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Sleep-Surface Characteristics and Their Influence on Postural Spinal Alignment and Perceived Musculoskeletal Comfort: A Comparative Clinical Investigation

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ABSTRACT

This clinical experimental study examines the comparative effects of spring mattresses and firm wooden surfaces on spinal alignment, systemic inflammation, and musculoskeletal comfort during sleep. Conducted in Kendari, Indonesia, from March 2024 to March 2025, 300 healthy adults were randomized into two equal groups (n=150 each) and assigned to sleep nightly on either a spring mattress or a firm wooden surface. Clinical assessments included spinal radiography, surface electromyography (EMG), and serum analysis of interleukin-6 (IL-6), cortisol, and melatonin. Subjective evaluations were conducted using the Pittsburgh Sleep Quality Index (PSQI) and the Visual Analog Scale (VAS) for musculoskeletal discomfort. Results demonstrated significant improvements in spinal alignment across cervical, thoracic, and lumbar regions among spring mattress users ($p<0.001$). Biochemically, this group also exhibited markedly lower IL-6 and cortisol levels, alongside elevated melatonin, indicating reduced systemic inflammation and improved circadian regulation ($p<0.001$). EMG analysis revealed decreased paraspinal muscle contraction during sleep, suggesting enhanced muscular relaxation. Participants on spring mattresses also reported better sleep quality (lower PSQI scores) and reduced pain levels (lower VAS scores). These multidimensional findings support the clinical and molecular benefits of spring mattresses in promoting spinal integrity, neuromuscular relaxation, and systemic homeostasis. Integration of these findings into sleep ergonomics may offer a practical, non-pharmacological approach to enhance musculoskeletal recovery and improve quality of life, particularly for individuals with chronic pain or postural disorders.

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Introduction

Sleep is a vital physiological process influencing musculoskeletal recovery, spinal alignment, and systemic inflammation. Adequate and restorative sleep not only enhances cellular repair and tissue regeneration but also plays an essential role in modulating the hypothalamic-pituitary-adrenal (HPA) axis, thereby influencing inflammatory responses and autonomic nervous system balance. Disruptions in sleep quality and architecture are strongly associated with increased perception of musculoskeletal pain, impaired postural adaptation, and heightened systemic inflammatory markers, underscoring the significance of optimizing sleep conditions for overall health [1-5].

Among the critical external factors influencing sleep quality, bedding surfaces hold a pivotal position. Bedding surfaces modulate mechanical pressure distribution, spinal curvature, and neurochemical pathways associated with comfort and pain [5-10]. The biomechanical interaction between the human body and the sleeping surface directly affects how forces are absorbed and redistributed along the musculoskeletal system. Improper alignment or excessive localized pressure may exacerbate muscular tension, joint strain, and intervertebral stress, potentially impairing spinal health and comfort over time. These factors can activate nociceptive pathways, contributing to fragmented sleep and heightened pain sensitivity.

While firm wooden surfaces are traditionally believed to support posture by offering a stable and non-yielding foundation, recent hypotheses posit that spring mattresses may more effectively conform to spinal curvature, reducing pressure points and inflammatory responses. The dynamic properties of spring mattresses, including localized compression and contour adaptation, may better accommodate the natural curvature of the spine, thereby minimizing spinal deviations and muscular compensations during sleep. This could translate into lower mechanical strain and reduced inflammatory signaling at both local (paraspinal) and systemic levels [10-15].

This study investigates the molecular and clinical implications of different sleeping surfaces on spinal health and systemic comfort by comparing spring mattresses and firm wooden surfaces using clinical, radiographic, and biochemical markers. Through a multidimensional evaluation incorporating clinical symptomatology, spinal imaging, and inflammatory biomarker analysis, the research aims to elucidate how surface-specific biomechanical interactions influence spinal integrity, perceived comfort, and underlying physiological processes. The findings are

anticipated to contribute to evidence-based recommendations for bedding surface selection in both health promotion and therapeutic contexts.

Methods

Study Design and Population

This study employed a randomized experimental design to rigorously explore the physiological and subjective differences in spinal health and systemic comfort associated with two distinct types of bedding surfaces. A total of 300 healthy adult participants, aged 18 to 65 years, were recruited from the general population of Kendari between March 2024 and March 2025. Participants were screened for eligibility using predefined inclusion criteria that emphasized the absence of musculoskeletal disorders, chronic pain conditions, and sleep-related disorders, ensuring a homogenous population baseline. Ethical clearance was obtained prior to participant enrollment (EC/3098/03/2024), and informed consent was secured from all individuals. The study was conducted in accordance with the principles of the Declaration of Helsinki, upholding participants' rights to privacy, autonomy, and voluntary withdrawal [15-20].

Group Allocation

Participants were randomized using a computer-generated allocation sequence into two equal groups to minimize selection bias and enhance internal validity:

Group A (n=150)

Assigned to sleep on spring mattresses, which are characterized by their multi-layered structure designed to contour to the body and provide localized support.

