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Seating, Sitting and Sitting Postures: A Theoretical and Ergonomic Review based on the Homo Sedens Concept

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Abstract

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seating ergonomics | sitting posture | homo sedens | spinal biomechanics | occupational ergonomics

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Abstract

Prolonged sitting has become an inherent characteristic of modern occupational and domestic activities, yet it is increasingly associated with musculoskeletal discomfort and chronic low back pain. Traditional seating ergonomics has long promoted the 90° hip–knee posture as an optimal sitting position; however, emerging evidence challenges its biomechanical suitability. This paper presents a theoretical and ergonomic review of seating and sitting postures, anchored on Mandal's Homo Sedens concept. The review examines the biomechanical limitations of conventional sitting, the physiological implications of static postures, and the ergonomic significance of forward-inclined and dynamic seating configurations. In addition, the paper incorporates a comparative postural framework illustrated in Figure 1, which delineates three primary sitting alignments: the active ergonomic sit, the passive reclined sit (110°–135° trunk–thigh angle), and the C-curve slump posture. The figure highlights their respective impacts on spinal curvature, pelvic orientation, and load distribution. While the neutral S-curve alignment promotes balanced muscular engagement and reduced disc pressure, the slumped C-curve posture is associated with thoracolumbar flexion, cervical strain, and increased mechanical stress on intervertebral structures. By synthesising theoretical principles, ergonomic modelling, and visual analysis, this study underscores the importance of posture variability, spinal alignment, and workstation integration in contemporary seating design. The paper concludes that ergonomically sound seating must prioritize movement, adaptability, and spinal health rather than rigid adherence to fixed postural angles.

Keywords: *seating ergonomics, sitting posture, homo sedens, spinal biomechanics, occupational ergonomics*

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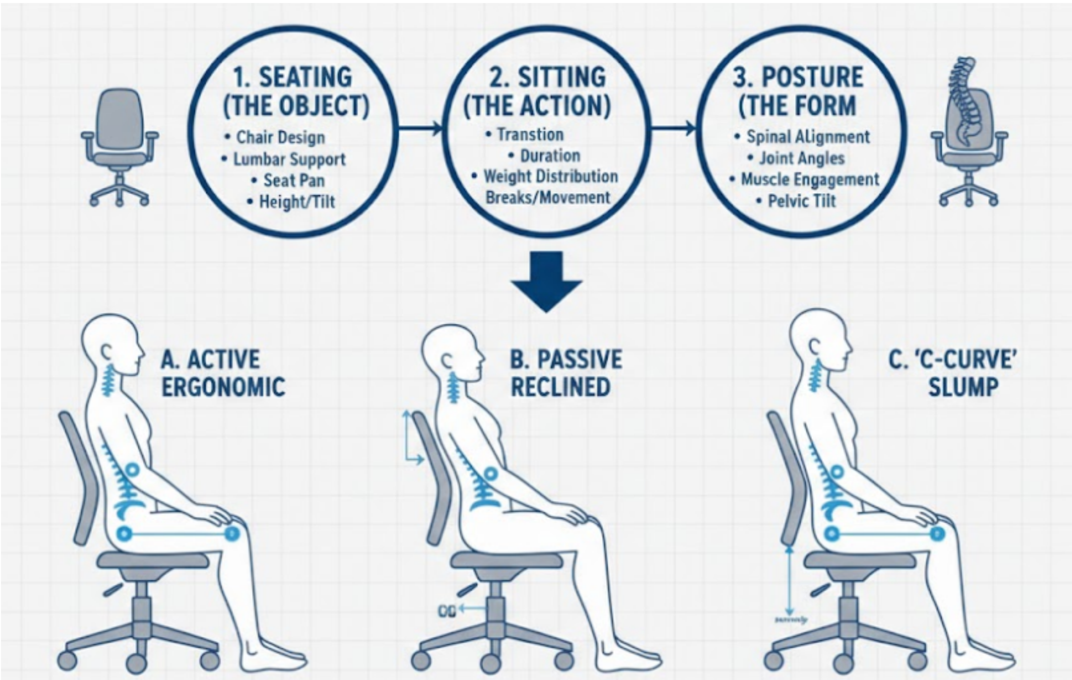

Figure 1. Graphical Abstract

1. Introduction

Sitting represents one of the most dominant postures in contemporary life, especially within office environments, transportation systems, educational settings, and domestic contexts. Although widely practiced, extended periods of sitting have been associated with musculoskeletal strain, deterioration of spinal integrity, and diminished work efficiency (Lis et al., 2007; Beach et al., 2005; Kastelic et al., 2018). Epidemiological findings indicate that sustained seated exposure increases the likelihood of Low Back Pain (LBP), particularly when combined with constrained movement and suboptimal postural alignment (Lis et al., 2007; Roman-Liu et al., 2023). Biomechanically, prolonged sitting has been shown to induce viscoelastic creep in passive spinal tissues, alter lumbar curvature, and modify neuromuscular activation patterns, thereby affecting spinal stability (Beach et al., 2005; Claus et al., 2018).

