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Research Article

Artificial Intelligence in Sleep Science: Evaluating User Satisfaction of Static and Dynamic Sleep Surfaces at User-Neurophysiological Interface

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Abstract

Sleep and brain health are inextricably linked. External sleep physiology is the study of how outside environmental cues and observable physical parameters interact with the body's internal sleep-wake cycles. Improving the complex relationship between sleep, brain function and neurological health remains at the frontiers of scientific and technological innovation. An AI-enabled Dynamic Mattress was developed for use within homes after two years of applied research in New Zealand. This study assessed short-term user satisfaction for comparing Static and Dynamic Sleep Surfaces combining full sample of 60 adults (31 Males, 29 Females), aged 30-70 years who tested two mattresses in Auckland and scored them quantitatively on Comfort, Firmness, Temperature, and Overall Satisfaction using the Boston Mattress Satisfaction Questionnaire (BMSQ) developed by the Harvard Medical School with qualitative feedback. Participants rated Dynamic Mattress higher than Static Mattress in terms of Comfort, Firmness, and Overall Satisfaction, with mean differences which were all highly statistically significant ($p < 0.001$). Temperature received a marginally higher rating which was not statistically significant. After trials 60% of the group qualitatively reasoned why they preferred to switch to a dynamic sleep surface. Sleep surface is indicated as a 'zeitgeber' or an 'entrainment parameter' for the circadian sleep-wake cycle determining a potential user–neurophysiological interface. Comparative advantages of static and dynamic sleep surfaces are elucidated for sleep and health worldwide within the framework of Medicine. AI-Smart beds demonstrate potential to evolve as one of the most significant innovations in Sleep Science for Neuroscience Healthcare in the twenty-first century.

Keywords: AI-Smart-Bed; Sleep Science; Chronobiology; Neurophysiology; Sleep Medicine

Introduction

Sleep is a fundamental biological process that supports brain function, physiological recovery, memory, cognition, and long-term health. The neurophysiology of sleep involves coordinated activity within the central and autonomic nervous systems that regulates transitions between wakefulness and sleep, sleep architecture, and associated changes in neural and physiological activity [1-3]. In parallel, emerging sleep-surface research suggests that the physical characteristics of a bed, including its pressure-distribution properties, can influence sleep-related physiological outcomes and subjective sleep quality; experimental evidence has demonstrated associations between mattress interface-pressure distribution, NREM sleep, micro-arousals, and perceived sleep quality [6]. Accordingly, the study of sleep surfaces can extend beyond conventional assessments of comfort and sleep quality toward understanding how the external sleep environment interacts with the physiological systems involved in sleep. This provides a conceptual foundation for investigating intelligent dynamic sleep surfaces as an external interface between the sleeping individual and the physiological processes underlying sleep.

While major advances in sleep medicine have been made to measure sleep including polysomnography, wearable biosensors, actigraphy and digital therapeutics, one of the most basic elements of almost all sleeping situations – 'the objective sleep surface' has received little scientific scrutiny. The mattress is the main point of contact between the human body and sleep environment, bearing the full weight of the body continuously for about 6 - 8 hours per night throughout a lifetime. Deviating from other modality of lifestyle intervention which needs active behavioral modification, the sleep surface influences sleep stages, biomechanics, pressure distribution, spinal alignment thermoregulation as well as movement during circadian sleep-wake cycles. Since a third of a lifetime may be spent in sleep, mattress design is an important factor regulating long-term health by affecting overall quality of sleep [4-30].

The conventional spring mattress was continually engineered with progressive materials such as multiple innerspring or pocket spring, polyurethane foams, viscoelastic memory foams, latex and gel-infused components using already established principles stimulating hybrid constructions. However, these traditional sleeping surfaces continue to be fundamentally "static". During manufacture, their mechanical properties are predetermined and remain relatively stable regardless of the sleeper's body morphology, weight, height, sleeping posture during sleep. On the other hand, human sleep is naturally "dynamic". Healthy adults shift sleeping position between 10 to 20 times every night against a backdrop of continuous physiological bodily changes in pressure loading, spinal alignment, respiratory mechanics, muscle tone and cardiovascular functioning. Thus, a static mattress is likely to only ever result in the same mechanical response actioning against an ever-changing biological system, possibly limiting its ability to provide optimized support throughout sleep (Van Deun et al., 2012; Verhaert et al., 2012). Research has sparked growing interest in customizing sleep surfaces that are capable of dynamically responding to individual biomechanical needs through real-time pressure distribution and mobility as opposed to being limited by fixed/static material properties [4-39].

Artificial Intelligence (AI) embedded sensor technology, ballistocardiography and pressure-mapping systems together with the availability of cloud computing connected via Internet of Things (IoT) have opened possibilities for an entirely different generation of intelligent sleep system designs with potential to measure sleep physiology as well as alleviate neurological sleep disorders when working in tandem as therapeutic sleep surfaces [31]. In contrast and distinct to regular mattresses, AI-enabled dynamic

sleep surfaces include pressure sensors that adapt air-cells technologies physiological monitoring and machine-learning algorithms with the ability of non-stop active response during sleep at night. The Smart-Tek AI is a Smart Bed that responds actively to changes in body posture, and measures body temperature, blood pressure, heart rate, respiration rate, sleep stages real-time automatically adjusting parameters associated with contouring versus pressure redistribution [32].

Integrated health metrics now allow for passive overnight monitoring with the opportunity to change a bed from merely a comfortable piece of furniture into an active wellness and preventive healthcare platform [29-38]. Due to the global burden of chronic musculoskeletal disorders, obesity, sleep-disordered breathing and cardiovascular disease alongside age-related disability as well as public stake in maintaining health-conscious lifestyles; bidirectional technologies can respectively improve therapeutic restorative functions whilst delivering reliable biomarkers for physiological functions [9-30]. There are several studies that have focused on how AI-smart beds provide neurological and musculoskeletal support highly suitable for elderly people and aged patients [1-30] (Yang, 2024).