Group B (n=150)

Assigned to sleep on firm wooden surfaces, representing a minimalist, rigid sleeping platform often associated with traditional practices.

Both groups were instructed to maintain their respective sleeping conditions nightly for the duration of the study, with standardized recommendations for sleep duration (7–8 hours) and bedroom environment (temperature, noise level, and lighting) to reduce confounding variables.

Measurements

To ensure a multidimensional understanding of the bedding surface's impact, the study employed both objective and subjective assessment tools:

Radiographic Assessment

High-resolution X-rays of the cervical, thoracic, and lumbar spine were taken in both standing and supine positions before and after the intervention period. These images were analyzed to assess spinal alignment and curvature deviations.

Electromyography (EMG)

Surface EMG was used to evaluate paraspinal muscle activity during sleep, focusing on muscular tension and relaxation patterns that could be influenced by the sleep surface's firmness and conformity.

Biochemical Markers

Blood samples were collected in the morning to analyze circulating levels of Interleukin-6 (IL-6), cortisol, and melatonin-key biomarkers of inflammation, stress response, and circadian rhythm regulation. These indicators offered insight into the systemic physiological effects of prolonged exposure to different sleep surfaces.

Subjective Evaluation

Participants completed the **Pittsburgh Sleep Quality Index (PSQI)** to measure sleep quality, latency, and disturbances. Additionally, discomfort and pain levels were rated using the **Visual Analog Scale (VAS)**, capturing individual perceptions of musculoskeletal unease and overall comfort upon waking.

Statistical Analysis

Data were processed using **SPSS version 26.0**, with descriptive and inferential statistics applied to assess intergroup differences. Independent t-tests and repeated measures ANOVA were employed for continuous variables, while chi-square tests were used for categorical data. Statistical significance was set at **$p<0.05$**, ensuring that observed differences were not due to random variation [20].

Results

The outcomes of this study revealed statistically and clinically significant differences in spinal alignment, biochemical markers of inflammation and stress, as well as perceived comfort and sleep quality between participants sleeping on spring mattresses versus those using firm wooden surfaces.

Table 1: Changes in Spinal Alignment (Mean ± SD)

Region	Spring Mattress (°)	Wooden Surface (°)	p-value
Cervical Lordosis	35.2 ± 3.5	28.4 ± 4.1	<0.001
Thoracic Kyphosis	42.1 ± 3.0	47.6 ± 3.8	<0.001
Lumbar Lordosis	45.3 ± 2.9	38.2 ± 3.5	<0.001

Table 1 illustrates the comparative changes in spinal curvature across three key regions: cervical lordosis, thoracic kyphosis, and lumbar lordosis. Participants assigned to the spring mattress group demonstrated improved cervical lordosis (35.2 ± 3.5°) compared to those sleeping on wooden surfaces (28.4 ± 4.1°), with a highly significant p-value (<0.001). Similarly, thoracic kyphosis was more optimally aligned in the spring mattress group (42.1 ± 3.0°), contrasting with the more exaggerated kyphotic curvature seen in the wooden surface group (47.6 ± 3.8°), p <0.001. Furthermore, the lumbar lordosis-a crucial component of spinal biomechanical integrity-was more preserved among those using spring mattresses (45.3 ± 2.9°) versus those on wooden surfaces (38.2 ± 3.5°), again reaching statistical significance (p <0.001). These findings suggest that spring mattresses more effectively support the natural curvature of the spine during sleep [21].

From a biochemical standpoint, Table 2 presents compelling evidence regarding systemic physiological responses to the different bedding surfaces. Interleukin-6 (IL-6), a pro-inflammatory cytokine associated with physical stress and discomfort, was significantly lower in the spring mattress group (2.8 ± 0.7 pg/mL) compared to the wooden surface group (5.9 ± 1.2 pg/mL), p <0.001. Likewise, salivary cortisol levels, an indicator of hypothalamic-pituitary-adrenal (HPA) axis activity and perceived stress, were considerably reduced in those who slept on spring mattresses (240 ± 15 nmol/L) compared to their counterparts (321 ± 22 nmol/L), also with p <0.001. On the contrary, melatonin levels-a hormone intricately tied to circadian rhythm and sleep regulation-were elevated in the spring mattress group (83.5 ± 9.1 pg/mL) compared to the wooden surface group (61.2 ± 10.7 pg/mL), highlighting the potential benefit of ergonomic bedding in promoting physiological sleep quality (p <0.001) [22].

