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Mattress Coil Spring Fatigue and Support: A Potential Association with Spine Stiffness and Pain

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Abstract

Prolong mattress use compresses the metal coil springs which may ultimately result in a compromised sleeping surface. This coil spring metal fatigue can result in spinal pain and stiffness. The purpose of this study was to compare the amount of metal fatigue of used mattresscoil springs from the areas bearing greatest body weight versus areas subjected to little compression to ascertain the. Six weight bearing coil springs (WBS) were extracted from the center the used (range 8-10 yr.) mattresses (*N*=32) and six non-weight bearing coil springs (NWBS) were extracted from the head/foot are of the same mattresses. To determine spring weakness a special frame and platform was constructed to compare unloaded spring height with compression distance height following placement of a 1,296 g ingot on the platform. Also, a pressure gauge was used to measure the amount of pressure required to compress the coil springsa distance of 2 cm. Comparison between WBS and NWBS data were statistically treated using independent t-tests and a one-way ANOVA. There were no significant group differences in weight or height in unloaded coils. However, there were significant ($p<0.05$) differences in coil spring compression distance under load (WBS = 2.78 ± 0.34 cm; NWBS = 1.52 ± 0.39 cm) and force gauge compression (WBS = 1090.51 ± 88.42 g; NWBS = 1213.12 ± 71.38 g) between groups. While manufacturers' recommendations to replace a mattress is ranges between 8 and 10yrs., these results indicate that coil spring weakness may occur before 8 yrs. of use. Weak springs leads to loss of weight bearing capacity of the mattress thereby resulting in sagging upon use.
Such sagging which may compromise sleep posture with accompanying back pain and poorsleep quality and quantity.

Keywords: Mattress, Sleep, Back Pain, Stiffness

Introduction

Sufficient sleep is essential to all living things and is essential in providing healing and restorative health. However, according to the National Sleep Foundation [1] 26% of Americans report obtaining a good night's sleep only a few times per month. Sleep deficiency interferes with activity, social interactions [2] and is linked with depression, emotional reactivity, mental health [3]. Additionally, sleep deficiency is also associated with loss of work production and injury [4]. While multiple psychological, physiological and chemical factors can interfere with sleep quality and quantity, the sleep surface is a feature that has not been thoroughly studied. Consumers seek comfort in choosing a sleep surface, which prompts mattress manufacturers to attempt to create newer and innovative forms of sleep surfaces. Contemporary mattress construction has evolved to include inner spring, viscoelastic foam, latex foam, and air bladdersand the U.S. mattress market is expected to grow from about $30 billion in 2019 to over $40 billion dollars by 2024 [5]. Consequently, in order to gain a competitive advantage, improving thequality and comfort of mattresses is of considerable interest to manufacturers.

Despite innovations in sleep surface technology, an estimated 50 to 70 million people in the United States suffer from sleep deficiency [6]. Furthermore, this number is expected to grow to over a 100 million by the middle of the 21st century [7]. Several studies have found that older mattresses have a negative impact on sleep and that by replacing the mattress, sleep quality and quantity along with musculoskeletal ailments improved significantly [8-10]. Furthermore, it has beendetermined that a sagging mattress interferes with sleep regardless of sleeping posture due to a lack of spinal support which may contribute to musculoskeletal pain [11]. One study introduced newinners spring and latex mattresses to compare sleep quality between the mattresses and found that both mattresses led to significant improvement in sleep, thereby suggesting that improvement in sleep may have been primarily due to the introduction of the new mattresses rather than the selected sleeping surface itself [12]. Correspondingly, our previous studies found that the age of the bed contributed to back ache and stiffness and that the introduction of a new bed significantly reduced ache and stiffness [9,13-14]. While mattresses are accompanied by warranties, however mattresses may not be visibly sagging sufficiently for the warranty to be honored. Manufacturer's definition of sagging differ from how the consumer defines sagging. For example, the predominance of mattress manufacturers require an unoccupied mattress indentation of 1.5 in. (3.81 cm.) [15]. Clearly, with an un-weighted indentation of 1.5 in., once oneenters the bed the indentation or sagging would be much greater and the spinal posture much more compromised.

