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Smartphone Use and Musculoskeletal Disorders: A Systematic Review of Epidemiological Evidence and Potential on Inflammatory Mechanisms

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HIGHLIGHTS

- Prolonged smartphone use with sustained neck flexion is associated with a high prevalence of neck and shoulder musculoskeletal pain in adults
- Most of the available evidence focuses on biomechanical and postural factors, while direct measurement of inflammatory biomarkers among smartphone users remains limited.
- Low physical activity and prolonged sedentary behavior appear to strengthen the link between intensive smartphone use and musculoskeletal complaints.

ABSTRACT

Smartphone use among adults has increased and often involves prolonged exposure with sustained non-neutral neck posture. Epidemiological studies report a high prevalence of neck and shoulder pain among frequent users. Biomechanical loading of the cervical spine is considered a main mechanism, while inflammatory processes have been proposed as an additional pathway. This systematic review evaluated the association between smartphone use and musculoskeletal complaints, focusing on inflammatory biomarkers as a potential biological mechanism.

The review followed PRISMA 2020 guidelines. Searches were conducted in PubMed and ScienceDirect for peer-reviewed studies published between 2018 and 2025. Eligible studies included adults aged 18 years or older who reported smartphone use exceeding 2 to 3 hours per day. Exposure was commonly assessed using self-report questionnaires or structured surveys. Studies examining neck or shoulder outcomes, posture, or inflammatory biomarkers were included. Observational studies, randomized controlled trials, and ergonomic interventions were eligible.

Thirty studies met the inclusion criteria. Most reported significant associations between prolonged smartphone use, sustained neck flexion, and musculoskeletal pain in the neck and shoulders. Prevalence ranged from moderate to high among students and workers with a daily use of 3 to 9 hours. No included study directly measured inflammatory biomarkers in general smartphone users. Related evidence indicates elevated IL-6 and C-reactive protein in sedentary populations with high device exposure.

INTRODUCTION

Use of mobile devices, especially smartphones, has risen rapidly over the past decade and has become an integral part of daily life among adults. In regions such as East Asia and the Middle East, smartphone ownership and use have increased sharply, with more than 80 percent of adults using smartphones. This widespread use increases exposure to prolonged screen time and sustained non-neutral neck posture, both of which are associated with musculoskeletal strain and related health outcomes. High exposure to improper postures and prolonged screen time, therefore, represents a relevant public health concern (Yoo et al., 2025).

Epidemiological studies show an association between smartphone use and musculoskeletal symptoms that increases with time spent on smartphones. A flexed head posture during smartphone use (text neck) imposes a greater mechanical load on the cervical musculature than a neutral position (Barrett et al., 2020). This mechanical load is plausibly linked to muscle fatigue and tension in the trapezius and levator scapulae muscles, as well as changes in musculoskeletal function that may trigger neck and shoulder pain. A high prevalence of neck pain is observed among active smartphone users, especially in student populations and workers engaged in monotonous tasks, such as prolonged computer use (Maayah et al., 2023; Sirajudeen et al., 2022). Previous studies in smartphone user populations reported a 64.6% prevalence of neck pain and a 42.3% prevalence of shoulder pain associated with smartphone use exceeding five hours per day (Hakami et al., 2024). The 12-month prevalence of neck pain among university students who use smartphones reached approximately 47.4% (Ayhualem et al., 2021). Among adolescents in Iran, the prevalence of neck pain was approximately 21.5%, and smartphone use for more than 6 hours per day was associated with neck pain (Azadvari et al., 2023). These findings indicate a substantial burden of neck symptoms among frequent smartphone users, although reported prevalence varies across populations and levels of daily exposure.

Based on the 2018 Riskesdas data, the prevalence of neck pain in the Indonesian population was approximately 7.3% (Kemenkes RI, 2018). This finding aligns with global evidence showing an increasing burden of neck pain. International burden of disease analyses also place Indonesia among countries with a significant burden of neck pain over the past decade (Shin et al., 2022). In contrast, studies focusing on high-exposure groups report higher prevalence. University and school students represent frequent smartphone users, particularly during periods of online learning, and musculoskeletal complaints appear more common in these populations. A study among university students assessing posture during smartphone use reported a significant association between non-ergonomic posture and musculoskeletal disorders, indicating increased risk in student populations (Hasiholan & Susilowati, 2022).

