs. A person who exercises for 30 minutes daily may still spend the remaining waking hours sitting. Therefore, prevention strategies should include both regular exercise and frequent interruptions of prolonged sedentary periods.

3. Postural alterations associated with modern lifestyles:

3.1. Forward head posture:

Forward head posture is characterized by anterior positioning of the head relative to the trunk. It is commonly observed during prolonged computer use, smartphone activities, and unsupported sitting. This posture may involve altered cervical alignment, increased demands on posterior cervical musculature, and changes in the coordination of the neck and shoulder girdle. Sustained forward head positioning may contribute to discomfort in individuals who demonstrate limited muscular endurance or reduced tolerance to prolonged static activity. Associated symptoms may include cervical stiffness, upper trapezius discomfort, headaches, and reduced tolerance for sustained visual tasks. However, forward head posture should not automatically be considered pathological. Postural variations are common, and radiological or visual abnormalities do not necessarily indicate pain or tissue damage. Clinical assessment should focus on symptoms, functional limitations, movement tolerance, and the individual's response to different positions.

3.2. Rounded shoulders and upper crossed movement patterns:

Rounded shoulder positioning generally involves increased anterior positioning of the shoulders and altered scapular resting alignment. It may occur during prolonged typing, reading, smartphone use, and activities performed with the arms positioned in front of the body. Some individuals demonstrate reduced endurance of the scapular stabilizing muscles, altered thoracic mobility, and increased activity of superficial cervical and shoulder muscles. These findings may contribute to discomfort during repetitive upper-limb activities. The traditional upper crossed syndrome model describes a combination of altered muscle length and activation patterns involving the cervical, thoracic, and shoulder regions. Although this model can provide a descriptive clinical framework, it should not be used as a universal diagnostic explanation for pain. Muscle imbalance findings must be interpreted alongside functional assessment and individual symptoms.

3.3. Increased thoracic flexion:

Prolonged reading, computer use, and smartphone activities may encourage sustained thoracic flexion. Reduced thoracic extension mobility may influence upper-limb movement, scapular mechanics, and cervical positioning. Individuals with thoracic discomfort may report stiffness between the shoulder blades, fatigue during prolonged sitting, and difficulty maintaining comfortable upper-body positioning. Thoracic mobility exercises, strengthening, and movement variation may be useful components of rehabilitation.

3.4. Sustained lumbar flexion and unsupported sitting:

Lumbar posture varies considerably between individuals and across daily activities. Prolonged unsupported sitting may increase discomfort in some individuals, particularly when combined with low physical activity, repetitive loading, or inadequate recovery. Sustained lumbar flexion is not inherently harmful, and the spine is capable of tolerating a wide range of movement and loading. However, remaining in a single position for extended periods may reduce movement variability and contribute to symptom aggravation in susceptible individuals. Physiotherapists should therefore encourage comfortable sitting arrangements and regular positional changes rather than imposing a rigid requirement to maintain a specific spinal curvature throughout the day.

3.5. Static postural loading and muscular fatigue:

Static muscular activity occurs when muscles generate force without substantial changes in joint position. During prolonged computer work, the cervical extensors, shoulder stabilizers, and trunk muscles may remain active at relatively low levels for extended periods. Although the intensity of muscular activation may be low, sustained activity without adequate recovery can contribute to perceived fatigue and discomfort. Repetitive exposure may become particularly problematic when combined with inadequate muscular endurance, psychosocial stress, and limited opportunities for movement. Figure 2 presents the principal postural patterns frequently encountered in young adults and identifies the corresponding physiotherapy assessment and intervention targets, illustrating forward head posture, rounded shoulders, increased thoracic flexion, and sustained sitting positions alongside corresponding physiotherapy intervention targets.