Coils

Mattress coils were introduced in the mid-late 19th century and first appeared in buggy seats and later added to mattresses. Despite the new innovations in sleep surface material and design, the innerspring mattress remains the most popular type of mattress [16]. The construction ofthe inner spring mattresses include a steel coil support system which can take several forms such as open coils, offset coils, Bonnell coils, continuous coils and pocket springs. The Bonnell coil (Figure 1) is the most popular and resemble an hourglass shape wired together to adjacent springs. Covering the innersprings are padding materials, usually consisting of the several layers including the insulator, the middle upholstery, the quilt, and the ticking which generally includes a thick fiber cotton-like mesh covering the innersprings and a middle upholstery layer typically made from polyurethane foam, latex foam, or viscoelastic foam. The outermost quilt layer (outer layer) is usually made of light foam or fibers stitched to the underside of the ticking to provide a soft surface texture. Ticking is the protective cover encasing the mattress and can be one of manymaterials such as knits, damask, rayon, cotton, wool, or nonwoven materials

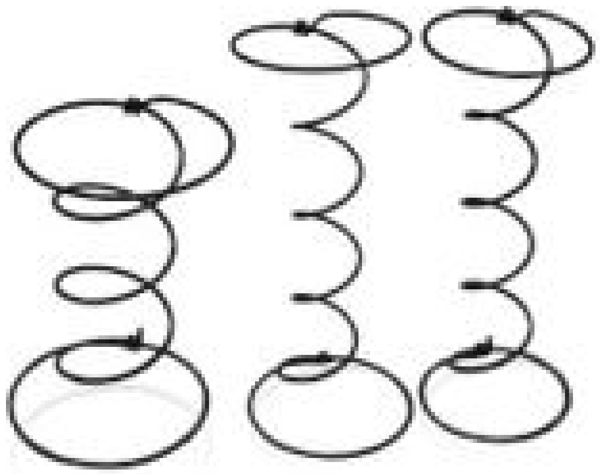

Figure 1: Bonell springs and Bonell mattress

Other than coil spring shape, factors such as coil count, coil gauge and working turns vary in mattresses and is directly related to mattress firmness and durability. Generally, higher coil counts provide better body support and increase mattress longevity. Minimum coil count recommendations consists of 300 for a full, 375 for a queen, and 450 for a king mattress [17]. Coil gauge refers to the measured thickness of the wire used to make the mattress coils [18]. Moreover, mattress coil gauges generally range from 12 to 15 with the lower number representing the thicker spring and the higher number a thinner spring [21]. A higher coil gauge number provides a softer, springier feel, whereas a low coil gauge offers firmer support [19]. Typically, 13 is the gaugefound in most mattresses. The working coil turn is defined as the number of turns in each coil and is determined by how many times the coil is wound 180° [17]. A higher number of turns results in a softer and more durable sleep surface.

Longevity

With continued use, mattresses eventually lose structural integrity. The material layers flatten and the coils weaken, resulting in reduced support and comfort of the mattress. While mattress longevity is not fully agreed upon, one source indicated that the comfort potential of aninnerspring mattress is approximately 10 years [20-21]. The National Sleep Foundation [1] recommends replacement every 8 yrs.

According a survey conducted by the Better Sleep Council[22], nearly 75% of the responders expected to keep their mattresses slightly more than 9 years. The findings of our previous studies [9,14,23] reported that participants' average mattress age was closer to 10 years. Considering the recommended eight hours of sleep per night, this equates to over three years use of a mattress. Given this rate of usage in relation to the typical longevity of mattress use, many individuals may inaccurately ascribe the pain and stiffness they experience to physical stress or ageing, rather than protracted use of the mattress. For these reasons, measuring the structural integrity of mattresses to determine potential causes of these musculoskeletal issues is warranted.

Comfort

Pressure over time tends to weaken coil springs through metal fatigue a condition induced by repeated stresses or loading, thus reducing their ability to sufficiently bear the load ofthe sleeper [24], Depending on the age and use of the mattress, weakened coil springs can negatively affect comfort and ultimately, sleep quantity and quality.[14] Concerning sleep quality, Addison and associates

[25] concluded that sleep problems are often related to an uncomfortable sleep surface which leads to physical discomfort. Others have found back pain to be the leading factor that interferes with sleep [26,27] and that a "clear connection" exists between mattress sagging and back pain [28]. Moreover, according a survey of over 27,000 individuals, a sagging mattress was the leading complaint of poor sleep [28]. Additionally, in a survey of mattress complaints, 60% of the respondents specified mattress sagging as the reason for aches and back pain [29,30,31]. Thus, when coil springs lose their original integrity so that the mattress sags, it causes, not only may this cause back ache, but also may initiate bulging discs and even nerve damage in extreme cases [32]. While foam mattresses will also sag, in general, innerspring mattresses are more prone to noticeable effects of fatigue and sag when bearing the sleeper's weight [19].