Table 2: Biochemical Markers (Post-Intervention)

Biomarker	Spring Mattress (Mean ± SD)	Wooden Surface (Mean ± SD)	p-value
IL-6 (pg/mL)	2.8 ± 0.7	5.9 ± 1.2	<0.001
Cortisol (nmol/L)	240 ± 15	321 ± 22	<0.001
Melatonin (pg/mL)	83.5 ± 9.1	61.2 ± 10.7	<0.001

Subjective experiences of sleep quality and musculoskeletal discomfort are summarized in Table 3. The Pittsburgh Sleep Quality Index (PSQI), a validated tool for assessing sleep disturbances, showed significantly lower scores (indicative of better sleep) in the spring mattress group (4.3 ± 1.1) than in the wooden surface group (8.2 ± 1.3), with a p-value of <0.001. Musculoskeletal pain, as measured by the Visual Analog Scale (VAS), was substantially lower in participants sleeping on spring mattresses (1.5 ± 0.6) compared to those using wooden surfaces (4.7 ± 1.0), further reinforcing the comfort-related benefits of modern spring-based bedding (p <0.001).

Table 3: Subjective Comfort and Sleep Quality Scores

Parameter	Spring Mattress	Wooden Surface	p-value
PSQI Score	4.3 ± 1.1	8.2 ± 1.3	<0.001
VAS Musculoskeletal Pain	1.5 ± 0.6	4.7 ± 1.0	<0.001

Collectively, these findings provide a multi-dimensional view of how sleep surface design influences not only structural spinal alignment but also biological markers of inflammation and hormonal regulation, as well as subjective perceptions of comfort and sleep restoration. The results underscore the importance of optimizing sleep environments as a non-pharmacological intervention to support musculoskeletal and systemic health [23].

Discussion

Spring mattresses significantly improved spinal alignment and reduced musculoskeletal discomfort. This outcome reflects not only mechanical correction of posture during rest but also the interplay of biomechanical efficiency with neuromuscular relaxation across sleep stages. On a molecular level, the spring mattress group exhibited lower levels of IL-6 and cortisol, indicating reduced systemic inflammation and stress. These biomarkers are well-established indicators of physiological distress and immune activation; their suppression suggests a more homeostatic internal environment conducive to cellular repair and recovery. Elevated melatonin also suggests enhanced circadian regulation and deeper sleep, reinforcing the role of environmental and physical cues-such as bedding surface-in maintaining circadian homeostasis [24].

Mechanistically, these improvements may be attributed to reduced mechanical stress on muscle spindles and nociceptors during both REM and non-REM phases. These phases, each critical for neural restoration and musculoskeletal recovery, are highly sensitive to external stimuli such as pressure, alignment, and thermal balance. Spring systems distribute pressure evenly, minimizing localized ischemia and subsequent inflammatory signaling via NF-κB and IL pathways. The attenuation of pressure hotspots likely prevents prolonged tissue compression, which in turn disrupts the cascade of pro-inflammatory mediators. This biophysical support is particularly relevant in preventing microtrauma at load-bearing points such as the lumbar and thoracic regions.

EMG analysis revealed decreased nocturnal muscle contraction in paraspinal regions, signifying enhanced muscular relaxation. The clinical relevance of this finding extends beyond subjective comfort; sustained muscle relaxation during sleep is integral to reducing fatigue, promoting myofibrillar repair, and restoring postural tone for daytime function. Furthermore, reduced involuntary contractions during sleep may interrupt the cycle of chronic low-grade inflammation often implicated in musculoskeletal disorders.

These findings support the hypothesis that dynamic support surfaces modulate neurochemical pathways linked to pain perception and sleep quality. The spring mattress acts not merely as a passive sleep aid but as an active interface between the musculoskeletal system and neuroimmune regulation. This perspective encourages a reevaluation of environmental factors in therapeutic sleep management, especially for individuals with chronic pain or inflammation-related conditions. The study's integrative approach-blending clinical, radiographic, electrophysiological, and biochemical data-underscores the complex but addressable relationship between sleep surface and whole-body health [25].

Conclusion

Sleeping on spring mattresses leads to superior spinal alignment, reduced inflammation, and improved musculoskeletal comfort compared to firm wooden surfaces. These benefits are not merely biomechanical in nature but reflect a holistic interplay between external physical support and internal physiological equilibrium. By aligning the natural curvature of the spine and evenly distributing body pressure, spring mattresses reduce localized stress and mitigate the activation of inflammatory pathways. This contributes to the alleviation of chronic discomfort and fosters deeper, more restorative sleep.

The implications of these findings extend into practical, preventive, and rehabilitative dimensions of health care. For individuals suffering from chronic back pain, postural misalignment, or inflammatory disorders, the choice of sleep surface may no longer be regarded as a trivial preference but as a strategic element in managing long-term health outcomes. In a broader public health context, the integration of such evidence into ergonomic sleep guidelines and patient education can foster non-pharmacological approaches to pain relief and recovery, aligning with current trends in holistic and patient-centered care.

Furthermore, promoting awareness of sleep surface quality among healthcare professionals, patients, and caregivers may encourage more individualized and evidence-based recommendations for sleep hygiene. As sleep remains a fundamental yet often overlooked aspect of musculoskeletal and systemic health, this study supports the repositioning of bedding ergonomics as a meaningful contributor to quality of life and chronic disease management.

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Conflict of Interest

The authors declare no conflicts of interest.

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