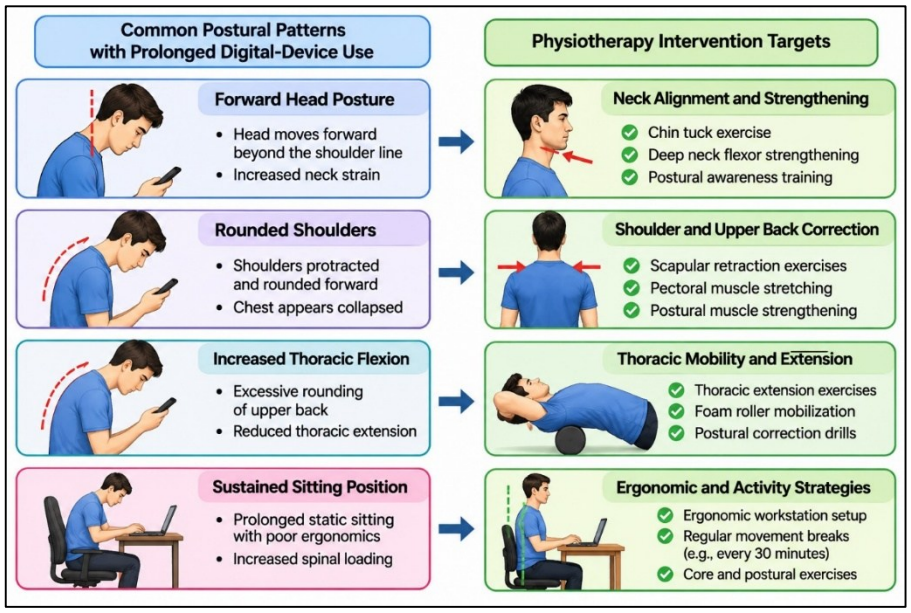


Figure. 2: Common postural patterns associated with prolonged digital-device use and sedentary activities

4. Epidemiology and patterns of musculoskeletal pain in young adults:

Musculoskeletal pain in young adults may involve multiple anatomical regions, including the cervical spine, shoulders, thoracic region, lumbar spine, wrists, and upper extremities. The prevalence of symptoms varies according to the population studied, age group, occupation, educational demands, measurement instruments, and duration of symptom reporting.

4.1. Neck pain:

Neck pain is frequently reported among individuals who use smartphones and computers for prolonged periods. Symptoms may include cervical stiffness, muscular discomfort, reduced movement tolerance, and headaches associated with neck dysfunction. The 2025 systematic review examining sedentary behaviour and neck pain reported an overall association of OR = 1.46 (95% CI: 1.33–1.60). Mobile phone-related sedentary behaviour demonstrated a particularly notable association (OR = 1.82), while computer use was also associated with increased risk (OR = 1.23). These findings indicate that the nature and duration of sedentary activities may be important considerations in cervical health.

4.2. Low back pain:

Low back pain represents one of the most common musculoskeletal complaints across adult populations. Young adults may experience lumbar discomfort associated with prolonged sitting, inadequate physical conditioning, repetitive lifting, stress, sleep disturbances, and occupational demands. University students may be particularly exposed to prolonged sitting during lectures, examination preparation, and computer-based learning. Inadequate classroom furniture and limited movement opportunities may further contribute to discomfort. Alaca et al. (2025) reported that sitting behaviour, fewer breaks, and static sitting were important factors identified in studies examining low back pain among office workers. Nevertheless, the relationship between sitting duration and pain is not completely consistent, suggesting that individual characteristics and exposure patterns should also be evaluated.

4.3. Shoulder and upper back pain:

Shoulder and upper back discomfort may occur because of sustained upper-limb positioning, repetitive computer activities, inadequate scapular muscle endurance, and limited thoracic movement variation. Individuals may report fatigue around the upper trapezius, rhomboid, and posterior shoulder regions. Symptoms may become more noticeable during prolonged typing, reading, or overhead activities.

4.4. Wrist and upper-limb complaints:

Extended keyboard and mouse use may expose the wrist and forearm to repetitive movements and sustained positioning. Some individuals experience discomfort, fatigue, or tingling symptoms associated with upper-limb musculoskeletal conditions. Assessment should distinguish general muscular discomfort from specific

peripheral nerve or tendon disorders. Persistent numbness, progressive weakness, and sensory disturbances require appropriate clinical evaluation.

4.5. Multisite musculoskeletal pain:

Some young adults experience symptoms in more than one anatomical region. Multisite pain may influence daily activity, sleep, concentration, and participation in recreational and occupational tasks. The presence of pain across multiple body regions emphasizes the importance of evaluating general physical activity, psychological well-being, sleep, and functional capacity rather than treating every painful region as an independent mechanical problem.

5. Pathophysiological mechanisms linking sedentary behaviour and musculoskeletal pain:

5.1. Altered muscular loading:

Prolonged static positions may influence the distribution of muscular activity across the cervical, thoracic, and lumbar regions. When individuals maintain a particular position for extended periods, selected muscle groups may remain continuously active while opportunities for muscular recovery become limited. The resulting fatigue and discomfort may influence movement behaviour and reduce tolerance for sustained activities. However, pain cannot be explained solely by muscular fatigue, and similar postural exposures may produce different symptoms among individuals.

5.2. Reduced muscular endurance:

Muscular endurance represents the capacity to maintain or repeatedly generate force over time. Individuals with limited cervical, scapular, abdominal, and spinal extensor endurance may experience greater difficulty tolerating prolonged occupational or academic activities. Reduced physical conditioning may also contribute to fatigue during daily activities. Progressive strengthening and endurance training can improve the capacity of the musculoskeletal system to tolerate functional demands.

5.3. Reduced movement variability:

The human musculoskeletal system is designed to accommodate a variety of positions and movement patterns. Prolonged sitting may reduce opportunities for changing joint positions and distributing mechanical loads across different tissues. Movement variability is therefore an important component of musculoskeletal health. Encouraging regular changes between sittings, standing, walking, and other activities may help reduce sustained exposure to a single position.