Predictably, mattress coil spring weakness is more evident toward the middle of themattress where the sleeper's greatest body mass rests [33]. However, the coil springs may not always display sagging when not bearing a load. Additionally, the outer cover of mattresses naturally retains the outward appearance because sheets and liners continually cover them. Thus,the mattress outward appearance typically appears to be new and unworn even after years of use.

To our knowledge, no previous study has attempted to evaluate the coil spring integrity inmattresses. We are aware that the literature is comprised, in part, of subjective information ratherthan empirical research. However, based on the predominance of information that implicates the mattress as a leading cause of poor sleep and backache, the need for the current study appears warranted. Therefore, the aim of this study was to determine if a difference in firmness existed between mattress coil springs that had been subjected to the sleeper's greatest body weight to those that had been subjected to less load.

Methods

Researchers accessed used mattresses (*N*=32) and extracted 13-gauge coil springs from mattresses used 8 to 10 years (Mean 9.2 yrs. SD ±2.65). Mattress age was determined and recorded by accessing the legally required tag attached to each mattress, which lists the month and year of manufacture. Mattresses missing these labels were omitted as were mattresses older than 12 yrs or newer than 6 yrs. Groups of six coil springs were extracted from the center of eachmattress where the greatest body mass was estimated to have been applied which are referred to as weight bearing springs (WBS) and groups of six coil springs were taken from the same mattress at the foot or head of the mattress where the least weight was estimated to have been placed. These coil springs were referred to as non-weight bearing springs (NWBS).

The initial assessment of the coil springs was to measures weight and height of each spring. Since Bunnell springs have an uneven top height (Figure 1), height was measured to thenearest 1.0 mm from the base to the highest point of the spring. Weight of the springs was measured by a digital scale (US Solid. Electronic Precision Balance. Mod. USS-DBS15-5) to thenearest 0.1 gram. This was done simply to ascertain that each of the coil springs were of equal gauge and construction.

For compression assessment, a special apparatus was constructed consisting of a vertical 60 cm stainless steel rod attached to a 30 x 30 cm stable base platform. A 12 cm long PVC tube attached to a thin, rigid 15 x 15 x 0.3 cm plate was slipped over the steel rod providing free vertical movement. In order to measure coil differences in compression strength, each group of Bonnell springs were placed on the platform and the plate was placed on top of the spring. Oncesecure, the elevation of the platform was recorded. Subsequently, a weight (1296 g) was placed on top of the plate and the displacement distance of the plate was recorded to the nearest 0.5 mmto determine the amount of compression registered by each spring. Thus, a weaker spring shouldresult in a greater compression distance than a stronger spring under the same load. To assure accuracy, this procedure was repeated three times and averaged for each spring.

For the additional compression measurement, the spring was placed on the base platform,under the top plate, in the same manner as in the first assessment. Once placed on the base platform and with the plate on top, a digital force gauge (Wagner Instruments FDX 10) was usedto compress each spring to an exact distance of 2.0 cm after which the peak force was automatically recorded by the force gauge. This procedure was also replicated three times and averaged for each coil spring.

Data Analysis

Pre-process data was checked for normality using the Shapiro-Wilk Test for normality.Independent *t*-tests were used to determine if a difference in weight and height between WBS and NWBS coil springs. Similarly, an independent *t*-test was used analyze the amount of pressureneeded to compress the coil springs 2 cm. A one-way ANOVA was used to compare the pre- and post-extent of pressure needed to displace the WBS and NB coils 2 cm. An alpha (α) level of$p<0.05$ was used to determine statistically significance.