Historically, ergonomic recommendations promoted static postural correction, commonly endorsing a 90° hip–knee configuration as the ideal seated position. This perspective was grounded in structural alignment principles that emphasized symmetry and neutral spinal positioning (Black et al., 1996; O'Sullivan et al., 2012). However, accumulating evidence challenges the appropriateness of maintaining a fixed 90° posture, demonstrating that sustained static sitting can elevate trunk stiffness, reduce spinal height, and increase perceived discomfort over time (Mörl & Bradl, 2013; Park & Srinivasan, 2021; Waongenngarm et al., 2015). Recent investigations suggest that postural variability and periodic movement may offer greater biomechanical protection than rigid adherence to a singular "optimal" sitting posture (Claus et al., 2018; Van Deursen et al., 1999).

The introduction of Mandal's *Homo Sedens* framework represented a conceptual shift in seating ergonomics by framing sitting as a dynamic activity rather than a static alignment task (Mandal, 1981). Mandal contested the traditional 90° seated model and proposed forward-inclined seating with greater hip extension to better preserve lumbar lordosis. Contemporary biomechanical research aligns with this paradigm, emphasizing dynamic seating solutions, adaptive chair mechanisms, and individualized postural strategies to mitigate discomfort and mechanical strain (De Carvalho, 2015; De Carvalho & Callaghan, 2023; Cho et al., 2023).

Accordingly, this paper examines seating posture from a theoretical standpoint, integrating biomechanical principles with ergonomic design considerations and their implications for modern occupational environments.

2. Theoretical Background: The *Homo Sedens* Concept

The *Homo Sedens* concept portrays modern humans as a population that spends extensive periods in seated positions despite not being evolutionarily adapted to sustained static sitting (Mandal, 1981). Mandal proposed that conventional chair designs and commonly adopted sitting postures generate a typical mechanical stresses on the lumbar spine. In particular, posterior pelvic rotation during relaxed or slumped sitting reduces lumbar lordosis, thereby increasing strain on passive spinal structures and altering load distribution across intervertebral tissues (Mandal, 1981; Beach et al., 2005; Claus et al., 2018). This perspective disputes the traditional notion that sitting is a passive or restorative posture. Rather, it conceptualizes sitting as a biomechanically demanding position that necessitates ongoing neuromuscular regulation and periodic postural modification to maintain spinal integrity (O'Sullivan et al., 2012; Mörl & Bradl, 2013). The theoretical significance of *Homo Sedens* lies in its integration of spinal biomechanics with ergonomic design, emphasizing the importance of lumbar curvature preservation, postural variability, and dynamic interaction between the human body and seating systems (De Carvalho, 2015; Van Deursen et al., 1999). By reframing sitting as an active and adaptive process rather than a static alignment task, the *Homo Sedens* model continues to inform contemporary ergonomic research and seating innovation.

Table 1 provides a critical synthesis of the theoretical foundations underlying the *Homo Sedens* concept (Mandal, 1981), outlining its key contributions to seating ergonomics while examining its methodological and contextual limitations within contemporary occupational settings. The framework's principal contribution lies in redefining sitting as a biomechanically active posture rather than a passive resting position, emphasizing lumbar lordosis preservation, anterior pelvic orientation, and dynamic postural adaptation (Mandal, 1981; O'Sullivan et al., 2012). Subsequent biomechanical and experimental research has reinforced the importance of posture variability and movement during prolonged sitting (Claus et al., 2018; Van Deursen et al., 1999; Park & Srinivasan, 2021).

However, while the *Homo Sedens* model provided an important conceptual shift, it was developed prior to the availability of advanced measurement techniques such as electromyography, radiographic alignment analysis, and finite element modeling, which now offer more detailed insight into spinal loading and neuromuscular responses (De Carvalho et al., 2010; Cho et al., 2023; Mörl & Bradl, 2013). Additionally, contemporary evidence suggests that no single "optimal" sitting posture universally minimizes spinal stress, as inter-individual variability and task-specific demands significantly influence biomechanical outcomes (Claus et al., 2018; Waongenngarm et al., 2015; Roman-Liu et al., 2023). Accordingly, Table 1 situates *Homo Sedens* within the broader evolution of seating biomechanics, acknowledging its foundational theoretical value while recognizing the need for adaptive, movement-oriented, and evidence-based ergonomic strategies in modern occupational environments.