Several studies explain the association between smartphone use and musculoskeletal complaints primarily due to biomechanical overload. Prolonged device use often promotes head posture, a reduced craniovertebral angle, and increased static load on the neck and shoulder muscles. Repetitive finger and wrist movements during typing or device handling further contribute to muscle tension, soft-tissue fatigue, and scapulothoracic dysfunction (Piruta & Kułak, 2025). Although this biomechanical model explains many acute symptoms, it does not fully account for persistent or chronic pain reported among frequent smartphone users (Elvan et al., 2024; Hakami et al., 2024).

Persistent mechanical strain on the neck and shoulder region may induce local microtrauma and activate low-grade inflammatory responses, a mechanism reported in several chronic musculoskeletal conditions. In line with this mechanism, studies on inflammatory biomarkers in chronic musculoskeletal pain report increased levels of IL-6, TNF- α, and CRP, which contribute to the development of persistent pain

and heightened pain perception. Studies by Hadgraft et al. (2021) and Li et al. (2023) found that IL-6 and CRP are the most frequently used inflammatory markers for evaluating the association between the degree of inflammation and both the intensity and progression of musculoskeletal pain.

Although many studies report an association between smartphone use and non-neutral postures, such as a flexed neck (text neck), and neck and shoulder musculoskeletal symptoms, substantial variation exists across studies. Differences appear in definitions and measurements of smartphone exposure, study populations, pain assessment methods, inflammatory biomarker measurement, and study design. Previous research indicates that forward-flexed posture during smartphone use alone was not significantly associated with neck pain over a one-year period (Correia et al., 2025). However, other research by Chen et al. (2025) reported that excessive smartphone use among more than 10,000 participants increased the risk of neck pain, with an odds ratio of approximately 2.34 and a 95% confidence interval of 1.44 to 3.82. Many studies did not adequately control for confounding factors such as physical activity or sleep quality.

Increasing smartphone use in daily activities is associated with a rise in musculoskeletal symptoms, especially in the neck and shoulder regions. A flexed-neck posture and prolonged use are thought to generate mechanical stress, leading to muscle tension and tissue inflammation. Multiple studies report associations between ergonomic factors in smartphone use and musculoskeletal disorders, yet few combine clinical or biomechanical assessments with evaluations of inflammatory biomarkers to test whether local or systemic inflammatory processes mediate or exacerbate musculoskeletal symptoms related to smartphone use. This systematic review has two objectives. First, to assess epidemiological evidence on the association between smartphone use and musculoskeletal symptoms. Second, to examine available evidence on the potential role of inflammatory biomarkers, including IL-6 and CRP, as biological mechanisms linking digital device exposure with musculoskeletal pain.

MATERIALS AND METHODS

This systematic review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. A literature search was conducted in PubMed and ScienceDirect to identify relevant studies. The search included peer-reviewed articles published between 2018 and 2025. The final search was performed in January 2026. Search terms combined keywords related to smartphone use, musculoskeletal symptoms, posture, and inflammatory biomarkers. Boolean operators were applied to refine the search across databases. The review protocol was not registered in PROSPERO.

Studies were included if they involved human adults aged 18 years or older and examined the association between smartphone use and musculoskeletal outcomes. The duration of smartphone use was typically reported as daily use exceeding 2 to 3 hours, based on self-reported exposure measures used in the included studies. This range reflects the exposure levels commonly reported across the eligible studies rather than a strict predefined eligibility threshold. Eligible study designs included observational studies (cross-sectional and cohort), randomized controlled trials, and ergonomic intervention studies. Outcomes of interest included musculoskeletal symptoms in the neck or shoulder region and inflammatory biomarkers. Only articles published in English or Indonesian were included.

Studies were excluded if they involved animal, translational, or in vitro models. Studies without relevant outcomes were excluded, such as those reporting smartphone use without musculoskeletal or biomarker data. Review articles, editorials, and single case reports were also excluded.

Study selection was conducted by a single reviewer. Titles and abstracts retrieved from the database search were screened for potentially relevant studies. Full-text articles were then assessed according to the predefined inclusion and exclusion criteria. Data extraction was performed by the same reviewer using a

standardized extraction form. Extracted information included study design, population characteristics, sample size, duration of smartphone use, posture-related exposure, reported musculoskeletal outcomes, and inflammatory biomarker findings when available.

A formal risk-of-bias assessment tool was not applied due to heterogeneity in study designs, exposure measurements, and outcome reporting across the included studies. Findings from the included studies were summarized using a narrative synthesis approach. Studies were grouped according to reported musculoskeletal outcomes, posture-related exposures, and evidence of inflammatory biomarkers. Quantitative meta-analysis was not performed due to variability in study designs and outcome measures.