Research over the last two decades from The United States has greatly contributed to understanding mattress biomechanics on a scientific level. The systematic review with the most impact, by [24] assessed the effectiveness of controlled clinical trials on mattress firmness, spinal alignment or direct measures sleep quality and pain reduction. The review also indicated pressure redistribution as one of the most important mechanisms for better sleep quality, however, evidence was lacking on optimal mattress temperature regulation. The paper pointed out that medium-firm mattresses produced the most consistent improvements in pressure redistribution, sleep quality (difficulty with falling asleep and staying awake), spinal alignment morning stiffness and chronic low back pain. This conclusion marks an important shift in sleep science from passive-bedding systems to intelligent active AI-bedding systems that provide individualized and unique technological support, mechanical elements with bio-mathematical data inputs [5-24].

Other studies in Europe, including work done by Italian researchers, and Belgian academics show similar findings validating the importance of pressure redistribution dynamics/spinal biomechanics during sleep or lying down. Medium-firm mattresses improve subjective sleep quality. Hospital-based clinical studies have also demonstrated that dynamic alternating-pressure support surfaces are effective in reducing prolonged interface pressures over bony prominences, contributing to decreased risk of pressure injuries among patients with limited mobility. Although many hospital studies reported relatively few small differences between high-quality static pressure-redistributing mattresses and intricate but expensive dynamic air systems; they have reiterated that the basic mechanisms of action by which these surfaces reduce mechanical loading are via cyclic redistribution of support under body areas. These discoveries have helped to promote pressure redistribution as a key biomechanical concept on which contemporary sleep-support technologies rest [4-38].

Recent studies from Asia, especially in China targeted to incorporate intelligent sensing technology and adaptive support systems has broadened mattress research. Sensor mattresses have been obtained by Chinese researchers to continuously map weight distribution on a bed that automatically adjust support features based on body shape and sleeping position. Recent studies investigated more artificial intelligence (AI), machine learning, physiological monitoring, posture recognition, respiratory sensing and thermal management into intelligent sleep systems. While many of these technologies are still in development or at an early commercial stage, preliminary data indicate that adaptive pressure-balancing systems improve subjective comfort and may provide improved pressure

redistribution characteristics than conventional static sleep surfaces [18-43]. These results lend support to the idea that mattress design constitutes an important, accessible environmental determinant of sleep health whilst offers a simple, non-pharmacologic alleviation approach for people with intermittent disturbances in sleep or subjective musculoskeletal discomfort [2].

AI-enabled dynamic sleep systems are one of the most exciting developments in modern sleep medicine with potential to influence the neurophysiology of sleep. While conventional static mattresses have mechanical properties that remain unchanged during the entire night, dynamic sleep surfaces utilize integrated pressure sensors (which detects pressures at 60 min intervals through capacitive measurement), adaptive air-cell technology with firmness control across multiple parameters along-a-bed and head-and-torso-to-feet programmable stiffness gradients sensed by various actuators in the mattress to recognize body-position changes and physiological monitoring activity for necessary biomechanical support. Lowered surface temperature enhances deeper sleep, hence external sleep surfaces with this modulation are unique. However, important evidence gaps still exist in user acceptance, perceived comfort and overall satisfaction in addition to subsequent downstream ramifications for daily sleep health [29-38].

The present pilot study was designed to compare short-term user satisfaction with a premium Static Mattress versus a brand-new commercial AI-enabled Dynamic Smart Tek AI mattress essentially an AI-Smart Bed using the Boston Mattress Satisfaction Questionnaire [26]. This study aims to combine quantitative measures of comfort, firmness, temperature and satisfaction as well as qualitative user ratings from early adopters to evaluate consumer reaction towards new AI-enabled Sleep Technology. The results support initial evidence surrounding the potential role that dynamic surfaces could play as user-interfaces in Neurophysiology to create a growing field of intelligent sleep ecosystems to improve muskoskeletal health, sleep synchronization with extrinsic zeitgebers, circadian physiology and gene expression patterns within framework of preventive medicine.

Materials and Methods

This was a experimental within-subject comparative study comparing short-term user satisfaction with Static Sleep Surface (traditional mattress) vs. Dynamic Sleep Surface (an AI-enabled Smart Tek AI mattress). Studies were carried out in the New Zealand Bed Company showroom at Westgate Lifestyle Shopping Centre, Auckland New Zealand between mid-March to mid-May 2026 as a first responder survey after the commercial launch of Smart Tek AI sleep system in April 2026 in New Zealand [33]. The study was an exploratory real-world consumer sleep technology assessment, measuring immediate subjective response to a high-tech adaptative bed surface in a controlled show-room environment. The study was conducted using a paired within-participant approach where each participant underwent two sequential mattress conditions. This design limited the inter-subject variation from body morphology, age, gender and prior experience of mattress use musculoskeletal attributes as well as perceptions of comfort by allowing each subject to be their own control. The study was performed in compliance with internationally recognized ethical principles including the General Ethical Principles for medical research Involving human subjects by the Declaration of Helsinki and terms of voluntary participation (amended 2024), informed consent and confidentiality or autonomy during study. The risk of the trial was negligible, with participants only exposed to routine consumer product mattress testing without undue pressure on any purchase. The study involved no invasive procedures or biological sampling for medical evaluation/diagnosis. I organized their participation as entirely voluntary and chose not to engage those unwilling to compare the surfaces by investing an hour or filling out the questionnaires. Their participation had

absolutely no effect on their ability to access products services or advice in Westgate or any other Showroom countrywide.