Table 1. Critical analysis of the *Homo Sedens* theoretical framework in seating ergonomics

Theoretical Aspect	Core Proposition (Mandal, 1981)	Ergonomic Significance	Critical Evaluation / Limitations	Reference
Concept of Homo Sedens	Humans are not biologically adapted to prolonged static sitting	Reframed sitting as a biomechanical stressor rather than a neutral posture	Largely conceptual; lacks evolutionary or longitudinal biological validation	Lis et al. (2007); Kastelic et al. (2018); Jochem et al. (2023)
Critique of 90° sitting posture	90° hip–knee posture increases lumbar flexion and disc pressure	Challenged dominant ergonomic standards of the time	Disc pressure data were inferred from earlier studies, not directly measured in the paper	Black et al. (1996); De Carvalho et al. (2010); Roman-Liu et al. (2023)
Pelvic rotation and lumbar lordosis	Posterior pelvic tilt flattens lumbar lordosis, increasing spinal load	Established pelvic orientation as central to seating ergonomics	Individual variability (age, BMI, pathology) not sufficiently addressed	Misir et al. (2019); Claus et al. (2018); Saiklang et al. (2024)
Forward-inclined sitting	Hip angle >90° preserves lumbar curvature and reduces disc compression	Influenced modern dynamic and saddle seating designs	Forward tilt may increase knee loading and is task-dependent	De Carvalho (2015); Cho et al. (2023); Zhao et al. (2026)
Static vs dynamic sitting	Static postures accelerate fatigue and musculoskeletal strain	Introduced posture variability as a design principle	Movement frequency and optimal variability thresholds not quantified	Park & Srinivasan (2021); Van Deursen et al. (1999); Waongenngarm et al. (2015)
Seat–workstation interaction	Seating must be designed as part of a system (seat + desk + task)	Shifted focus from chair-only design to integrated ergonomics	Limited empirical workstation testing in real occupational environments	Azimuddin et al. (2017); Musa (2024); Bai et al. (2024)
Anthropometric adaptability	Fixed seating fails to accommodate human variability	Supported adjustable and customizable seating solutions	Population diversity (gender, ethnicity, disability) underrepresented	Lee (2019); Daniel (2024); Podrekar (2023)
Clinical relevance	Poor seating contributes to low back pain and discomfort	Linked ergonomics to occupational health outcomes	Causal relationships not experimentally established	De Carvalho et al. (2020); Alaca et al. (2025); Jung et al. (2020)

Table 2. Key characteristics and ergonomic limitations of the conventional sitting posture

Aspect	Description	Ergonomic Limitation
Hip–knee angle	Approximately 90° flexion	Promotes posterior pelvic tilt
Pelvic orientation	Posterior rotation of pelvis	Reduces lumbar lordosis
Lumbar spine loading	Increased disc compression	Higher risk of low back pain
Muscle activity	Sustained static activation	Accelerated muscle fatigue
Posture variability	Minimal	Poor load redistribution
Task suitability	Historically standardized	Inflexible for diverse work tasks

3. Biomechanics of Sitting Postures

3.1. Conventional Sitting Posture

In the conventional 90° seated configuration, the hips are flexed at approximately a right angle, a position frequently associated with posterior pelvic rotation and reduction of lumbar lordosis (Black et al., 1996; De Carvalho et al., 2010). This alignment alters normal spinopelvic mechanics and has been shown to increase mechanical loading on lumbar intervertebral discs while shifting stress toward passive spinal tissues (Beach et al., 2005; Roman-Liu et al., 2023). Sustained exposure to this posture may elevate trunk muscle stiffness and reduce spinal height, reflecting viscoelastic creep and neuromuscular adaptation during prolonged sitting (Mörl & Bradl, 2013; Waongenngarm et al., 2015). Over time, these biomechanical changes are associated with increased perceived discomfort, muscular fatigue, and heightened risk of low back pain (Lis et al., 2007; Jung et al., 2020).

Conventional sitting postures characterised by a 90° hip–knee angle have been shown (Figure 2) to promote posterior pelvic rotation and increased lumbar disc loading, thereby contributing to musculoskeletal discomfort during prolonged sitting (Mandal, 1981).

The figure presents a comparative representation of three principal seated postural configurations and their associated biomechanical consequences for spinal health. The **Active Ergonomic Sit** preserves a neutral, physiologically curved S-shaped spinal alignment, typically characterized by approximately 90° hip and knee flexion. When lumbar lordosis is maintained and pelvic positioning remains neutral, spinal loading is more evenly distributed across vertebral and muscular structures, potentially reducing excessive passive tissue strain (Black et al., 1996; De Carvalho et al., 2010; Mörl & Bradl, 2013).