Systematic search in 2 databases: PubMed and ScienceDirect with Boolean Keywords: ("smartphone" OR "mobile phone") AND ("neck pain" OR "shoulder pain" OR "musculoskeletal disorder" OR "text neck") AND ("inflammation" OR "IL-6" OR "TNF-α" OR "CRP"). Selection of search was conducted in two stages: (1) title and abstract screening and (2) full text review based on inclusion and exclusion criteria.

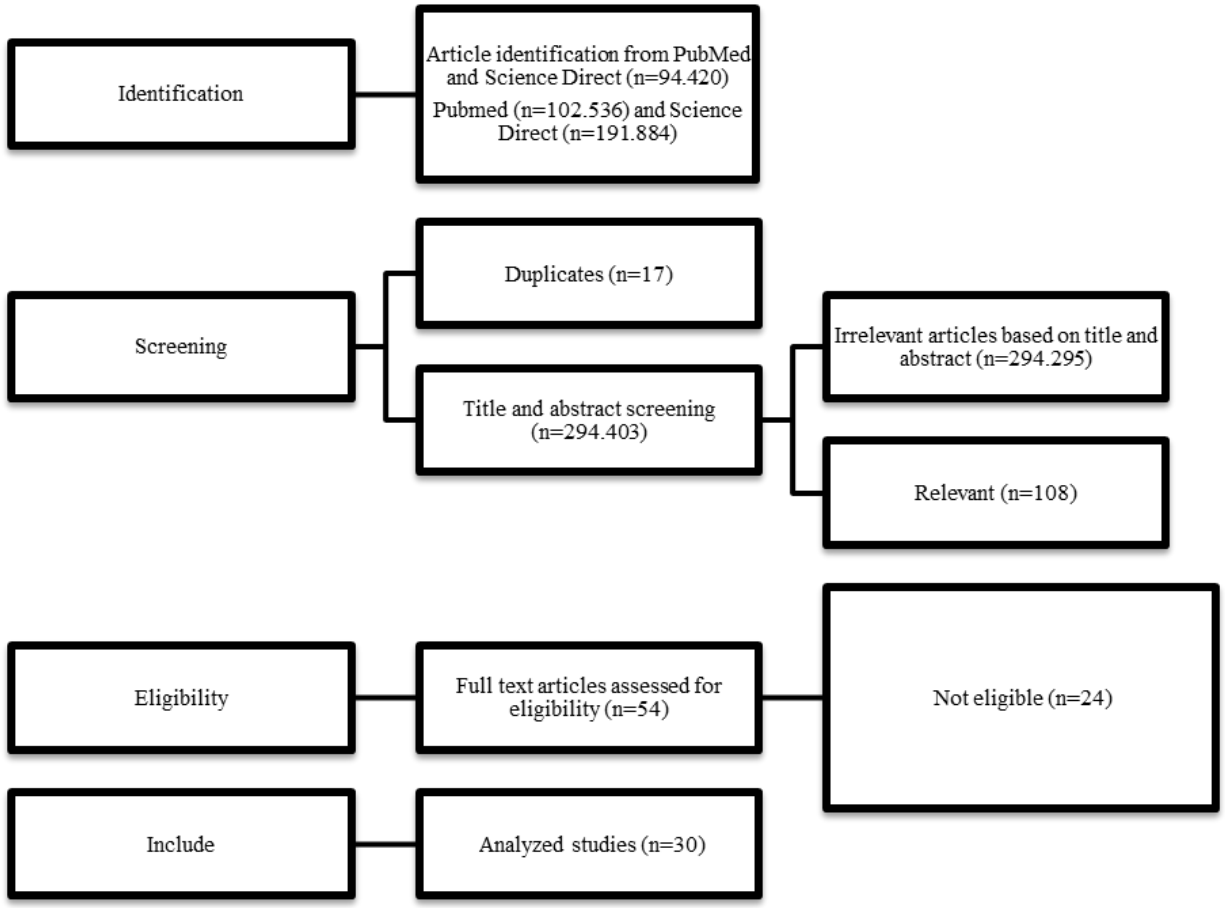

Figure 1. PRISMA flow diagram outlining search strategy for review

RESULTS

Based on the PRISMA literature selection process, a number of studies were identified, screened, and assessed for eligibility. After exclusion of duplicates and non-relevant articles, 30 studies met the inclusion criteria and were included in the qualitative analysis. Extracted information included author, year, country, study design, exposure, outcomes, and relevance of effects.