Results

The pre-process Shapiro-Wilks Test indicated a normal (symmetric) data distribution ($p>0.05$). Height measurements of unloaded coil springs indicated that the WBS coil springs were 0.4 cm shorter than the NWBS coil springs (12.2 cm vs 12.6 cm respectively). An independent *t*-test yielded a non-significant ($p>0.05$) difference (Fig. 2) between the two groups.Hence, the coil springs that had sustained the greatest compression would not visually appear to be weaker or sagging when not occupied (Figure 2).

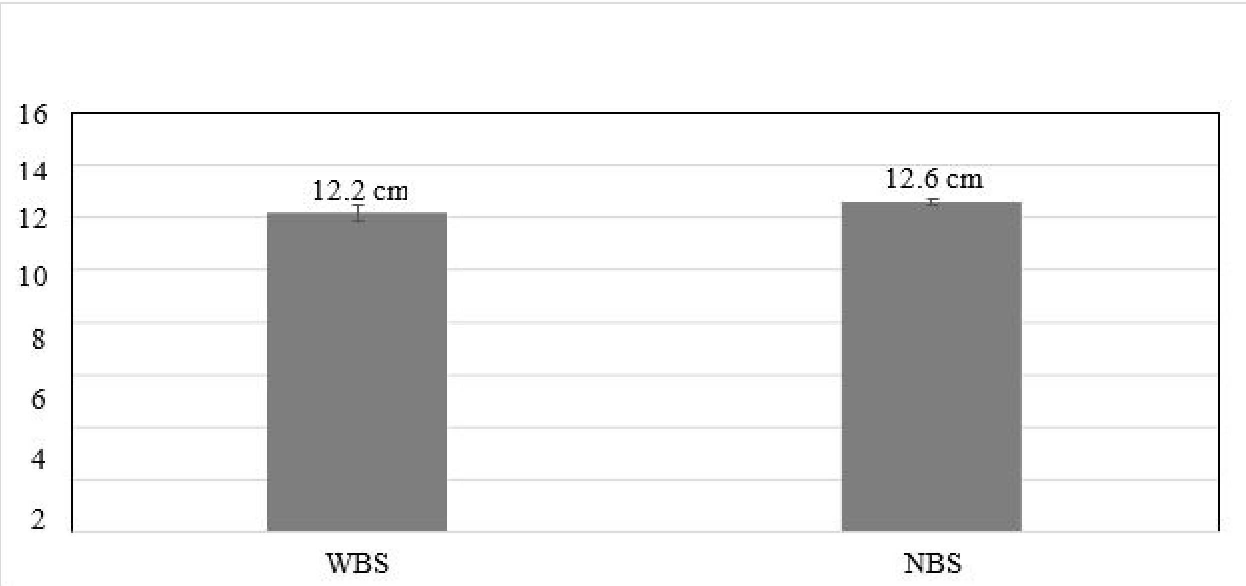

Figure 2: Comparison of unweighted height (cm) means and SD betweenWBS and NWBS

Weight measurements of unloaded coil springs resulted in a very slight difference between the WBS and the NWBS groups (35.5 g vs 35.7 g respectively). An independent *t*-testyielded a non-significant ($p>0.05$) difference (Figure 3) between the two groups.