Study subjects comprising 60 mature adults (31 males and 29 female) aged between 30 to 70 years participated in the study. Participants in this study were random visitors and individuals who made use of the New Zealand Bed Company Westgate showroom during the time span of two months over which the study was conducted. During the study, strict confidentiality procedures were used, names were not taken and photos were consented. To facilitate data management, all participants were given a unique numerical research identification code (Participant ID). Responses to the questionnaires and sleeping on highest rated mattress were recorded only with coded identifiers that could not be traced back to individual participants. All participants completed the mattress testing protocol by lying down on the sleeping surface in their preferred position of sleep. Participants trialed both the traditional Static Mattress; which is a premium static mattress, followed by guided trails on an AI-enabled Dynamic Smart Tek-AI Mattress. Subjects thus tested each mattress for about 30 minutes, during which they took their normal sleeping positions (supine, lateral and preferred resting postures) to replicate natural sleep behavior. Using a within-subject design ensured that everyone acted as their own control, enabling direct comparison of individual perceptions between the two sleep surfaces while minimizing variation related to body composition, age, gender and mattress experience (Figure 1).



Figure 1: Trialing a Static and Dynamic (Smart Tek AI Bed) at Auckland, New Zealand. Traditional mattress Smart Tek – AI (Smart-bed) Experiential demo/trials.

The main endpoint was filling in the Boston Mattress Satisfaction Questionnaire (BMSQ), which assessed major attributes of mattress performance in terms of comfort, firmness/temp control and overall satisfaction. For each domain, subjects were asked to rate their satisfaction using a 1 to 10-point scale (higher scores indicate greater perceived satisfaction) comparing Static vs Dynamic Mattress. The numerical data provided quantitative comparisons of subjective sleep-surface preferences which were further tested statistically. Moreover, qualitative feedback of participant perceptions and acceptance were used as secondary outcomes to collate more data. Such qualitative information helped interpret the quantitative BMSQ results by contextualizing user perspectives better for the adaptive sleep surface.

Results

Participant Characteristics

A total of 60 adults (31 males and 29 females), aged between 30–70 years, completed all stages of the study protocol, with data from each being included in final analysis. All subjects completed an evaluation of each mattress condition and filling in of the Boston Mattress Satisfaction Questionnaire (BMSQ) after every trial. The within-subject design used here enabled a direct comparison of participant responses as follows.

Quantitative Comparison Between Static and Dynamic Sleep Surfaces

The formulated statistical analysis performed on the satisfaction ratings exhibited higher continuous summative mean for Dynamic Smart Tek AI Mattress when compared to Static Mattresses in all 3 domains. For each mattress condition, mean scores were calculated for Comfort, Firmness, Temperature and Overall Satisfaction. A paired-samples t-test was computed to determine if the differences between Static and Dynamic Mattress ratings were statistically significant.

Dynamic Mattress showed much higher ratings for:

- Comfort: Median increase of +1.12 over the Static Mattress ($p < 0.001$)
- Firmness: Improved mean score of +1.06 versus the Static Mattress ($p < 0.001$).
- Overall Satisfaction: Mean improvement of +1.05 points over the Static Mattress ($p < 0.001$).

In the area of Temperature Regulation, a higher mean rating (+0.30 points) was reported from using Dynamic Mattress compared to Static Mattress. However, this difference was quite close to traditional statistical significance ($p = 0.051$), further supporting suggestions that potential thermal benefits might not manifest themselves during such a short trial of just 30 min.

The principal statistical outcomes are summarized below:

BMSQ Outcome Measure	Mean Difference (Dynamic – Static)	Paired samples t-test	Significance (2-tailed)
Comfort	1.12	$t = 5.36$	$p < 0.001$
Firmness	1.06	$t = 5.11$	$p < 0.001$
Temperature	0.3	$t = 1.98$	$p = 0.051$
Overall Satisfaction	1.05	$t = 5.47$	$p < 0.001$

Representation of Statistical Findings

In summary, the results show that in a short-term consumer trial environment, an AI-enabled Dynamic Smart Tek AI Mattress can achieve far superior user satisfaction than compared to a conventional Static mattress across perceived comfort-related as well as overall experience elements. The results provide initial evidence to support future longitudinal studies aimed at whether adaptive AI-driven sleep surfaces can affect objective sleep quality, core pressure management, comfort and clinically defined long-term health outcomes.

Effect Size Analysis (Cohen's d)

To assess the magnitude and practical relevance of differences between the Static Mattress and Dynamic Smart Tek AI Mattress, effect sizes were calculated using Cohen's d for paired samples. The formula applied was:

$$d = \frac{\bar{X}_{Dynamic} - \bar{X}_{Static}}{SD_{Difference}}$$

where:

- X¯_Dynamic= mean participant rating for Dynamic Mattress
- X ¯_Static= mean participant rating for Static Mattress
- SD_Difference= standard deviation of individual participant score differences between the two mattress conditions.

Outcome Measure	Static Mattress Mean Difference	Dynamic Advantage	Paired t-test Result	Cohen's d	Effect Size Interpretation
Comfort	Dynamic – Static	1.12	$p < 0.001$	0.69	Moderate–Large
Firmness	Dynamic – Static	1.06	$p < 0.001$	0.72	Moderate–Large
Temperature	Dynamic – Static	0.3	$p = 0.051$	0.19	Small
Overall Satisfaction	Dynamic – Static	1.05	$p < 0.001$	0.78	Large

Summary of Statistical Findings

Generally, the effect-size analysis revealed that subjects receiving the Smart Tek AI Dynamic Mattress not only had significant differences in comfort and firmness, but also very meaningful improvements expressed by users themselves on all reports of satisfaction. With regards to the three categories of user experience, adaptive mechanical response (Cohen's d = 0.78) contributed most followed by pressure redistribution (d=0.72), and personalized support (d=0.69). In contrast and aligned with participant comments on heating advantages requiring an overnight stay rather than a short trial, temperature regulation showed smaller effects (d = 0.19). These results imply a measurable perceptual advantage for AI-enabled dynamic sleep surfaces over conventional static mattresses.