Table 1. Extraction Table

Author (Year)	Research Design	Sample & Characteristics	Exposure	Results	Direction of Association
(Ahmed et al., 2021)	Cross-sectional	General population; N≈500; age 18–60 years old	Physical activity decreased during lockdown	Increased neck and back pain associated with prolonged sitting	Positive association between smartphone use duration and musculoskeletal complaints
(Ahmed et al., 2022)	Cross-sectional	Students; N≈300; age 18–25 years old	Smartphone use duration	A significant association between high smartphone use and neck and shoulder pain	Positive association between higher smartphone use duration and increased neck and shoulder pain
(Akodu et al., 2018)	Cross-sectional	Physiotherapy students; N≈120; age 18–24 years old	Smartphone addiction	Smartphone addiction reduced the craniovertebral angle, leading to poor neck posture	Higher smartphone addiction is associated with reduced craniovertebral angle and poorer neck posture
(Alghadir et al., 2025)	Cross-sectional	Students; N≈150; age 18–25 years old	Smartphone use duration and neck posture	Smartphone addiction was associated with neck, shoulder, and hand pain, along with changes in neck biomechanics	Higher smartphone addiction is associated with increased musculoskeletal pain and altered neck biomechanics
(Al-Hadidi et al., 2019)	Cross-sectional	Students; N≈200; age 18–25 years old	Smartphone use duration	Smartphone use for >3 hours per day was associated with increased neck pain	Smartphone use exceeding 3 hours per day is associated with a higher prevalence of neck pain
(Anan et al., 2021)	RCT	Office workers; N≈150; age 25–55 years old	Prolonged sitting and work posture	Neck and shoulder pain decreased significantly, and posture improved	Ergonomic intervention reduced neck and shoulder pain and improved posture
(Ayhualem et al., 2021)	Cross-sectional	Students; N≈300; age 18–25 years old	Smartphone use duration and neck posture	Neck pain was prevalent and associated with smartphone use duration	Longer smartphone use duration is associated with higher prevalence of neck pain

Author (Year)	Research Design	Sample & Characteristics	Exposure	Results	Direction of Association
(AzizAli & Sreedharan, 2024)	Cross-sectional	Healthcare workers; N≈200; age 22–55 years old	Work posture and prolonged standing	Good ergonomic knowledge with low implementation in practice	Good ergonomic knowledge reported, but low implementation of ergonomic practices in daily work
(Baek et al., 2020)	RCT	Female farmers; N≈120; age 25–50 years old	Physical work and prolonged standing	Neck and shoulder pain reduced significantly	Ergonomic intervention is associated with a significant reduction in neck and shoulder pain
(Banadaki et al., 2024)	Cross-sectional	Students; N≈200; age 18–25 years old	Smartphone duration hand and wrist posture	Increasing duration and improper posture are associated with hand pain	Longer smartphone use and improper hand posture are associated with a higher prevalence of hand pain
(Bertozzi et al., 2021)	Cross-sectional	Students/Young Adults; N≈150; age 18–25 years old	Smartphone use duration and posture	Neck musculoskeletal pain	No significant association between smartphone use duration or posture and neck pain
(de Souza et al., 2023)	Cross-sectional	School teachers; N≈180; age 25–55 years old	Prolonged sitting and physical activity	Musculoskeletal pain	Sedentary behavior is associated with increased musculoskeletal pain, while higher physical activity is associated with a lower risk
(Depreli & Angin, 2024)	Cross-sectional	Students; N≈200; age 18–25 years old	Smartphone addiction, hand and neck posture	Hand musculoskeletal pain and hand function	Higher smartphone use and poor posture are associated with increased hand pain and reduced hand function
(Farooq et al., 2023)	RCT	Smartphone users; N≈120; age 18–30 years old	Smartphone duration and neck posture	Neck musculoskeletal pain and functional status	Intervention targeting posture and smartphone use associated with a significant reduction in neck pain and improvement in neck function