5.4. Neuromuscular adaptations:

Repeated exposure to specific movement patterns may influence muscle recruitment strategies and coordination. For example, individuals with recurrent neck discomfort may demonstrate altered cervical muscle activation and reduced movement confidence. Motor-control exercises may help improve coordination, endurance, and functional movement performance. Nevertheless, rehabilitation should avoid assuming that every individual with pain has an identifiable muscular imbalance.

5.5. Pain sensitization and altered pain processing:

Persistent musculoskeletal pain may involve changes in peripheral and central nervous system processing. In some individuals, repeated nociceptive input, stress, poor sleep, and psychological distress may contribute to increased pain sensitivity. These mechanisms help explain why the severity of pain does not always correspond directly to the amount of structural or postural alteration observed during examination.

5.6. Psychosocial influences:

Academic stress, occupational pressure, anxiety, low mood, fear of movement, and negative expectations may influence pain perception and recovery. Young adults experiencing examination stress or demanding employment schedules may demonstrate increased muscular tension, reduced sleep quality, and decreased participation in physical activity. A biopsychosocial approach is therefore essential for comprehensive musculoskeletal management.

6. Major risk factors for musculoskeletal pain in young adults:

The development of musculoskeletal symptoms is multifactorial. Several risk factors may operate simultaneously, increasing the likelihood of discomfort and functional limitations.

Table. 1: Major lifestyle, postural, physical, and psychosocial risk factors associated with musculoskeletal pain in young adults

Risk factor	Common exposure or characteristic	Potential musculoskeletal consequence
Prolonged sitting	Extended academic or occupational sitting	Sustained loading and discomfort
Excessive smartphone use	Repeated downward viewing and static neck positioning	Cervical and shoulder discomfort
Poor workstation arrangement	Inappropriate screen, chair, and desk height	Increased postural demands
Physical inactivity	Insufficient aerobic and strengthening activity	Reduced muscular endurance
Reduced movement breaks	Long uninterrupted working periods	Limited recovery and movement variability
Repetitive upper-limb activity	Prolonged typing and mouse use	Forearm, wrist, and shoulder complaints
Inadequate sleep	Irregular sleeping patterns and poor sleep quality	Increased pain sensitivity and fatigue
Psychological stress	Academic and occupational pressure	Increased symptom burden
Low physical conditioning	Limited strength and endurance	Reduced tolerance to functional loading
Multisite pain history	Recurrent symptoms in several anatomical regions	Increased risk of persistent disability

6.1. Individual factors:

Age, sex, body composition, previous pain episodes, physical conditioning, sleep quality, and genetic susceptibility may influence the development of musculoskeletal symptoms. These variables should be considered during clinical assessment without assuming that any single factor determines an individual's pain experience.

6.2. Environmental factors:

Classroom furniture, workstation design, screen positioning, commuting arrangements, and opportunities for movement influence daily postural exposures. Environmental modification may be particularly important for students and young professionals who spend considerable time in structured sitting environments.

6.3. Behavioural factors:

Continuous smartphone use, recreational gaming, reduced exercise participation, and limited movement breaks are potentially modifiable behaviours. Physiotherapists can address these factors through education, behavioural counselling, and individualized activity planning.

6.4. Psychosocial factors:

Stress, anxiety, depression, fear avoidance, and inadequate social support may influence pain severity and rehabilitation outcomes. These factors should be incorporated into the assessment and management process.

7. Clinical assessment of posture and musculoskeletal pain:

Comprehensive assessment is necessary to identify the principal factors contributing to symptoms and establish appropriate physiotherapy goals. Assessment should include subjective evaluation, physical examination, functional testing, and consideration of psychosocial influences.

7.1. Patient history:

The physiotherapist should obtain information regarding symptom onset, duration, anatomical location, intensity, aggravating factors, relieving factors, previous episodes, and functional limitations.

Lifestyle assessment should include:

1. Daily sitting duration and patterns.

2. Smartphone, tablet, and computer usage.
3. Frequency of movement breaks.
4. Occupational and academic activities.
5. Weekly exercise participation.
6. Sleep duration and quality.
7. Stress levels and psychological well-being.
8. Previous injuries and relevant medical history.

7.2. Postural assessment:

Postural assessment may involve observation of head position, shoulder alignment, thoracic curvature, pelvic positioning, and spinal movement. Assessment can be performed in sitting, standing, and task-specific positions. Photographic posture analysis may be useful for monitoring changes over time, provided that measurements are standardized. However, postural photographs should not be used independently to diagnose the cause of pain.

7.3. Range-of-motion assessment:

Cervical, thoracic, lumbar, and shoulder range of motion should be assessed according to the individual's presenting symptoms. Active movement testing may identify stiffness, movement restrictions, pain provocation, and functional limitations.