Qualitative Feedback Analysis

After the quantitative component was completed, participants made critical qualitative assessments of their preference for the Static vs Dynamic sleep surfaces on open-ended questions derived from the Boston Mattress Satisfaction Questionnaire. While the Dynamic Mattress had better total satisfaction scores than the Static Mattresses, 40% of participants preferred the Static Mattress as long term sleep surfaces which

may suggest that traditional sleep surfaces remain acceptable and have continual relevance in society. Those who preferred their own Static Mattress stated appreciation for its simplicity, familiarity of surface composition, and established useability with many individuals feeling very satisfied regarding their current mattress and expressed not wanting to move away from a normal sleep environment. Other users, particularly those who liked the option to choose between discrete firmness categories (i.e., soft or medium, firm and so on) valued a familiar choice of architecture which conventional mattresses allow. Many participants also stated that they did not want technology updates of their health, with surfaces tracking their course of sleep, citing factors such as detrimental effects of overuse of technology, background noises and psychological stress due to physiological data monitoring. Several participants had reservations on the possible emissions of electromagnetic radiation, electrical signals and electronics in their sleep environment being disruptive to natural sleep. Others raised questions about data privacy, ownership, and the prospective future application of personal health information, raising issues that echo societal concerns related to digital health technologies or connected devices more broadly. Participants also raised issues about the long-term reliability, maintenance requirements, warranty coverage and durability of an electronically integrated sleep system versus a traditional mattress which they considered to be more enduring.

Few participants voiced practical and ergonomic considerations with the Dynamic system that made static surfaces their preferred choice. These included perceptions of it being a narrow sleep surface, if automated adjustments would disrupt sleep, and misgivings about the segmented or partitioned architecture of adaptive zones. Others mentioned higher elevation of the combined mattress and base system of the Smart Tek AI Smarted were not suitable. Some participants also questioned whether controls of sleep systems activated remotely were a safety hazard in homes with children. Lastly, few participants liked the new AI-Bed, but they assumed it relevant only for hospitals/clinics or geriatric care. Overall, these qualitative findings indicate that while AI-enabled dynamic sleep surfaces present opportunities for personalized support and health optimization solutions to gain consumer acceptance in practice the psychological responses suggest consumers will still need much more reassurance with respect to privacy or potential encroachment on their lives as well as practical concerns about safety, reliability, simplicity of use and maintaining some semblance of emotional functionality and stability associated with traditional static-bed-like structures.

After the comparative trial, 60% of participants preferred switching to use of the Dynamic Smart Tek AI Mattress owing to strong initial acceptance of this technology-enabled adaptive sleep system. Overall impressions were overwhelmingly positive, and participants often describing the Dynamic Mattress as a more individualized, advanced approach to the sleep surface in relation to traditional static designs. Some participants reported feeling significantly different post-trial; perceiving deeper relaxation, better body support and all-round sleep readiness after trialing the decompression, cradling and zero-gravity features. Participants looking to improve their blood circulation or nervous health or relieve further the effects of existing ailments particularly enquired how well-directed and intelligent the Dynamic Mattress was. Those with conditions associated with osteoarthritis, chronic back pain and sleep-disordered breathing were among the first to contemplate abandoning their existing mattress systems for one that might provide greater ergonomic benefit through individualized support or improved pressure management. One participant with vertigo was hesitant about the adaptive movement features, raising consideration that acceptance of dynamic sleep technologies may depend on individual sensory

preferences as well as some disease states. Another participant with a stent in the heart was advised not to complete the study as best decided mutually. In contrast, one of the oldest participants who reported she already had an adjustable bed-base mentioned that the Dynamic Mattress trialed was possibly the best sleep surface she had ever tried, in fact suggesting future directions for her to purchase such adaptive technology.

Overall, the Dynamic Mattress was considered functionally "better" than a traditional adjustable bases as the mattress was mobile rather than the wooden base, it allowed better conformity and snug fit. Moreover, because of its built-in adaptive response mechanism versus mechanical elevation or positional adjustment, this provided insights that could possibly meet the needs of ageing populations facing increasing healthcare demands. Availability of the Sleep App functionality, multiple user interfaces and digital interaction features were perceived positively; participants described the technology as intuitively easy to use rather than complex. Most preferred remotes to a tablet or phone as an interactive gadget to control the bed. Acceptance was similar for both males and females, indicating that gender did not appear to be a major factor influencing interest in AI-enabled sleep technology within this sample.

Several limitations were also identified by the participants, although there was an overall positive response. The greatest barrier was affordability itself, with some participants mentioning they were interested as potential customers but needed to take financial considerations into account before purchasing a $30,000 super king-sized automated Smart Tek AI Bed. Flexible finance options were recommended by some participants to increase access to availing advanced sleep technology. One responded that he needed his partners' validation also, another preferred to hold off on procurement until old age.