Author (Year)	Research Design	Sample & Characteristics	Exposure	Results	Direction of Association
(Intipanya et al., 2025)	Cluster-RCT	Office workers; N≈150; age 25–55 years old	Prolonged sitting and neck posture	Incidental neck pain reduced	Ergonomic intervention targeting sitting posture associated with reduced incidence of neck pain
(Kamel et al., 2020)	Cross-sectional	Students/office workers; N≈180; age 18–35 years old	Smartphone duration, hand size, and smartphone	Hand size and smartphone use in relation to hand pain and discomfort	Longer smartphone use and a mismatch between hand size and device are associated with higher hand pain and discomfort
(Khan & Ambati, 2022)	Cross-sectional	Students; N≈120; age 18–25 years old	Typing duration on a smartphone	Neck and hand pain increased with longer typing duration.	Longer typing duration is associated with a higher prevalence of neck and hand pain
(Kurtaran, 2024)	Cross-sectional	Students; N≈200; age 18–25 years old	Smartphone addiction	Smartphone addiction has increased the pain in the neck, shoulders, and hands.	Higher smartphone addiction is associated with increased pain in the neck, shoulders, and hands
(Labeeb et al., 2021)	Cross-sectional	Smartphone users; N≈100; age 18–35 years old	Smartphone duration and hand posture	Early pain detection and hand neuropathy. Neural change was identified.	Prolonged smartphone use and improper hand posture are associated with early hand pain and signs of neuropathy
(Ladeira et al., 2023)	Cross-sectional	Physiotherapy students; N≈150; age 18–25 years old	Smartphone duration and stress	Smartphone overuse is related to neck and shoulder pain. Stress was worsening the pain.	Smartphone overuse is associated with higher neck and shoulder pain, with stress contributing to increased pain severity
(Ma'touq et al., 2023)	Cross-sectional	Students/young adults; N≈200; age 18–30 years old	Smartphone duration and posture	Smartphone use is related to neck, shoulder, and back pain.	Longer smartphone use and non-neutral posture associated with higher prevalence of neck, shoulder, and back pain
(Metin et al., 2023)	Cross-sectional	Students; N≈120; age 18–25 years old	Smartphone duration and posture	Smartphone use disrupts spinal posture and gait, with increased upper back and neck pain	Higher smartphone use is associated with disrupted spinal posture and gait, with increased upper back, neck pain

Author (Year)	Research Design	Sample & Characteristics	Exposure	Results	Direction of Association
(Morcillo-Muñoz et al., 2022)	RCT	People with chronic pain; N≈100; age 25–65 years old	Intervention for chronic pain management	Chronic musculoskeletal pain intensity	Intervention associated with a significant reduction in pain levels
(Naeimi et al., 2024)	RCT	Smartphone users; N≈120; age 18–30 years old	Smartphone duration and neck posture	Reduced neck pain and improved function	Ergonomic or posture intervention associated with reduced neck pain and improved neck function
(Rafiyan et al., 2025)	Cross-sectional	Medical students; N≈150; age 18–25 years old	Smartphone addiction	Increased neck and hand pain prevalence in relation to smartphone addiction.	Higher smartphone addiction associated with increased prevalence of neck and hand pain
(Rahimian et al., 2024)	Cross-sectional	Students; N≈200; age 18–25 years old	Smartphone size, weight, grip	Smartphone characteristics affecting hand pain	Larger smartphone size, heavier weight, and improper grip are associated with increased hand pain
(Tapanya et al., 2021)	Experimental, cross-sectional	Students and workers; N≈100; age 18–35 years old	Smartphone duration and shoulder posture	Shoulder posture affecting neck and shoulder pain	Altered shoulder posture is associated with increased neck and shoulder pain during smartphone use
(Tezcan & Erbay, 2025)	Cross-sectional	Students and workers; N≈80; age 18–35 years old	Smartphone duration	Neck muscle thickness in relation to duration of smartphone use	Longer smartphone use duration is associated with changes in neck muscle thickness
(Thorburn et al., 2021)	Retrospective	Smartphone/ tablet adult users; N≈150; age 18–50 years old	Smartphone use duration and frequency	Neck, shoulder, and hand. Risk increased with increasing duration.	Higher duration and frequency of device use are associated with increased risk of neck, shoulder, and hand pain
(Yoo et al., 2025)	Observational	Adult; N≈80; age 20–50 years old	Neck and shoulder posture	Different scapula patterns related to neck pain	Altered scapular movement patterns associated with higher neck pain

*Study quality classification: RCT, Cluster-RCT (high); cross-sectional, experimental cross-sectional, retrospective, observational (moderate).

DISCUSSION

Study characteristics

A total of 30 studies met the inclusion criteria in this systematic review. The included studies employed cross-sectional designs, randomized controlled trials, cluster randomized controlled trials, and other observational study designs. The studies originated from East Asia and the Middle East. The largest populations included students aged 18 to 25 years, office workers, and healthcare workers. Sample sizes ranged from 80 to 500 participants.

Thirty studies examined associations between smartphone or gadget use and musculoskeletal outcomes in adult populations. Most studies applied cross-sectional designs, while several randomized controlled trials and one retrospective study evaluated ergonomic or posture-related interventions. Sample populations mainly involved students, office workers, and general adult smartphone users.