The **Passive Relaxed Sit** involves a reclined trunk position, generally between 110° and 135° trunk–thigh inclination, often accompanied by posterior pelvic rotation. This configuration may reduce certain compressive forces on the lumbar discs through backrest support and redistribution of upper body mass; however, prolonged reliance on this posture can diminish active muscular engagement and alter spinopelvic alignment (Roman-Liu et al., 2023; Park & Srinivasan, 2021). Although reclined seating may temporarily decrease discomfort, static loading patterns remain a concern if posture variability is limited (Lis et al., 2007).

In contrast, the **C-Curve Slump** posture is characterized by thoracolumbar flexion, posterior pelvic tilt, rounded shoulders, and anterior head translation often referred to as "tech-neck." This alignment reduces lumbar lordosis and increases strain on passive spinal tissues, contributing to altered neuromuscular activation and elevated spinal loading (Beach et al., 2005; Jung et al., 2020; Waongenngarm et al., 2015). Sustained flexed sitting has been associated with increased muscle fatigue, spinal creep, and heightened risk of discomfort and chronic low back pain (Claus et al., 2018; Lis et al., 2007).

Together, these postural comparisons highlight the importance of lumbar curvature preservation, movement variability, and appropri-

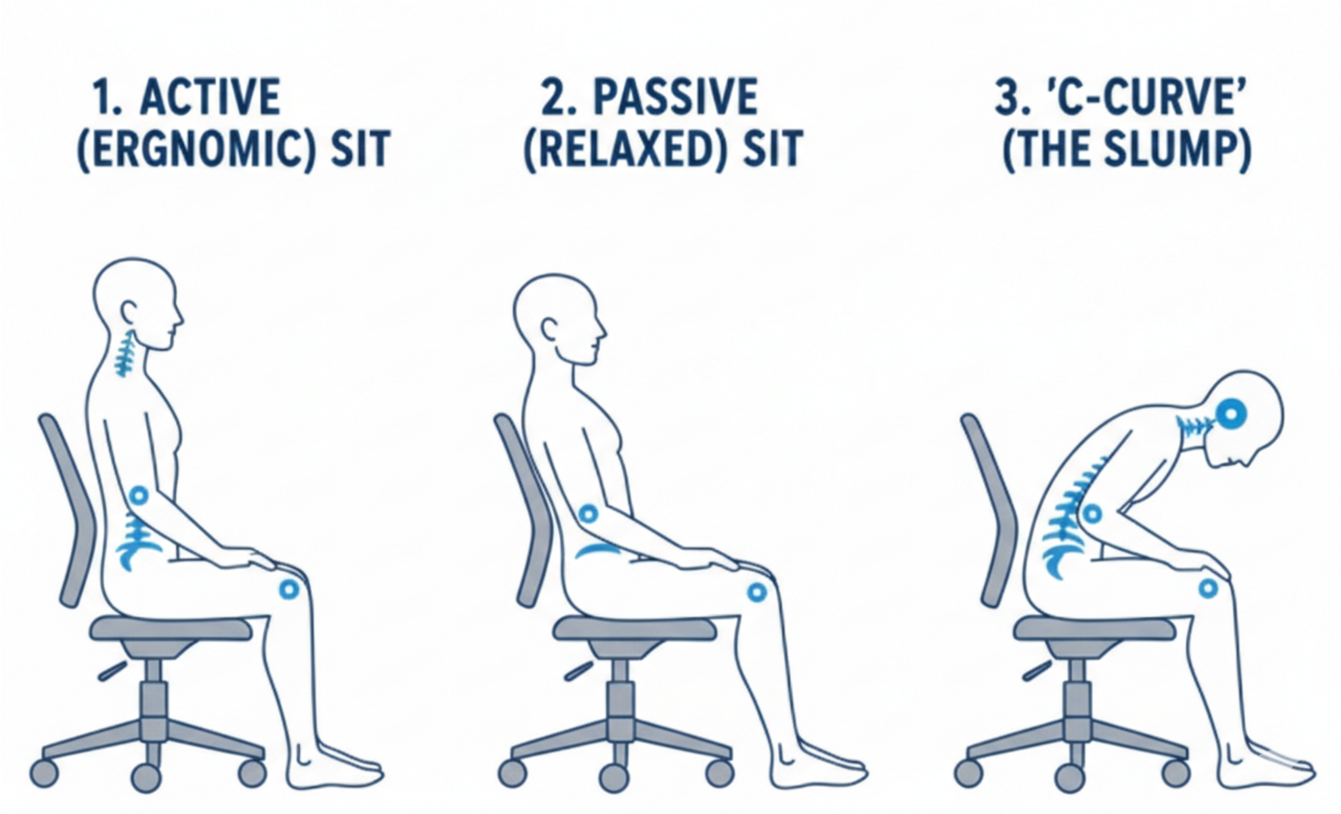

Figure 2. Comparative Analysis of Common Sitting Postures

ate seating design in mitigating the biomechanical risks associated with prolonged sitting.