Discussion

Sleep neurophysiology signifies a complex interaction between the central and autonomic nervous systems regulating transitions from wakefulness to sleep, as well as maintaining normal sleep architecture. The archetypal sleep can be characterized in terms of non-rapid eye movement (NREM) and rapid-eye-movement (REM) states, which are orchestrated by interactions between discrete brain regions such as those within the hypothalamus, thalamus, basal forebrain and brainstem combined with reciprocal inputs from various neurotransmitter systems including GABAergic projections together with modulatory roles for serotonin, norepinephrine, acetylcholine, dopamine, glutamate and orexin/hypocretin containing neurons [3-35]. At the same time, sleep is coupled with changes in autonomic activity and different regulatory patterns of cardiovascular and respiratory systems depending on specific sleep stages [8]. In contrast to this internal neurophysiological system, the external sensory, thermal, firmness level and biomechanical environment presented by the physical sleep surface influences comfort-user-satisfaction experience through body positioning or capacity of concentrating pressure in certain points of contact with a sleeping subject's torso.

The material properties of a mattress lead to certain distributions of mechanical pressure in the body, and studies carried out in experimental sleep laboratories indicate that polysomnographically quantified NREM measures are sensitive to different interface-pressure distributions [6]. Principally affecting micro-arousal events as well as subjective quality. A biomechanical review shows that the mattress design will have an impact on pressure distribution, body support and spinal alignment parameters which are determinants of sleeping comfort although definitive optimal thresholds for these predictors remain incompletely established [5]. Interactions between thermoregulation and the

thermal characteristics of the sleep environment may be due to core and brain temperature reduction, which is associated with sleep onset and NREM-sleep [13-15]. W hile heat inputs from skin have an influence on pathways regulating body functions related to those that are modulating/regulating aspects of SWS (Raymann et al., 2008). Thus, pressure redistribution, thermal regulation and biomechanical support could be regarded as the external sleep-surface environmental factors that interact with one another to affect the sensory systems involved in initiating or maintaining sleep. This may conceptually link user experience, smart mattress technology and sleep neurophysiology, but acknowledges that direct effects on neural activity or sleep structure would need to be quantified using objective methods such as electroencephalography (EEG), polysomnography or similar validated physiological monitoring techniques.

Sleep represents an important period for the brain to rest, cognition, tissue-repair, metabolism, immune function, cardiovascular health and emotional well-being. Utility of sleep in human health makes it an essential factor even modulating the ageing process [11-19]. Developing an optimal sleep ecosystem, including an appropriate sleep surface, may represent an important yet often overlooked component of personal sleep hygiene and sleep health as described by [22]. Millions of adults worldwide still suffer from insomnia, persistent musculoskeletal pain, obstructive sleep apnea (OSA) and negative issues related to good sleep quality. Poor sleep triggers diseases like cardiovascular disorder, obesity, diabetes mellitus (DM), depression, cholesterol level and eventually impair quality of life [12]. This current pilot study provides a novel insight that the AI-enabled Dynamic Sleep Surface could elicit significantly higher short-term user satisfaction compared with those using a Static Mattress [11-22] and has significant ability to influence external sleep physiology.

Transition from Passive Static Sleep Surfaces to Intelligent Dynamic Sleep Ecosystems

Participants provided ratings for Comfort (+1.12, $p < 0.001$), Firmness (+1.06, $p < 0.001$), and Overall Satisfaction (+1.05, $p < 0.001$) that were significantly higher on average with moderate-to-large effect sizes [95%CI: Cohen's $d = 0.69–0.78$]. These results imply that the evolution of sleep technology from a passive mattress architecture where mechanical properties do not change throughout the night into an adaptive dynamic system able to sense and modify support properties is a big step forward in sleep technology. Traditional static mattresses work on a set mechanical response; yet human sleep is dynamic with constant positional changes, pressure distribution variances, muscle tone fluctuations and physiological need changes throughout one night of sleep. Thus, a single stationary firmness profile may not be optimal at maximizing support across all individuals, sleeping positions, body morphologies, and physiological states. Additionally, recent research directions highlight the potential of personalized and adaptive support to surpass the limitations linked to traditional static designs. There is evidence from systematic reviews that medium-firm and adjustable/customized mattresses are better for comfort, sleep quality and spinal alignment than inappropriate (rejectable) firmness levels [4-24]. Results from the present study build on this idea by indicating that mattress technologies of the future may not simply be a matter of finding the "right" firmness at purchase but rather electronic sleep systems able to continuously modulate highly individualized needs e.g. surfaces with temperature regulation (can be cooled or warmed), hypoallergenic (anti dust, mite resistant and preventing hypersensitivity skin reactions), pressure redistributing (real-time based on sleeping posture), massage-modes (rolling wave for muscle relaxation), zero-G (better blood circulation), mobility (raising upper body or legs), etc. This shifts the paradigm from

a static comfort optimization process to a dynamic in-the-moment physiological adaptation which transforms the mattress into an integral part of a controlled sleep environment thereby affecting Neurophysiology of Sleep [4-43].

Sleep Surface as a Zeitgeber

One of the primary explanations for the superior ratings observed with the Dynamic Mattress may relate to its ability to provide adaptive pressure redistribution. Known extrinsic zeitgebers (time-givers) of the human sleep-wake cycle include light-dark cycles, temperature, food intake, relative humidity, social cues, exercise, medication, etc [7-17] (Patterson, 2019). Automated real-time pressure redistribution on the sleep surface could possibly transform into a dynamic surface and make it act as a zeitgeber as majority participants in this study preferred it even after trying it only for the very first time in their life. Entrainment (synchronization of the biological clock) is a dynamic process that can be modulated by extrinsic factors including sleeping surfaces. Previous smart mattress research has demonstrated the feasibility of pressure sensor arrays combined with automated control systems to detect body structure and modify support to influence sleep better [43]. Developed a smart mattress incorporating pressure sensors and adjustable air-cell technology capable of recognizing body pressure patterns and automatically modifying mattress configuration to achieve more uniform force distribution. Therefore, the improved comfort and overall user-satisfaction ratings observed in the present study reflect a user-Neurophysiological advantage of adaptive pressure management where the sleep surface responds actively to the individual.