Across the 30 studies, the majority reported a positive association between prolonged smartphone use, non-neutral posture, and musculoskeletal complaints. Twenty-four studies identified increased prevalence of neck, shoulder, back, or hand pain among individuals with longer smartphone use duration, higher typing activity, or greater levels of smartphone addiction. Neck pain emerged as the most frequently reported outcome, particularly among students and young adults with daily smartphone use ranging from three to nine hours. Several studies also reported hand pain, reduced hand function, or early neuropathic symptoms associated with device grip, typing duration, or smartphone size.

Four randomized controlled trials and one cluster randomized trial evaluated ergonomic or posture interventions. These studies consistently reported reductions in neck or shoulder pain and improvements in posture or functional outcomes following ergonomic modification or posture correction.

Only one cross-sectional study reported no significant association between smartphone duration or posture and neck pain. Differences in measurement methods, exposure assessment, and sample characteristics may explain these inconsistencies.

Overall, current evidence supports a consistent relationship between prolonged smartphone use, poor posture, and increased musculoskeletal complaints in the neck, shoulders, and upper extremities. Intervention studies suggest ergonomic strategies reduce these risks.

67% of the analyzed articles identified smartphone use duration and body posture during use as the main risk factors. Other frequently examined exposure factors included smartphone addiction; physical characteristics of smartphones, such as size, weight, and grip style; sedentary behavior; and low levels of physical activity. Several studies applied biomechanical measurements, including the craniovertebral angle, scapular dyskinesis, and neck muscle ultrasonography, to assess postural effects on the musculoskeletal system.

Affected body parts

Most studies showed a significant association between the intensity or duration of smartphone use and musculoskeletal pain in the neck (94 percent) and shoulders (67 percent) among heavy smartphone users (Chen et al., 2025). Wrist and hand pain and dysfunction were associated with use duration and improper posture in 49 percent of users (Depreli & Angin, 2024). Upper back (26 percent) and lower back pain (18 percent) were also reported, with prolonged smartphone use while sitting increasing back complaints (Chen et al., 2025).

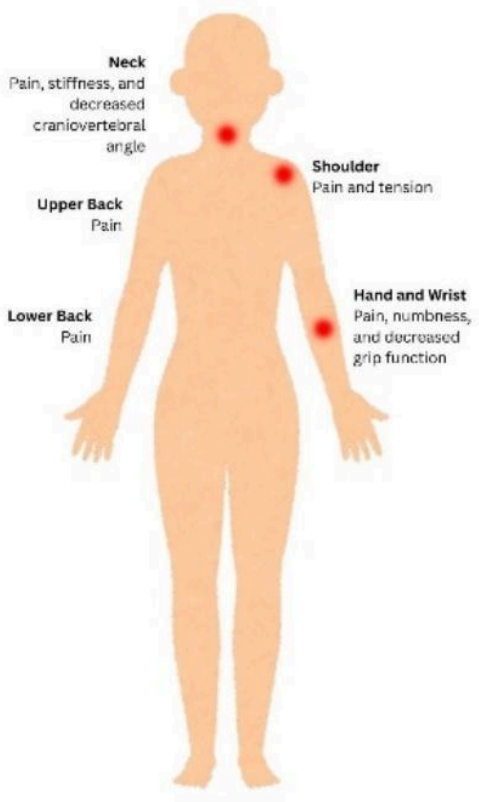

Figure 2. Anatomical musculoskeletal strain associated with smartphone use

Several biomechanical studies have shown that intensive smartphone use reduces the craniovertebral angle, indicating a forward-head posture that contributes to chronic neck pain and changes in neck muscle function (Alghadir et al., 2025; Chen et al., 2025). In addition, psychosocial factors such as academic stress and smartphone addiction worsen musculoskeletal complaints (Kurtaran, 2024). Reported smartphone use duration ranged from 3 to 9 hours per day, with a dominant neck flexion position greater than 30 degrees during typing or screen viewing (Elvan et al., 2024).

Relevance to inflammatory biomarkers

Although all included articles evaluated musculoskeletal complaints related to smartphone use, no study directly measured inflammatory biomarkers such as IL-6, TNF-α, or CRP in the general smartphone user population. However, two relevant studies, although excluded from the final criteria due to differences in population context, reported that smartphone addiction was associated with increased levels of TIMP-1, TIMP-2, MDA, and TAC, which are markers of oxidative stress involved in subclinical inflammation (Alghadir et al., 2025), In addition, longer smartphone use duration and low levels of physical activity were associated with increased IL-6 and CRP levels among university students (Li et al., 2023). These findings support the presence of low-grade inflammatory mechanisms underlying musculoskeletal complaints resulting from prolonged static posture and repetitive biomechanical stress.