7.4. Muscle strength and endurance testing:

Relevant tests may include cervical flexor endurance, scapular muscle strength, trunk endurance, hip strength, and functional lower-limb assessment. Testing should be selected according to the clinical presentation rather than applying an identical battery to every patient.

7.5. Functional assessment:

Functional assessment identifies how symptoms influence daily activities. Relevant measures may include:

1. Neck Disability Index.
2. Oswestry Disability Index.
3. Roland-Morris Disability Questionnaire.
4. Numeric Pain Rating Scale.
5. Patient-Specific Functional Scale.
6. Patient-Reported Outcomes Measurement Information System measures.

These instruments can help establish baseline status and monitor rehabilitation outcomes.

7.6. Red flags and referral considerations:

Physiotherapists should screen for symptoms suggesting serious underlying conditions. These include progressive neurological deficits, significant trauma, unexplained weight loss, fever, suspected infection, history of malignancy with concerning new symptoms, and other features requiring medical assessment. Persistent or progressive numbness, significant weakness, bowel or bladder dysfunction, saddle sensory disturbance, or other signs of possible serious neurological involvement require urgent medical evaluation.

8. Physiotherapy-based interventions for musculoskeletal pain:

Physiotherapy management should focus on improving physical capacity, reducing symptom-related limitations, restoring functional movement, and developing sustainable self-management strategies. Treatment should be individualized according to clinical presentation, patient preferences, occupational requirements, and functional goals.

8.1. Therapeutic exercise:

Exercise therapy represents a central component of contemporary musculoskeletal rehabilitation. It can improve muscular strength, endurance, movement confidence, physical conditioning, and functional capacity. Exercise programmes should incorporate progressive loading, appropriate recovery, and regular reassessment. The objective is not simply to correct posture but to improve the individual's ability to tolerate everyday physical demands.

8.2. Cervical stabilization exercises:

Cervical stabilization exercises target the coordination and endurance of deep and superficial cervical muscles. Common exercises include gentle cranio-cervical flexion, controlled cervical retraction, and graded cervical movement activities. These exercises may be useful for individuals with neck pain and impaired cervical muscle endurance. Progression should be based on symptom response, movement quality, and functional improvement.

8.3. Scapular stabilization exercises:

Scapular strengthening may include:

1. Resistance-band rows.
2. Scapular retraction exercises.
3. Wall slides.
4. Serratus anterior activation.
5. Lower trapezius strengthening.
6. Controlled shoulder external rotation.

These exercises aim to improve shoulder girdle strength and endurance during functional upper-limb activities.

8.4. Thoracic mobility exercises:

Thoracic mobility exercises may help individuals who demonstrate restricted thoracic movement or discomfort during prolonged sitting. Examples include seated thoracic extension, open-book rotations, quadruped thoracic rotation, and controlled extension over a foam roller. The purpose is to improve movement capacity rather than maintain a permanently extended thoracic position.

8.5. Core stabilization and trunk strengthening:

Trunk strengthening may improve the capacity to perform sitting, lifting, walking, and other functional activities. Exercises may include modified planks, bird-dog movements, bridges, dead-bug exercises, and progressive trunk resistance training. The selection of exercises should depend on the patient's functional limitations and tolerance.

8.6. Aerobic conditioning:

Walking, cycling, swimming, and other aerobic activities may improve cardiovascular fitness and contribute to general musculoskeletal health. Regular aerobic exercise is particularly important for individuals with low physical activity levels. Gradual progression can improve exercise tolerance and support participation in daily activities.

8.7. Flexibility and mobility training:

Targeted mobility exercises may be prescribed for individuals demonstrating relevant movement restrictions. These may include pectoral stretching, cervical mobility, hip flexor stretching, hamstring mobility, and thoracic rotation. Stretching should be selected according to clinical findings rather than prescribed routinely to every individual with postural complaints.

8.8. Manual therapy:

Manual therapy may include mobilization, soft tissue techniques, and other therapist-delivered interventions intended to improve short-term symptom management and movement tolerance. It should generally be incorporated alongside active rehabilitation rather than used as an isolated long-term treatment strategy. The 2021 low back pain clinical practice guideline supports selected manual therapy approaches alongside appropriate exercise and education (George et al., 2021).

8.9. Motor-control training:

Motor-control exercises focus on movement coordination, control, and the integration of muscular activity during functional tasks. They may be useful for individuals demonstrating movement-control impairments or difficulty performing specific activities. Training may progress from controlled isolated movements to more complex functional tasks involving the trunk, pelvis, and upper limbs.

8.10. Pain neuroscience education:

Pain neuroscience education explains the complex relationship between the nervous system, tissue loading, psychological influences, and pain perception. It can help patients understand that pain does not always

indicate ongoing tissue damage. Education should encourage appropriate movement, reduce unnecessary fear, and support active participation in rehabilitation.