Thermoregulation and the Importance of long-term Evaluation

Thermal surface comfort is a complex physiological phenomenon influenced by ambient temperature, humidity, bedding materials, metabolic activity, hormonal changes and duration of exposure hence this finding becomes significant. Prior mattress research also documented insufficient evidence for ideal thermal properties of sleep surfaces; however, this appears to be constrained by laboratory or showroom type exposure [24]. For example, a 30-minute trial provides sufficient exposure for immediate comfort and support perception assessment but may underestimate longer-term physiological responses of the sleep surface such as overnight heat storage induction via sweating, ethnic preference for higher or lower sleeping temperatures, hot/cold sleepers, room temperature, relative humidity of the area (e.g., Smith et al., 2018), sleep-stage disruption factors or circadian temperature regulation. The same applies for the Dynamic Mattress, which did not reach statistical significance but scored +0.30 points better on overall temperature rating compared to placebo ($p = 0.051$; Cohen's $d = 0.19$). Thus, further studies should employ a full-night assessment with objective measurements such as skin temperature recording, overall sleep efficiency, slow-wave sleep duration and nocturnal awakenings. [16-24]. This study could not carry out full-nights assessment due to inability to access a highly expensive and new dynamic smart-mattresses for several people to sleep on for protracted periods of time.

Healthcare Implications: From Fixed Preference to Dynamic Personalization

Comfort is one of the most controversial psychological parameters in mattress science. Whether it is a psychological thought, feeling or emotional wellbeing is still being worked through by humans. Purchases are made based on available information and array of bedding equipment in the market. Earlier robust pocket springs of different tensile strengths, gauges, materials like stainless steel or copper or titanium alloy or different densities of foam or latex or gel for firmness adjustment were used far and wide. Advice given to consumers attempting to choose a Static mattress was based on categories that were largely subjective: choose

either soft, medium or firm. Yet scientific evidence has demonstrated that ideal firmness varies widely across individuals depending on body weight, skeletal geometry, sleeping posture and musculoskeletal condition. In the present study, a major contrast between Dynamic Mattress was found about optimistic firmness (+1.06 focuses, $p<0.001$). This improvement does not imply that participants preferred a consistently firmer mattress; rather, the findings suggest participants 'experienced' the Dynamic Mattress delivered a more appropriate (dynamic) support response. This distinction is scientifically important (Figure 2). A static mattress delivers one structural support response regardless of the sleeper lying supine, lateral or prone. On the other hand, an adaptive system offers multiple customized support responses based on real-time changes in body pressure patterns and sleeping position [4-43].



Figure 2: Smart AI-Beds in Clinical and Hospitals.

AI-Enabled Sleep Systems and Personalized Health Monitoring

The development of AI-enabled sleep systems is not merely about engineering advancements but is a fundamental shift in sleep science combining responsive sensing, advanced analytics and individualized feedback. New smart sleep technologies can transform the bed into a therapeutic health-monitoring device hence their use in hospitals. Previous studies have investigated smart sleep technologies in healthcare that can act like robots to move parts, elevate, lower, compress, decompress, activate signals, monitor sleep position, pressure distribution, facilitate actigraphy, and physiological signals. These systems have potential use for sleep monitoring, elderly care and. While recent studies using AI to develop mattress systems to prevent pressure injury by automatic pressure redistribution are still in their infancy, they show potential for clinical applications beyond consumer comfort [10-43]. Our study is significant because it represents a unique paradigm not just as a clinical monitoring device, but rather as a consumer-facing wellness technology for domestic settings within homes globally.

Improving Relationship Between Dynamic Sleep Surfaces and Sleep Stages

Sleep Neurophysiology is a tightly regulated biological phenomenon that requires a stable environment, extrinsic zeitgebers, good ecosystem, low physical discomfort episodes and minimal nighttime interruptions

(caused by social cues or ambient noises). In theory, an adaptive mattress may modulate the neural architecture of sleep by attenuating discomfort-related arousals and maintaining stable body positioning while also limiting mechanical stress during extended periods of sleep. Research has shown that slow-wave sleep and aspects of sleep continuity can be modulated using external sensory input or optimization of the environmental conditions including using Neurotechnology and AI-Smart Beds [34]. No polysomnography parameters were measured directly in this study, although these comfort and satisfaction findings assist as a basis for future research to explore objective sleep effects of dynamic sleep surfaces. This proposes an alternative and exciting concept of a mattress serving as an "entrainment parameter" within the sleep ecosystem to optimize sleep merits further investigation (Figure 3). Using dynamic mechanical support to maintain ideal pressures, combination with physiological sensing and continuous adaptation, AI sleep systems in the future may enable personalized circadian and restorative sleep maintenance [21-43].