3.2. Forward-Inclined Sitting

Mandal proposed that increasing the hip angle beyond the conventional 90° configurations typically achieved through a forward-tilted seat surface encourages anterior pelvic rotation and helps maintain physiological lumbar lordosis (Mandal, 1981). By reducing posterior pelvic tilt, this alignment supports more favorable lumbar curvature and may decrease excessive loading on passive spinal structures (De Carvalho et al., 2010; Roman-Liu et al., 2023). Preservation of lumbar lordosis has been associated with more balanced trunk muscle activation and improved postural control during seated tasks (Claus et al., 2018; Mörl & Bradl, 2013).

In addition to its spinal implications, forward-inclined sitting positions the trunk closer to the work surface, potentially reducing excessive thoracic flexion and forward head translation during visual and manual activities (Black et al., 1996; O'Sullivan et al., 2012). By promoting an upright yet dynamically engaged posture (Table 3), this seating configuration may enhance task efficiency while mitigating musculoskeletal strain during prolonged desk-based work (De Carvalho, 2015; Park & Srinivasan, 2021).

3.3. Static versus Dynamic Sitting

Prolonged static sitting, irrespective of whether the posture is considered ergonomically "correct," has been associated with increased muscle fatigue, heightened trunk stiffness, and progressive discomfort (Waongenngarm et al., 2015; Mörl & Bradl, 2013). Sustained immobility may contribute to passive tissue creep and altered neuromuscular activation patterns, thereby compromising spinal stability over time (Beach et al., 2005; Claus et al., 2018). These physiological responses suggest that the detrimental effects of sitting are not solely dependent on posture quality, but also on the absence of movement variability (Lis et al., 2007).

In contrast, dynamic sitting defined by periodic postural adjustments and micro-movements facilitates redistribution of mechanical loads across spinal and muscular structures. Experimental evidence indicates that movement-based seating strategies, including alternating sit–stand patterns and dynamic stimuli, can reduce discomfort and improve trunk mechanical behavior during prolonged tasks (Van Deursen et al., 1999; Park & Srinivasan, 2021). This principle forms the foundation of contemporary ergonomic seating design, which increasingly emphasizes adaptive mechanisms and posture variability rather than rigid fixation in a single "ideal" alignment (De Carvalho, 2015; Cho et al., 2023).

Table 3. Ergonomic characteristics and implications of forward-inclined sitting posture

Aspect	Description	Ergonomic Implication	Reference
Hip–knee angle	Greater than 90°	Opens hip joint, reduces pelvic constraint	Mandal (1981); De Carvalho (2015); Zhao et al. (2026)
Pelvic orientation	Anterior pelvic rotation	Preserves lumbar lordosis	De Carvalho et al. (2010); Misir et al. (2019); Claus et al. (2018)
Lumbar spine loading	Reduced disc compression	Lower risk of low back strain	Roman-Liu et al. (2023); Beach et al. (2005); Cho et al. (2023)
Muscle activity	More evenly distributed activation	Delays onset of fatigue	Mörl & Bradl (2013); Waongenngarm et al. (2015); Park & Srinivasan (2021)
Posture variability	Facilitates micro-movement	Supports dynamic sitting	Van Deursen et al. (1999); Gregory et al. (2006); Bai et al. (2024)
Task suitability	Precision and forward-reach tasks	Improves task efficiency and comfort	Black et al. (1996); Azimuddin et al. (2017); De Carvalho (2015)

Table 4. Comparison of static and dynamic sitting in seated work ergonomics

Aspect	Static Sitting	Dynamic Sitting	Reference
Posture pattern	Fixed or minimally changing posture	Continuous posture variation	O'Sullivan et al. (2012); Bai et al. (2024)
Muscle activity	Sustained isometric contraction	Alternating muscle activation	Mörl & Bradl (2013); Gregory et al. (2006)
Spinal loading	Concentrated and prolonged	Periodically redistributed	Beach et al. (2005); Van Deursen et al. (1999)
Circulation	Reduced blood flow over time	Improved circulation through movement	Park & Srinivasan (2021); Jochem et al. (2023)
Fatigue development	Rapid onset	Delayed onset	Waongenngarm et al. (2015); Claus et al. (2018)
Musculoskeletal risk	Higher risk of discomfort and low back pain	Lower cumulative strain	Lis et al. (2007); Jung et al. (2020)
Ergonomic suitability	Appropriate primarily for short-duration tasks	More suitable for prolonged seated work	De Carvalho et al. (2020); Bai et al. (2024)

4. Ergonomic Design Implications

4.1. Seat Design and Geometry

Ergonomic seating systems should incorporate adjustable seat height, forward-tilt functionality, and appropriately contoured lumbar support to accommodate individual anatomical differences and task-specific demands. Anthropometric design research emphasizes that fixed furniture dimensions often fail to reflect population variability, leading to suboptimal posture and increased musculoskeletal strain (Lee, 2019; Daniel, 2024). In educational and occupational settings, poorly matched seating dimensions have been shown to compromise spinal alignment and contribute to discomfort during prolonged tasks (Podrekar, 2023; Cho, 2020).