9. Ergonomic modification and postural education:

Ergonomic modification is an important component of prevention and rehabilitation for individuals with prolonged academic or occupational sitting. However, ergonomic advice should be individualized and should not imply that one particular workstation arrangement will eliminate all musculoskeletal pain.

9.1. Computer workstation modification:

A workstation should allow the individual to work comfortably without excessive reaching, sustained neck rotation, or unnecessary shoulder elevation. The monitor should be positioned at a comfortable viewing height and distance. The keyboard and mouse should be placed to permit relaxed shoulder positioning and supported forearms where appropriate. The chair should provide adequate support and allow comfortable foot placement. However, regular positional variation is more important than attempting to maintain a perfectly standardized sitting posture throughout the day.

9.2. Smartphone ergonomics:

Smartphone users can reduce sustained neck flexion by raising the device closer to eye level when practical, supporting the arms, changing positions, and taking frequent breaks. Long periods of uninterrupted scrolling should be replaced with varied activities and opportunities for movement. Voice-based communication and other hands-free options may reduce repetitive device handling in appropriate situations.

9.3. Movement breaks:

Movement breaks provide opportunities to interrupt prolonged sitting and introduce changes in muscular activity. Brief periods of standing, walking, gentle mobility exercises, and postural variation can be incorporated into academic and occupational routines. A practical strategy is to introduce short movement opportunities approximately every 30–60 minutes, adjusted according to the individual's symptoms and work demands. This is a practical behavioural recommendation rather than a universally established therapeutic threshold.

9.4. Sit-stand strategies:

Alternating between sitting and standing may increase movement opportunities. However, prolonged standing can also produce discomfort when performed continuously. Therefore, the preferred strategy is to alternate between comfortable sitting, standing, walking, and other movements.

9.5. Educational interventions:

Education should emphasize:

1. The importance of regular movement.
2. Comfortable and adjustable workstation arrangements.
3. Gradual development of physical activity.
4. Appropriate exercise participation.
5. Sleep and recovery.
6. Self-monitoring of symptoms.
7. Avoidance of unnecessary fear related to normal spinal movement.

10. PHYSIOTHERAPY MANAGEMENT OF REGION-SPECIFIC MUSCULOSKELETAL PAIN:

10.1. Management of neck pain:

Management of neck pain should include assessment of cervical movement, muscle endurance, shoulder girdle function, neurological status, and functional limitations. An individualized programme may incorporate cervical strengthening, deep cervical flexor training, scapular stabilization, thoracic mobility, aerobic activity, and education regarding screen-related behaviour. The 2017 clinical practice guideline by Blanpied et al. provides evidence-informed recommendations for evaluating and managing neck pain. More recent research also supports the use of exercise-based approaches for office workers with chronic neck pain, although the magnitude of benefit varies between interventions and populations (Jones et al., 2024).

10.2. Management of low back pain:

Low back pain rehabilitation should emphasize maintaining appropriate activity, progressive strengthening, trunk endurance, aerobic conditioning, and functional movement training. The 2021 clinical practice guideline by George et al. recommends a range of exercise interventions for chronic low back pain, including strengthening, endurance, aerobic, movement-control, and multimodal exercise approaches. Physiotherapists should also assess hip mobility, lower-limb strength, lifting strategies, and the individual's tolerance for prolonged sitting and standing.

10.3. Management of shoulder discomfort:

Shoulder rehabilitation may include scapular strengthening, rotator cuff conditioning, thoracic mobility, and graded upper-limb functional activities. The programme should be directed by the underlying clinical presentation. Persistent weakness, marked restriction of movement, or suspected structural pathology may require further assessment.

10.4. Management of upper-limb discomfort:

Management may include activity modification, graded strengthening, tendon-loading exercises where indicated, ergonomic guidance, and assessment for peripheral nerve involvement. The physiotherapist should distinguish nonspecific muscular discomfort from specific neurological and tendon-related conditions.

11. Integrated physiotherapy-based rehabilitation model:

A comprehensive rehabilitation programme should combine physical conditioning, postural education, ergonomic modification, movement breaks, and behavioural strategies. This integrated approach recognizes that musculoskeletal pain is influenced by multiple interacting factors. The programme should begin with a detailed assessment of symptoms, activity patterns, functional limitations, and individual goals. Based on these findings, the physiotherapist can establish a personalized intervention plan involving symptom management, mobility restoration, strengthening, movement retraining, and long-term self-management.