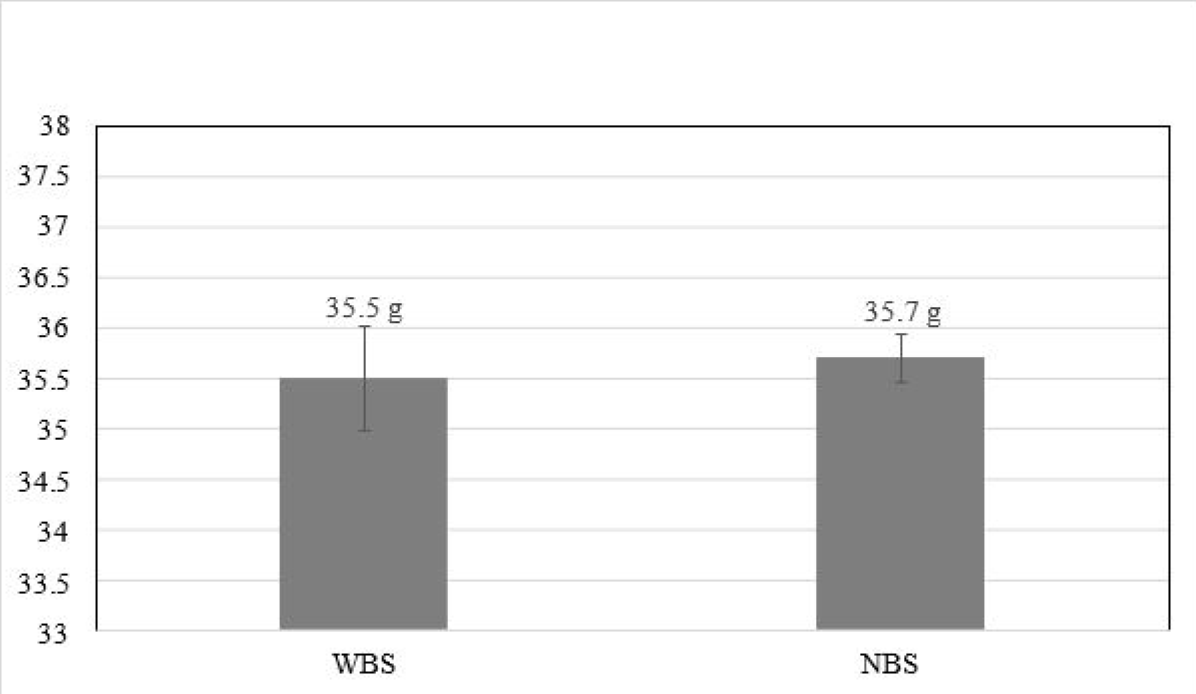

Figure 3: Comparison of weight (g) means and SD betweenWB and NWB

The one-way ANOVA comparison of the pre- and post-test difference for the 1296 g weighted conditions yielded a significant difference (p<0.05) between the NWBS and the WBScoil springs, with the WBS springs compressing a significantly greater distance than the NWBS(1.52 cm vs 2.78 cm respectively) (Figure 4).

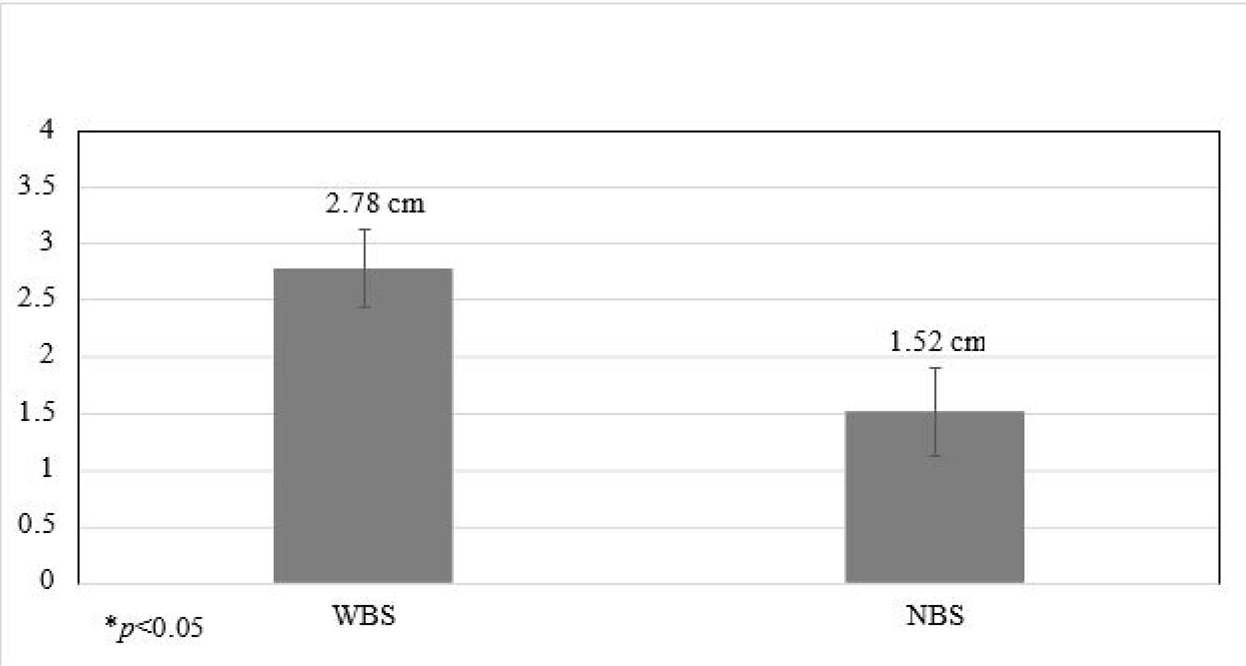

Figure 4: Comparison of distance (cm) means and SD resulting fromweighted (1296 g) compression between WBS and NBS