No study explicitly measured inflammatory biomarkers in smartphone users. Nevertheless, many studies have identified potential inflammatory mechanisms, including repeated muscle activation and soft-tissue fatigue, increased oxidative stress due to static posture, psychosomatic stress, and comorbidities such as sleep deprivation and low physical activity, which are known to increase proinflammatory cytokine levels (Alghadir et al., 2025).

Table 2. Synthesis of research findings

Synthesis Theme	Main Findings	Evidence & Example Studies (Year)	Scientific Interpretation and Relevance to Inflammatory Biomarkers
Affected Body Part	Musculoskeletal pain most frequently occurred in the neck (94 percent), shoulders (67 percent), hands (49 percent), and upper back (26 percent).	(Chen et al., 2025; Park et al., 2021; Depreli & Angin, 2024)	Neck flexion greater than 30 degrees increases the load on the trapezius and levator scapulae muscles, leading to micro-tears and local low-grade inflammation.
Duration and Intensity of Smartphone Use	Average use of 3 to 9 hours per day was significantly associated with neck, shoulder, and hand pain.	(Hakami et al., 2024; Ayhualem et al., 2021; Alghamdi et al., 2024)	Prolonged static exposure leads to muscle fatigue and chronic mechanical stress, which can trigger systemic IL-6 and CRP expression in sedentary individuals.
Posture and Biomechanics	Smartphone use reduces the craniovertebral angle, increases forward head posture, and causes scapular dysfunction.	(Lee et al., 2021; Zhang et al., 2022; Alghadir et al., 2025)	Improper posture increases mechanical stress on soft tissues, leading to mechanotransduction that triggers the production of proinflammatory cytokines, including IL-6 and TNF-α, through the NF-κB pathway.
Physical Characteristics of Smartphones	Smartphone size, weight, and grip style influence hand and wrist complaints.	(Chen et al., 2025)	Extreme ergonomic factors can cause local ischemia and the release of inflammatory mediators in distal muscle and tendon tissues.
Psychosocial and Behavioural Factors	Academic stress and smartphone addiction increase the risk and perception of musculoskeletal pain.	(Kurtaran, 2024; Park et al., 2021)	Chronic activation of the HPA axis and cortisol elevation increase systemic inflammatory responses through higher IL-6 and CRP levels.
Physical Activity and Sedentary Behaviour	Physical Activity and Sedentary Behaviour. Low physical activity worsens musculoskeletal complaints. Prolonged sitting habits serve as a strong predictor.	(Mohamaddan et al., 2021)	A sedentary lifestyle reduces muscle anti-inflammatory activity, including the myokine IL-10, and promotes chronic low-grade pro-inflammatory conditions.
Biological Evidence and Inflammatory Biomarkers	No studies directly measured biomarkers among general smartphone users. Two external studies reported increased IL-6, CRP, MDA, and TIMP-1/2 among heavy smartphone users.	(Li et al., 2023; Alghadir et al., 2025)	These findings support the hypothesis microinflammation and oxidative stress serve as biological mediators between static posture and musculoskeletal pain.

Synthesis Theme	Main Findings	Evidence & Example Studies (Year)	Scientific Interpretation and Relevance to Inflammatory Biomarkers
Intervention Approaches	Randomized controlled trials using post-facilitation stretching and ergonomic exercises showed significant reductions in neck and shoulder pain.	(Zhang et al., 2022)	Active exercise improves local circulation and reduces IL-6 expression, supporting nonpharmacological approaches for mild inflammation related to static posture.
Clinical Evaluation and Muscle Imaging	Neck muscle ultrasound showed reduced extensor muscle thickness among long-term smartphone users	(Lee et al., 2021)	Muscle atrophy from chronic use reduces load absorption capacity and increases the risk of low-grade inflammation and nociceptive sensitization.
Research Gap	Few studies simultaneously combine clinical measurements, including posture and pain, with inflammatory biomarkers.	(Li et al., 2023)	Longitudinal studies assessing IL-6, TNF-α, CRP, and myokines, including IL-10 and irisin, are needed to elucidate causal links between biomechanical exposure and inflammation.

The relationship between smartphone use and musculoskeletal complaints

The results of this review show a consistent association between long smartphone use duration and prolonged improper posture, which correlates with increased incidence of musculoskeletal pain, particularly in the neck and shoulder regions (Chen et al., 2025). Previous studies showed people with excessive smartphone use had an approximately 2.34-fold higher risk of neck pain compared with non-excessive users (Lee & Son, 2025). Other studies among office workers also showed excessive smartphone use increased the likelihood of neck pain by approximately six-fold (Derakhshanrad et al., 2020). This finding strengthens the view that static mechanical load and repetitive actions during smartphone use, including neck flexion greater than 30 degrees, shoulder elevation, and finger repetition, trigger muscle fatigue, structural changes, and musculoskeletal pain (Chen & Chan, 2023).