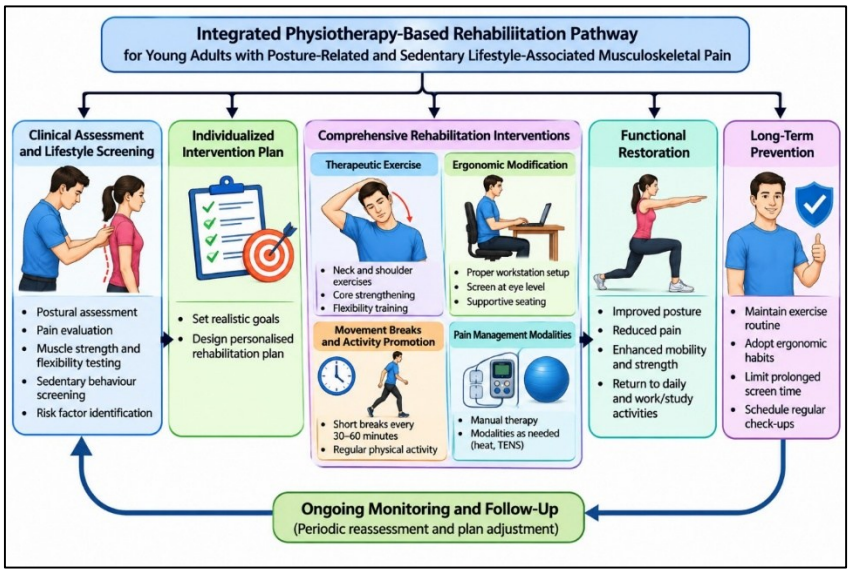


Figure. 3: Integrated physiotherapy-based rehabilitation pathway for young adults with posture-related and sedentary lifestyle-associated musculoskeletal pain, progressing from clinical assessment and lifestyle screening through individualized exercise, ergonomic modification, movement breaks, functional restoration, and long-term prevention

Phase I: Initial assessment and symptom management:

The first phase focuses on identifying symptoms, functional limitations, relevant risk factors, and possible contraindications to exercise. Interventions may include education, comfortable movement, gentle mobility exercises, and appropriate modification of aggravating activities.

Phase II: Mobility and muscular activation:

The second phase emphasizes restoration of relevant movement capacity and activation of muscles required for functional activities. Exercises may target cervical control, thoracic mobility, scapular coordination, and trunk activation.

Phase III: Progressive strengthening and endurance:
The third phase introduces progressive resistance training and muscular endurance activities. Exercise intensity should increase gradually according to tolerance and functional goals.

Phase IV: Functional rehabilitation:
Functional training incorporates activities relevant to academic, occupational, recreational, and domestic requirements. Examples include prolonged computer work with appropriate movement variation, lifting, carrying, walking, and sports-related activities.

Phase V: Long-term prevention and self-management:
The final phase focuses on maintaining physical activity, independent exercise participation, ergonomic awareness, and effective symptom-management strategies. Patients should be encouraged to continue physical activity even after symptoms improve, because long-term musculoskeletal health depends on sustainable behavioural changes.

12. Role of physiotherapy in prevention among university students and young professionals:
Physiotherapy services should extend beyond the treatment of established musculoskeletal disorders. Preventive interventions can be incorporated into educational institutions, workplaces, community health programmes, and digital health platforms.

12.1. University-based screening programmes:
Universities can introduce screening programmes to identify students experiencing recurrent neck, shoulder, and lower back discomfort. Screening should include lifestyle assessment, physical activity patterns, symptom questionnaires, and functional evaluation when clinically indicated. Students identified with significant symptoms should be referred for appropriate assessment rather than receiving only generalized posture-correction advice.

12.2. Physiotherapy awareness programmes:
Educational programmes can improve awareness regarding the relationship between prolonged sitting, physical inactivity, movement variability, and musculoskeletal health. Workshops may include practical demonstrations of workstation adjustment, exercise techniques, smartphone use strategies, and movement-break routines.

12.3. Workplace rehabilitation programmes:
Young professionals working in computer-based occupations may benefit from workplace physiotherapy programmes incorporating exercise sessions, ergonomic assessment, physical activity promotion, and early identification of symptoms.

12.4. Community-based physical activity initiatives:
Community programmes can encourage participation in walking groups, recreational sports, cycling, resistance exercise, and other accessible physical activities. These initiatives can support the development of active lifestyles during early adulthood and reduce dependence on sedentary recreational behaviour.

13. Digital physiotherapy and emerging technologies:
Technological advances are creating new opportunities for monitoring physical activity, delivering exercise programmes, and supporting behavioural change.

13.1. Mobile health applications:
Mobile health applications can provide exercise instructions, activity reminders, symptom tracking, and educational content. These applications may help individuals maintain consistency with prescribed exercises and movement-break routines. However, the effectiveness of an application depends on usability, adherence, individualized recommendations, and clinical relevance.

13.2. Wearable activity monitors:

Wearable devices can estimate daily steps, physical activity levels, and sedentary periods. These data may help physiotherapists identify behavioural patterns and establish realistic activity goals. Wearables should be considered supportive tools rather than diagnostic instruments for musculoskeletal pain.