Beyond static dimensional fit, seat height and inclination significantly influence lower-limb muscle activation and sit-to-stand mechanics, further underscoring the importance of adjustability (Zhao et al., 2026). Systematic reviews of seating ergonomics likewise highlight the limitations of one-size-fits-all designs and advocate for adaptable configurations that respond to both anthropometric diversity and movement patterns (Bai et al., 2024; Acharya et al., 2023). Even in specialized occupational contexts such as micro-surgery or apparel manufacturing, adjustable seating features have demonstrated measurable benefits in load distribution and posture optimization (Oyama et al., 2022; Dillard & Frazier Schwager, 1997).

Mandal's foundational argument that seating should conform to human anatomy rather than impose restrictive geometric constraints remains central to modern ergonomic theory (Mandal, 1981). Contemporary design approaches increasingly reflect this principle by integrating adaptive mechanisms, sensor-informed feedback, and user-centered evaluation frameworks into seating systems (Gustafsson & Lackner, 2024). Together, these findings reinforce the notion that ergonomic seating must be dynamic, adjustable, and anatomically responsive rather than dimensionally fixed.

4.2. Workstation Integration

Effective seating ergonomics cannot be considered independently of overall workstation configuration. Seat height, desk height, visual demands, and upper-limb task requirements function as an integrated biomechanical system, where misalignment in one component can compromise the effectiveness of the others (Musa, 2024; Azimuddin et al., 2017). In clinical and surgical contexts, mismatched relationships between seat and work surface height have been shown to alter trunk inclination and upper-body loading patterns, thereby increasing musculoskeletal strain despite the use of ergonomically designed chairs (Oyama et al., 2022; Azimuddin et al., 2017).

Anthropometric analyses further demonstrate that discrepancies between seated elbow height, eye level, and desk elevation contribute to compensatory cervical and lumbar postures (Lee, 2019; Daniel, 2024). In occupational environments, such mismatches may lead to sustained forward trunk flexion or shoulder elevation, negating the intended biomechanical advantages of lumbar-supportive seating (Bai et al., 2024). Even in educational settings, improperly coordinated furniture dimensions have been associated with maladaptive postural behaviors during prolonged seated tasks (Podrekar, 2023).

From a systems-design perspective, ergonomic interventions must therefore address the workstation holistically rather than focusing solely on chair features. Reviews of seated work exposures emphasize that task demands, duration, and environmental layout collectively influence musculoskeletal outcomes (De Carvalho et al., 2020; Alaca et al., 2025). Consequently, optimal ergonomic outcomes depend on coordinated adjustments across seating, work surfaces, and task configuration to ensure biomechanical coherence and minimize compensatory loading patterns.

4.3. Task-Dependent Postures

Different occupational tasks impose distinct biomechanical and postural demands. Precision-oriented activities that require fine motor control and close visual engagement may benefit from

Table 5. Analytical summary of seating ergonomics principles derived from Mandal's framework

Domain	Core Principle	Ergonomic Benefit	Critical Consideration
Seat design and geometry	Adjustable height, forward tilt, lumbar support	Accommodates anthropometric variability and spinal alignment	Effectiveness depends on correct adjustment and user awareness
Workstation integration	Seating and desk must function as a system	Prevents posture mismatch and compensatory strain	Limited flexibility in fixed or shared workstations
Task-dependent postures	Posture should vary with task demands	Enhances comfort, efficiency, and musculoskeletal health	Optimal posture-change frequency not clearly quantified
Overall ergonomic strategy	Adaptability over rigidity	Reduces cumulative spinal and muscular load	Requires user education and supportive design

forward-inclined sitting, as this configuration promotes anterior pelvic rotation and facilitates proximity to the work surface (Mandal, 1981; De Carvalho, 2015). In contrast, prolonged computer-based tasks often involve sustained visual focus and repetitive upper-limb activity, conditions under which alternating between upright and moderately reclined postures may help redistribute spinal loading and reduce cumulative tissue strain (Park & Srinivasan, 2021; Van Deursen et al., 1999).

Empirical investigations demonstrate that muscle activation patterns and spinal stiffness vary depending on seated alignment and task exposure, indicating that no single posture consistently minimizes mechanical stress (Claus et al., 2018; Mörl & Bradl, 2013). Additionally, evidence suggests that prolonged maintenance of any fixed posture regardless of its ergonomic classification can contribute to discomfort and neuromuscular fatigue (Waongenngarm et al., 2015; Beach et al., 2005).