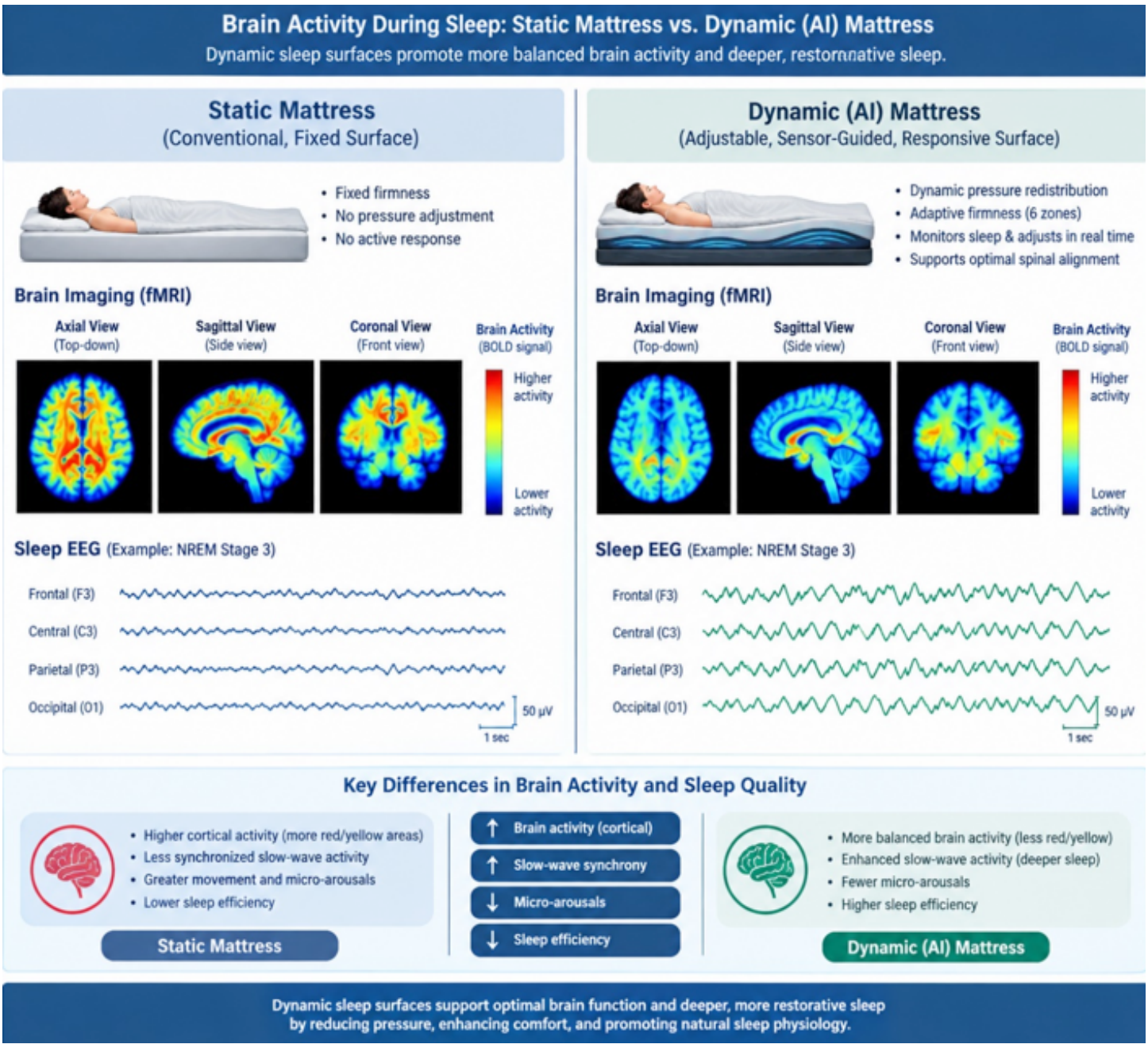


Figure 3: Conceptual Schematic of Optimizing Sleep via Sleep Surface–Neurophysiological Interface.

The schematic illustrates hypothesized pathways through which static and dynamically responsive sleep surfaces may influence sleep-related neurophysiological processes; brain-imaging and EEG representations are only an illustrative example.

Clinical and Public Health Implications

The importance of adaptive sleep technology is more than just consumer preference. The use of Dynamic surfaces/AI Smart Beds are seen prevalent in use to alleviate symptoms in sleep medicine and several other diseases as below [4-24] (Table 1).

Medical Area	Conditions
Sleep Medicine	Insomnia, Sleep Apnea, Circadian Disorders, Restless Legs Syndrome
Cardiovascular	Heart Failure, Hypertension, Arrhythmias
Neurology	Parkinson's Disease, Dementia, Stroke
Musculoskeletal	Back Pain, Osteoarthritis, Post-surgical Recovery
Respiratory	COPD, Asthma
Geriatrics	Frailty, Falls, Immobility
Hospital Care	Pressure Ulcers, ICU Monitoring, Patient Safety
Mental Health	Depression, Anxiety
Metabolic Health	Obesity, Diabetes

Table 1: Implications of AI-Smart Beds in Healthcare.

Future Applications of AI Smart Beds in New Zealand and rest of the World

Future applications are accompanied by an ever-challenging demographic, almost one third of the population in New Zealand now affected by conditions like sleep disorders, muskoskeletal disorders and osteoarthritis in aging populations which necessitate the use of AI-Smart Beds [31]. Therefore, adoption of these beds within domestic settings in homes or old age homes for rest and recovery may aid healthy aging and relieve the public health burden associated with specific diseases/disorders. Connected devices with embedded physiology sensors may facilitate passive and continuous monitoring of sleep patterns, heart rate, respiratory rate, movement and other health-related metrics to detect changes in physiological status sooner. These capabilities play an increasingly vital role in the global emphasis on predictive, preventive, personalized and participatory (P4) medicine [14-43].

The public health relevance of these results extends far beyond New Zealand and into the world. Billions of people around the globe sleep on conventional static mattresses whilst suffering from chronic conditions including low back pain, osteoarthritis, obesity, diabetes, obstructive sleep apnea, pressure-induced discomfort, reduced mobility and neurological disorders as well as age-associated musculoskeletal decline. According to a World Health Organization estimate, as many as 1.71 billion people worldwide suffer with musculoskeletal conditions, and low back pain has remained one of the biggest single causes of disability across the world. In addition, hundreds of millions of adults suffer from chronic insomnia, sleep-disordered breathing or chronic pain conditions that are often exacerbated by long-term exposure to suboptimal sleep surfaces (Figure 4). With chronic populations aging around the globe in North America, Europe, Asia, and Oceania after which more unique growing nations like the ones of China and India this market will probably develop proficiently at full pace as individuals search for innovations to improve non-restorative rest and physical recuperation [4-41].