13.3. Artificial intelligence-based posture monitoring:

Artificial intelligence and computer-vision technologies are increasingly being explored for identifying prolonged static postures and providing movement reminders. Future systems may integrate workstation cameras, wearable sensors, and activity-monitoring platforms to identify patterns of prolonged inactivity. However, automated systems must avoid presenting normal postural variation as pathological. Their clinical value should be established through appropriate validation and patient-centred outcome studies.

13.4. Tele-physiotherapy:

Tele-physiotherapy can improve access to rehabilitation for students and young professionals who experience difficulties attending in-person appointments. Remote consultations may include symptom evaluation, exercise demonstrations, functional monitoring, and follow-up education. Nevertheless, patients requiring hands-on examination or urgent assessment should be directed to appropriate face-to-face services.

14. Outcome measures for evaluating physiotherapy interventions:

The success of rehabilitation should be evaluated using measurable clinical and functional outcomes rather than relying exclusively on visual postural changes.

Table. 2: Recommended clinical and functional outcome measures for assessing musculoskeletal health and physiotherapy intervention effectiveness in young adults

Outcome domain	Assessment tool	Clinical purpose
Pain intensity	Numeric Pain Rating Scale	Measures perceived pain severity
Neck-related disability	Neck Disability Index	Evaluates functional limitations associated with neck pain
Low back disability	Oswestry Disability Index	Measures disability related to low back pain
Back-related function	Roland-Morris Disability Questionnaire	Assesses activity limitations
Functional improvement	Patient-Specific Functional Scale	Measures progress in personally relevant activities
Physical activity	International Physical Activity Questionnaire	Evaluates activity patterns
Sedentary behaviour	Sedentary Behaviour Questionnaire	Estimates sedentary exposure
Muscular endurance	Region-specific endurance tests	Evaluates muscular performance
Cervical mobility	Cervical range-of-motion assessment	Measures movement capacity
Shoulder function	Shoulder Pain and Disability Index	Evaluates shoulder-related limitations
Quality of life	SF-12 or SF-36	Assesses general health-related quality of life
Patient confidence	Self-efficacy questionnaires	Evaluates confidence in managing symptoms

14.1. Pain intensity:

Pain intensity can be monitored using the Numeric Pain Rating Scale. Measurements should be collected at baseline and appropriate follow-up intervals.

14.2. Functional disability:
Condition-specific measures can help identify improvements in activities such as sitting, lifting, working, studying, and performing recreational tasks.

14.3. Physical activity and sedentary exposure:
Activity questionnaires, step counts, and wearable monitoring may help evaluate changes in daily movement patterns.

14.4. Muscular performance:
Strength and endurance testing can demonstrate improvements in physical capacity. Changes should be interpreted in relation to functional goals and symptom response.

14.5. Quality of life:
Quality-of-life assessment provides a broader understanding of rehabilitation outcomes and the influence of musculoskeletal pain on daily participation.

15. Comparison of physiotherapy-based interventions:
Different interventions target different components of musculoskeletal dysfunction. A combined programme may be more clinically appropriate than relying on a single treatment approach.

Table. 3: Comparison of physiotherapy-based interventions for managing posture-related and sedentary lifestyle-associated musculoskeletal pain in young adults

Intervention	Main therapeutic objective	Potential clinical benefits	Important considerations
Cervical stabilization	Improve cervical muscle control	Better cervical endurance and movement tolerance	Individualize exercise intensity
Scapular strengthening	Improve shoulder girdle capacity	Improved upper-limb function	Progress resistance gradually
Thoracic mobility	Improve thoracic movement	Reduced movement restriction	Avoid unnecessary forced stretching
Core strengthening	Improve trunk capacity	Better functional loading tolerance	Integrate functional movements
Aerobic exercise	Improve general conditioning	Improved fitness and activity participation	Follow progressive exercise principles
Motor-control training	Improve movement coordination	Better movement confidence	Select according to clinical findings
Manual therapy	Support short-term symptom management	Improved movement tolerance in selected patients	Combine with active rehabilitation
Ergonomic modification	Reduce prolonged unfavourable exposure	Improved working comfort	Avoid rigid posture prescriptions
Movement breaks	Interrupt prolonged sitting	Increased daily movement variation	Establish realistic routines
Pain neuroscience education	Improve pain understanding	Reduced fear and improved self-management	Use alongside active treatment
Tele-physiotherapy	Improve rehabilitation access	Flexible follow-up and exercise support	Ensure appropriate clinical screening

16. Challenges and limitations in current physiotherapy practice:

16.1. Lack of standardized assessment protocols:
There is considerable variation in the methods used to assess posture, sedentary behaviour, screen exposure, and musculoskeletal symptoms. Differences in questionnaires and measurement techniques make direct comparison between studies difficult.

16.2. Difficulty establishing causality:

Many studies examining posture and musculoskeletal pain use cross-sectional designs. Such studies can identify associations but cannot establish whether sedentary behaviour causes pain or whether individuals experiencing pain become more sedentary. Longitudinal research and well-designed intervention trials are required to clarify these relationships.