Accordingly, contemporary ergonomic theory increasingly emphasizes postural adaptability rather than adherence to a singular "ideal" sitting configuration (O'Sullivan et al., 2012; De Carvalho et al., 2020). Systematic reviews further support the view that task variability, exposure duration, and environmental context mediate the relationship between sitting posture and musculoskeletal outcomes (Bai et al., 2024; Lis et al., 2007). Together, these findings reinforce the principle that effective seating design should enable dynamic adjustment and task-specific alignment rather than impose rigid positional standards.

Table 5 synthesises the core ergonomic principles underlying seat design, workstation integration, and task-dependent posture, illustrating their combined role in promoting adaptable, biomechanically efficient, and health-supportive seated work environments. Contemporary evidence indicates that optimal seating outcomes depend not only on chair geometry but also on coordinated alignment between seat height, desk configuration, and task demands (Azimuddin et al., 2017; Musa, 2024). Adjustable seating parameters and anthropometric compatibility further enhance postural alignment and reduce compensatory spinal loading (Lee, 2019; Daniel, 2024).

Moreover, research emphasizing posture variability and dynamic sitting demonstrates that ergonomic effectiveness is maximized when seating systems facilitate movement and load redistribution rather than enforcing rigid alignment (Park & Srinivasan, 2021; Bai et al., 2024). By integrating these principles, Table 5 underscores the necessity of a systems-based ergonomic approach in which seating design, workstation configuration, and task requirements function synergistically to support musculoskeletal health and sustained occupational performance (De Carvalho et al., 2020; Lis et al., 2007).

5. Relevance to Contemporary Ergonomics

The principles articulated in Mandal's *Homo Sedens* framework remain highly relevant within contemporary ergonomics research, particularly in the context of expanding sedentary occupations and technology-mediated work environments (Mandal, 1981). Mandal's central proposition that prolonged static sitting is biomechanically incongruent with human spinal physiology has been reinforced by epidemiological and experimental evidence linking sustained seated exposure to low back pain, passive tissue creep, altered neuromuscular activation, and discomfort (Lis et al., 2007; Beach et al., 2005; Kastelic et al., 2018). Radiographic and biomechanical investigations further confirm that lumbar curvature and spinopelvic parameters change significantly in seated positions, particularly when posture is sustained without variability (De Carvalho et al., 2010; Misir et al., 2019).

Contemporary ergonomic interventions such as sit–stand workstations, dynamic seating systems, and movement-oriented task organization reflect a practical translation of the *Homo Sedens* emphasis on posture variability (Park & Srinivasan, 2021; Van Deursen et al., 1999). Experimental studies demonstrate that alternating postures and incorporating dynamic stimuli can reduce trunk stiffness and perceived discomfort compared to prolonged static sitting (Park & Srinivasan, 2021; Gregory et al., 2006). Similarly, lumbar support technologies and adaptive seating mechanisms have shown measurable benefits in redistributing mechanical load and improving comfort during extended seated tasks (Aota et al., 2007; Grondin et al., 2013). Importantly, the conceptual transition from posture "correction" toward posture "variation" aligns closely with Mandal's critique of rigid 90° sitting standards and reflects a broader theoretical evolution in ergonomic science (O'Sullivan et al., 2012; De Carvalho, 2015).

Despite this progress, implementation challenges remain. Systematic reviews indicate that while reducing static exposure is beneficial, consensus regarding the optimal frequency, duration, and magnitude of posture change remains limited (Bai et al., 2024; De Carvalho et al., 2020). Moreover, biomechanical responses to seated postures vary considerably between individuals, particularly among those with chronic low back pain or altered neuromuscular control (Claus et al., 2018; Saiklang et al., 2024). Anthropometric variability, task specificity, and environmental constraints further complicate universal ergonomic prescriptions (Lee, 2019; Daniel, 2024). Evidence from occupational and educational settings also demonstrates that workstation configuration and behavioral compliance strongly influence the effectiveness of ergonomic interventions (Azimuddin et al., 2017; Podrekar, 2023). These findings suggest that ergonomic design alone cannot fully mitigate sedentary-related risks without considering organizational culture and user engagement.

Nevertheless, *Homo Sedens* continues to provide a robust theoretical framework for integrating biomechanics, occupational health, and human-centered design. Its relevance extends beyond chair geometry to encompass holistic workplace ergonomics, including adaptive systems, posture monitoring technologies, and evidence-informed environmental design strategies (Markova et al., 2024). As sedentary behaviour increases globally across professional and educational contexts (Jochem et al., 2023), Mandal's theoretical insights remain foundational in guiding ergonomic strategies that prioritize adaptability, movement variability, and long-term musculoskeletal resilience.