An independent t-test comparing the amount of force needed to compress the coil springs 2 cm resulted a significant difference ($p<0.05$) between the NWBS and the WBS, with NWBS requiring greater force to compress the spring 2 cm than the WBS (1234.1g vs 1129.7 g) (Figure 5).

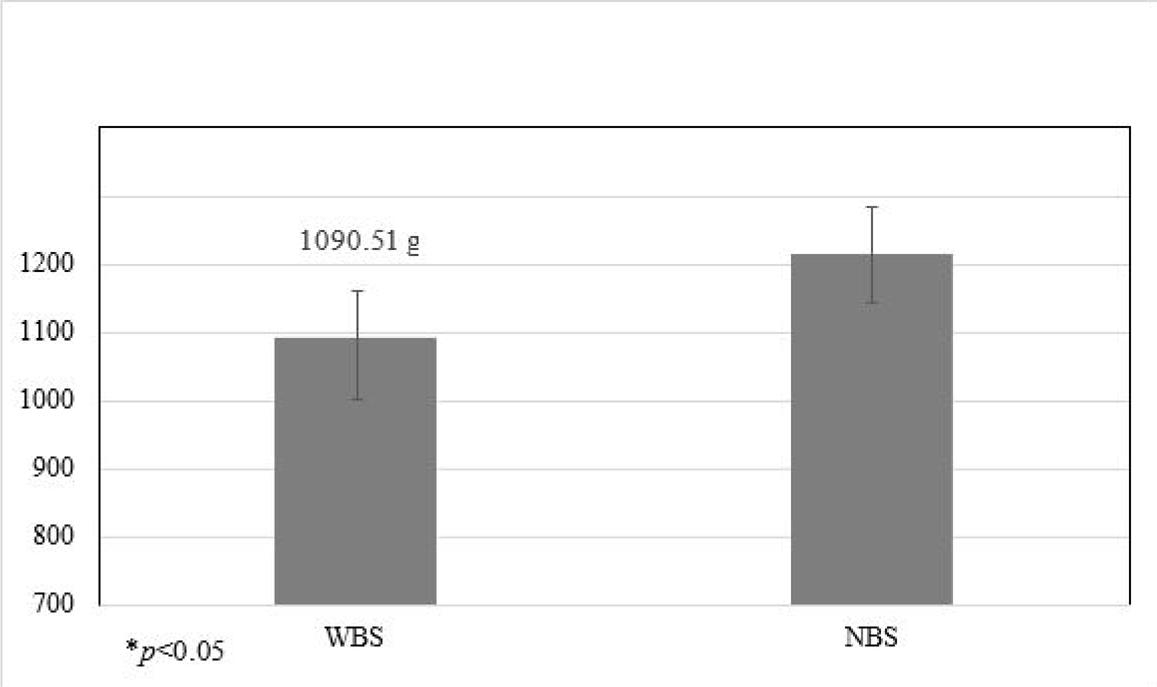

Figure 5: Comparison of pressure (g) required to compress springs20 cm. between WBS and NBS

Discussion

Makes and models of mattresses are constantly being developed, but scant information isavailable to accurately determine what sleep bedding system is best and why. Other than what the manufacturers' claim, little can be found that is supported by science. Based on these results, it is evident that coil springs in the bedding system will eventually fail to provide the initial structural support found to be suitable and comfortable at the time of purchase. Furthermore, theweakened coil springs may eventually negatively impact overall sleep quality and quantity, as well as impact musculoskeletal and spine health [11,34]. The optimal sleeping surface for average individuals should support the spine in a natural position and bedding system support to improveoverall body alignment is imperative so to allow the inter-vertebral disc to re-hydrate, and muscles of the spine to relax while sleeping [35]. With side and prone sleeping positions being the most popular positions, a sagging bed compromises the spine in excessive lateral flexion and in extension respectively. The range of motion in both of the aforementioned spinal movements exhibits significant reduction after the age of 40 [36]. For example, Troke, et al., [37] in a cross-sectional study of 405 subjects ranging in age from 19 to 90, found that left and right lateral flexion ranged between 28° and 14° and declined 45% and 48% respectively. Spinal extension ranged between 29° and 6° and declined by 79% as individuals' age. Therefore, weakened coil springs in the area of the trunk can lead to mattress sagging and spinal misalignment, therebycausing extended limit-range positions of the spinal joints over an extended period of time [38]. Further research is needed to determine the when a mattress should be reevaluated before theprevalence of sleep disturbances and musculoskeletal issues arise.