Biomechanical mechanism and inflammatory potential

A forward head posture increases the mechanical load on the posterior cervical muscles, ligaments, and other soft-tissue structures. Prolonged neck flexion during smartphone use increases the static load on the posterior cervical muscles, ligamentous structures, and intervertebral discs, leading to significant fatigue (Lee & Son, 2025). Chronic mechanical loading and repetitive muscle tension trigger tissue microtrauma and activate low-grade inflammatory pathways, leading to sustained postural stress (Wu et al., 2024).

Cyclic loading significantly increases expression of pro-inflammatory cytokines, including IL-6, IL-1β, IL-8, and TNF-α, several hours after exposure. This finding supports the hypothesis that repeated mechanical exposure triggers local inflammation in viscoelastic tissues such as ligaments, which, with prolonged exposure, progresses toward chronic inflammation. In addition, human tendon cells and fibroblasts stimulated by cyclic stretching also show increased IL-6 secretion (Skutek et al., 2001). These findings suggest that repetitive mechanical loading, including postural strain during prolonged smartphone

use, may induce inflammatory responses in ligaments and tendon fibroblasts, which generate inflammatory responses under repeated stress. Cellular mechanisms receive further support from previous studies on ligament and tendon arthritis, in which tenocytes or fibroblasts are damaged by excessive mechanical stress. This process releases danger-associated molecular patterns that activate the inflammasome and promote cytokine release, including IL-1β, TNF-α, and IL-6 (Gracey et al., 2020).

Mechanical stress also activates the NF-κB pathway, thereby increasing IL-6 transcription. Previous studies have shown that mechanical stress in tissues induces IL-6 through NF-κB activation (Shen et al., 2025). Experimental studies suggest that chronic mechanical exposure from improper posture during smartphone use may contribute to low-grade inflammation. This response acts as a mediator of tissue fatigue and long-term musculoskeletal pain.

The role of physical activity as a mediator between smartphone use and systemic inflammation was demonstrated in previous research. Earlier studies showed that smartphone use duration and level of dependence correlated with inflammatory biomarkers, including TNF-α, IL-6, and CRP, though not through a direct pathway. This effect was significantly mediated by physical activity level, with reduced physical activity alongside increased smartphone use leading to higher IL-6 and CRP and lower TNF-α (Li et al., 2023). These findings align with the association between sitting time or screen time and inflammatory profiles. Screen-based sedentary behavior showed an independent association with increased IL-6 and CRP after adjustment for moderate-to-vigorous physical activity (Arouca et al., 2019). Other studies have shown that replacing sitting time with physical activity reduces IL-6 and CRP (Phillips et al., 2017).

High smartphone use and reduced physical activity are associated with increased levels of pro-inflammatory cytokines, including IL-6, TNF-α, and CRP. Physical activity acts as a buffer or protective factor against chronic low-grade inflammation triggered by a sedentary lifestyle or digital exposure (Magni et al., 2025).

This review presents epidemiological evidence of an association between excessive smartphone use and musculoskeletal pain. No studies have assessed smartphone use duration, clinical outcomes, and inflammatory biomarkers within a single study design. Most studies used cross-sectional designs, which limit causal inference. Long-term and interventional studies that assess exposure, clinical outcomes, and inflammatory biomarkers together are required to test causal relationships (Barbe & Barr, 2006).

CONCLUSION

This systematic review shows a consistent association between excessive smartphone use and musculoskeletal pain in the working-age population. High exposure patterns are associated with increased discomfort in the neck, shoulders, and back, often related to prolonged neck flexion and sustained device use. The findings highlight the need to manage smartphone use duration and improve ergonomic awareness in daily device use.

No included study directly measured inflammatory biomarkers such as Interleukin-6, Tumor Necrosis Factor-α, or C-reactive protein in general smartphone user populations. This gap indicates limited evidence regarding biological mechanisms linking smartphone exposure with musculoskeletal pain. Future research should apply longitudinal or interventional designs that integrate exposure assessment, clinical musculoskeletal outcomes, and inflammatory biomarker measurements within a single analytical framework.

AUTHOR CONTRIBUTIONS

NAH: Conceptualization, Methodology, Investigation, Formal Analysis, Writing–Original draft. **MU:** Methodology, Validation, Supervision, Writing–Review & Editing.

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COMPETING INTERESTS

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