6. Limitations of the Theoretical Framework

Although Mandal's *Homo Sedens* framework offers influential conceptual and biomechanical perspectives on seated posture, it is not without limitations. A primary constraint concerns its methodological foundation, which relied largely on theoretical reasoning and observational interpretation rather than controlled experimental or longitudinal outcome data (Mandal, 1981). While its biomechanical propositions regarding pelvic orientation, lumbar lordosis preservation, and spinal loading patterns were logically grounded, they preceded the widespread use of radiographic alignment analysis, electromyography, and finite element modeling that now permit direct in vivo and simulation-based validation (De Carvalho et al., 2010; Cho et al., 2023). Contemporary systematic reviews further indicate that although prolonged sitting is associated with low back discomfort, causal relationships between specific seating configurations and long-term musculoskeletal outcomes remain complex and context-dependent (De Carvalho et al., 2020; Bai et al., 2024). Thus, many of the early causal inferences within *Homo Sedens* were theoretically compelling but not empirically verified at the time of publication.

Additionally, the framework was developed within the context of traditional desk-based occupational environments and does not explicitly address the biomechanical demands introduced by modern technology-driven work patterns. Current occupational behaviour frequently involve laptop use, handheld devices, and multi-surface task transitions, which are associated with sustained cervical flexion, altered thoracolumbar curvature, and asymmetrical upper-limb loading (Black et al., 1996; Markova et al., 2024). Epidemiological discussions of sedentary behaviour further demonstrate that sitting exposure today is embedded within broader behavioral and environmental contexts that extend beyond static desk posture (Jochem et al., 2023). These contemporary patterns introduce spinal loading dynamics that were not explicitly modeled within the original *Homo Sedens* construct.

Another limitation lies in the limited integration of population diversity variables. Differences in anthropometry, age, conditioning status, and existing musculoskeletal pathology influence spinal mechanics and neuromuscular responses to seated postures (Claus et al., 2018; Saiklang et al., 2024). Anthropometric analyses emphasise that variability in body dimensions significantly affects seated alignment and workstation fit, challenging universal design assumptions (Lee, 2019; Daniel, 2024). Consequently, recommendations such as forward-inclined seating may not produce uniform biomechanical outcomes across populations. Furthermore, contemporary ergonomic research recognises that psychosocial stressors, organisational culture, and task demands interact with physical posture to influence musculoskeletal risk, dimensions largely absent from early theoretical ergonomic models (Lis et al., 2007; Alaca et al., 2025).

Despite these limitations, the enduring value of *Homo Sedens* lies in its capacity to challenge static sitting paradigms and catalyse empirical investigation. Subsequent biomechanical experiments, intervention trials, and adaptive seating technologies can be viewed as extensions of Mandal's original critique of rigid 90° seating standards (Park & Srinivasan, 2021). Rather than diminishing its relevance, the identified constraints delineate clear pathways for contemporary validation through advanced modelling techniques, wearable posture monitoring systems, and longitudinal occupational health research (Cho et al., 2023; De Carvalho et al., 2020). As sedentary exposure continues to increase globally, *Homo Sedens* remains a foundational theoretical reference one that evolves through integration with modern biomechanics, epidemiology, and human-centered design research.

7. Conclusion

Seating ergonomics should be conceptualised as a dynamic interaction among posture, biomechanics, and task demands rather than as a fixed prescription of spinal alignment. Accumulating biomechanical and occupational evidence demonstrates that static sitting regardless of whether it is considered "correct" can lead to altered spinal loading, neuromuscular adaptation, and discomfort over time (Beach et al., 2005; Claus et al., 2018). Consequently, ergonomic effectiveness depends not on enforcing a single ideal posture but on facilitating variability and task-responsive adjustment (O'Sullivan et al., 2012; Bai et al., 2024).

The *Homo Sedens* framework offers a robust theoretical foundation for understanding the biomechanical incompatibilities associated with prolonged static sitting and the importance of preserving lumbar curvature through dynamic adaptation (Mandal, 1981). Its emphasis on forward-inclined seating, movement-based posture regulation, and workstation integration aligns with contemporary findings supporting alternating sit–stand patterns and adaptive seating mechanisms as strategies to redistribute spinal loading and reduce sustained muscular activation (Park & Srinivasan, 2021; Van Deursen et al., 1999). In this regard, Mandal's critique of rigid 90° seating standards remains highly influential within modern ergonomic design and occupational health practice.

Future research should extend these principles through advanced biomechanical modelling, wearable posture-monitoring technologies, and longitudinal occupational health investigations to better quantify optimal movement frequency, individualised seating responses, and long-term musculoskeletal outcomes (Cho et al., 2023; De Carvalho et al., 2020). By integrating empirical validation with human-centered design, contemporary ergonomics can further refine seated work environments to prioritize adaptability, spinal health, and sustainable occupational performance.

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