16.3. Poor long-term adherence:

Young adults may initially participate in exercise programmes but discontinue them because of academic schedules, employment responsibilities, reduced motivation, or limited access to rehabilitation facilities. Physiotherapists should therefore develop flexible and practical exercise programmes that can be incorporated into everyday routines.

16.4. Overemphasis on ideal posture:

Traditional approaches sometimes emphasize maintaining a single ideal sitting posture. However, contemporary rehabilitation recognizes that individuals can adopt different comfortable positions without necessarily experiencing pain. Excessive concern regarding posture may increase fear and unnecessary movement restriction. Physiotherapy education should emphasize movement variability, functional capacity, and individual comfort.

16.5. Limited access to preventive physiotherapy:

Many students and young professionals seek physiotherapy only after symptoms become persistent or interfere with daily activities. Preventive programmes remain insufficiently integrated into educational institutions and workplaces.

16.6. Individual differences in pain experience:

Musculoskeletal symptoms vary considerably between individuals. Factors such as physical conditioning, previous pain, sleep, stress, and environmental exposures influence outcomes. Consequently, standardized treatment programmes may not provide equal benefits to all patients.

17. Future directions in research and clinical practice:

Future research should investigate the interaction between sedentary behaviour, postural exposure, physical activity, and psychosocial factors using longitudinal and experimental research designs. Objective measurement of sitting time, movement variability, and physical activity may improve the accuracy of exposure assessment. Wearable sensors and digital monitoring platforms may also support individualized physiotherapy interventions. Research should place greater emphasis on young adult populations, particularly university students, remote workers, and individuals engaged in prolonged computer-based occupations. Studies should investigate the effectiveness of combined interventions involving progressive exercise, movement breaks, ergonomic education, and behavioural counselling. Another important research priority is the identification of clinically meaningful outcomes. Pain intensity alone may not adequately represent recovery. Future studies should include functional capacity, academic and occupational participation, quality of life, physical activity, and long-term adherence. Physiotherapy practice should increasingly adopt preventive and health-promoting approaches. Rather than concentrating exclusively on correcting visible postural deviations, clinicians should help young adults develop adequate physical capacity, confidence in movement, and sustainable daily activity patterns.

18. PRACTICAL RECOMMENDATIONS FOR YOUNG ADULTS:

The following recommendations can be incorporated into academic, occupational, and recreational routines:

1. Avoid uninterrupted sitting for prolonged periods and introduce regular movement opportunities.
2. Alternate between sitting, standing, and walking according to comfort and activity requirements.
3. Position computer screens at a comfortable viewing height.
4. Avoid prolonged unsupported smartphone use.
5. Participate in regular aerobic physical activity.
6. Include progressive strengthening exercises for the cervical, shoulder, trunk, and lower-limb muscles.
7. Perform mobility exercises when relevant movement restrictions are present.
8. Maintain adequate sleep and recovery habits.
9. Avoid unnecessary fear of normal spinal movement and postural variation.
10. Seek professional assessment when pain becomes persistent, recurrent, or functionally limiting.

The WHO (2020) recommends that adults undertake 150–300 minutes of moderate-intensity aerobic physical activity or 75–150 minutes of vigorous-intensity activity per week, or an equivalent combination, alongside muscle-strengthening activities involving major muscle groups on at least two days per week. These recommendations provide an important foundation for general health promotion, although individual exercise prescriptions should be adapted to health status and functional capacity.

19. Conclusion:

Posture, sedentary behaviour, and musculoskeletal pain represent interconnected challenges for contemporary young adult populations. Increasing dependence on digital technology, prolonged academic and occupational sitting, reduced physical activity, and limited movement opportunities may contribute to the development and persistence of neck, shoulder, thoracic, and lower back complaints. Nevertheless, musculoskeletal pain is multifactorial and cannot be attributed to a single posture or lifestyle exposure. Physical conditioning, previous pain, psychological stress, sleep quality, occupational demands, and individual pain sensitivity also influence clinical outcomes. Physiotherapy provides a comprehensive framework for prevention and management through individualized assessment, progressive strengthening, cervical and scapular stabilization, trunk conditioning, aerobic exercise, mobility training, ergonomic education, and behavioural modification. Movement breaks and postural variation should be encouraged as practical strategies for reducing prolonged static exposure. Importantly, rehabilitation should prioritize functional improvement and sustainable physical activity rather than rigid correction of an assumed ideal posture. Educational institutions, workplaces, healthcare professionals, and community organizations should collaborate to promote active lifestyles and early access to physiotherapy services. Future research should evaluate integrated rehabilitation programmes and identify effective long-term strategies for reducing musculoskeletal pain among young adults. A preventive, individualized, and movement-oriented physiotherapy approach may contribute significantly to improved musculoskeletal health, functional independence, and quality of life during early adulthood.

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