Despite the fact that middle WBS springs were highly compressed compared to the less compressed NWBS coil springs, net weight between the groups was not anticipated to differ since it is doubtful that erosion of the metal would occur. Principally because each coil spring functions independently with only wired connections to the adjacent springs by wires to the topsand bottoms of the coil springs.

While WBSs were found to be weaker when compressed than the NWBS, such characteristics may not be visually apparent as a sagging mattress when not in use. It was determined that NWBS and WBS unweighted height differed slightly (0.4 cm) when not compressed, therefore only by close inspection such difference may be difficult to determine as sagging. Hence, most mattresses will appear supportive, with little to no visual sagging when notoccupied. Only when an individual enters the bed will they experience the weakness of the coil springs and a sagging of the mattress. For the typical mattress warranty to be effective, an unoccupied mattress must exhibit an indentation of 1.5 in. (3.81 cm.) [24], which would result in considerably greater compression/sagging when occupied. Ultimately, if the unoccupied mattressexhibits such sagging it is well beyond the need to be replaced. The fact that weak springs do not appear to be sagging when not occupied may reduce any warranty refund when it only applies to the unloaded sagging criteria of 1.5" or more.

Perhaps an equally convincing result of coil metal weakness is the data related to the extent of compression force difference between the NWBS and WBS springs. The data yieldedby the compression gauge revealed that significantly ($p>0.05$) less pressure was required to compress the WBS 20 cm. compared to the NWBS (1090.519 g vs 1213.12 g respectively), suggesting considerably weaker WBS in comparison to the less occupied NWBS.

Research regarding sleep quality and/or mattress related back pain has principally revolved around factors such as aging, stress, mattress type, and comfort with little considerationfor independently evaluating the mattress structures independently. Much of our previous research compared new mattresses and mattresses owned by participants presenting with specificphysical complaints such as nondescript back pain and stiffness [8,9,14]. Hence, our previous research, as well as others advocates that medium-firm mattresses are the commonly recommended surfaces for the general population, while giving exception to outlying conditions such as chronic pain, post-surgery, obesity, or other physical circumstances [8,13,39,40,41,42].

However, with the innerspring mattress being the most popular bedding system, we are not aware of previous studies that have sought to look more closely at the physical properties of coil springs after normal prolonged use. These data suggest that the condition of the metal coil springs tend to weaken after protracted use. Further research should also focus on variables such as body weight, usage and mattress quality as determining factors in spring weakness that were not available to these researchers. Nevertheless, it remains axiomatic that continuous compression of coil springs will weaken the spring to the point that the mattress does not provide the necessary support or comfort that was initially preferred.

Limitations

No attempt was made to determine the weight of the mattress occupants, nor was it possible to trace the mattresses to the original owners. Additionally, the amount of mattress usage was overthe years was not available.

Conclusion

In conclusion, both nonrestorative sleep and musculoskeletal health issues my potentiallybe attributed to the structural integrity of the mattress. These data suggests that coil spring weakness in the weight bearing areas of the mattress contributes to sagging which places the length of the spine in a compromising position throughout the time the bed is occupied. Several studies have concluded the selective bedding system may be of less importance than the amount of use the mattress has incurred. Hence, the age of the bed and the structurally weakened components contributed to back pain and stiffness and when new mattresses were introduced, musculoskeletal pain significantly improved even for those suffering from chronic back pain 23 Better [8,9,1213,14,23]. Therefore, it is recommended that bed mattresses be evaluated periodically and consistently to determine the amount of support the coil springs afford, and mattresses should be replaced accordingly to enhance overall sleep quality, quantity and maintain musculoskeletal health.

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