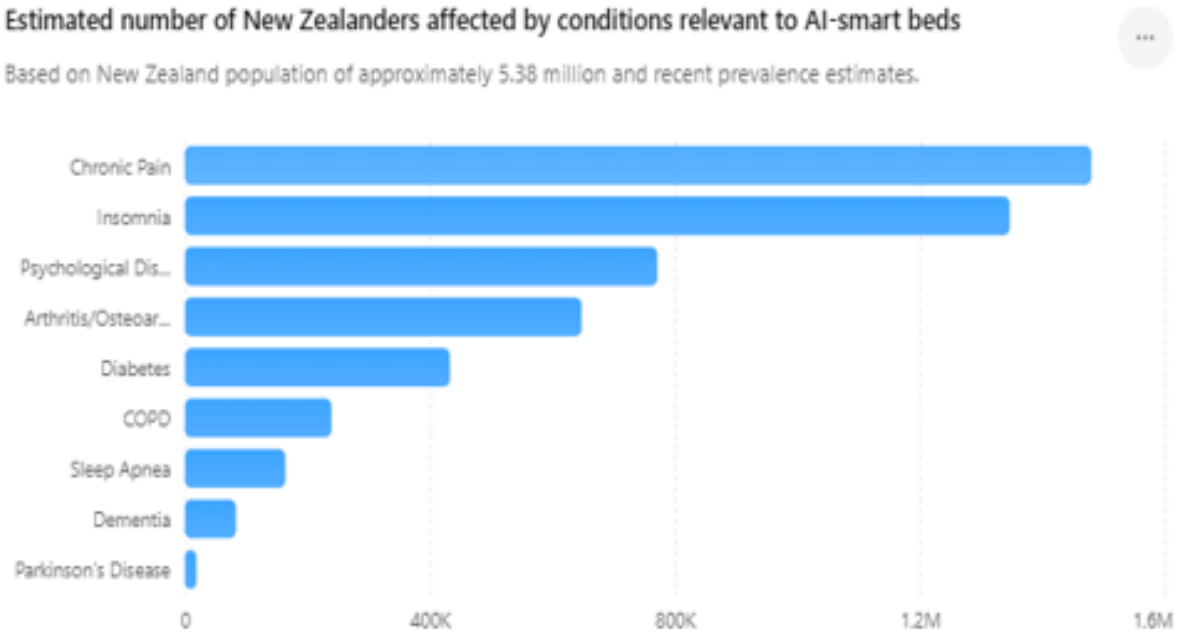


Figure 4: Estimated number of New Zealanders affected by conditions relevant to AI-Smart Beds.

Ministry of Health. (2025). Annual update of key results 2024/25: New Zealand Health Survey. Ministry of Health

Stats NZ. (2025). National population estimates: 31 December 2025.

Conclusions

This pilot study shows that a new AI-enabled Dynamic Sleep Surface was significantly more satisfying to use in the short term than a standard Static Mattress, especially in terms of comfort and firmness perception, as well as overall satisfaction. Yet few limitations should be acknowledged. This was a study in showroom and not in a longitudinal home sleep ecosystem. Despite the benefit of within-subject design for internal comparison, 30 min trial cannot mimic actual overnight sleep or the sleep quality indicator. Second, outcomes were mostly subjective, based on perceived comfort and satisfaction rather than objectively evaluated sleep quality comparison afforded by both mattresses, hence concluded only at the User-Neurophysiology interface so that the Neurophysiology of sleep could perhaps be measured in future experiments. The Smart-tek AI bed may emerge as key pillars of smart homes, digital healthcare ecosystems and smart lifestyles. Instead of continuing to be passive furniture, AI-enabled smart beds can be transformed into therapeutic sleep surfaces by unlocking the potential of artificial intelligence [10-43]. With the growing integration of artificial intelligence into everyday healthcare, adaptive sleep surfaces may soon come to change the role of an originally passive surfaces into dynamic platforms for restorative sleep physiology, preventive medicine, and personalized health. When validated in scale through clinical research and implemented in cost-effective consumer markets, AI-enabled smart bed models could evolve as one of the most important innovations in sleep science and home-based healthcare applications of the twenty-first century [14-43].

Experimental studies have previously shown that subjective assessments of mattress-interface pressure distribution are associated with objectively measured sleep outcomes, such as NREM (non-rapid eye movement) sleep and micro-arousals suggesting an interaction between the properties of the sleeping surface and physiological mechanisms occurring during sleep. The approach we take is dynamic coupling of central nervous system activity and autonomic cardiovascular regulation, with relationships among cortical activity, cardiac activity, arousals and heart-rate variability [8]. Thermal environment surrounding the body interacts with physiological processes responsible for sleep regulation and initiation [13]. For this reason, subjective satisfaction establishes a finite user–sleep-surface relationship, which could define the first level of the user's side of an interface called user–sleep-surface–neurophysiology, rather than direct neural evidence. Future clinical studies could bridge this framework by integrating intelligent dynamic sleep surfaces with objective measures e.g., electroencephalography [EEG], polysomnography, electrocardiogram and heart-rate variability, respiratory measurements, and other verified physiological signals to determine if adjustments in pressure distribution or postural support elicit altered states of sleep architecture and neurophysiological activity. Polysomnography is still an established reference method for objective assessment of sleep and includes EEG, electrooculography (EOG), electromyography (EMG) signals, respiratory measures ECG as well as peripheral deoxygenation saturation. Therefore, the results of this pilot study can be interpreted as a first empirical step for moving AI-enabled sleep surfaces beyond mere passive comfort provision towards an adaptive biosensor–actuator interface between sleeping individuals and underlying physiology during sleep.

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