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Abstract:

Bedsores, also known as pressure ulcers, are wounds caused by the applied external force (pressure) on body segments, thereby preventing blood supply from delivering the required elements to the skin tissue. Missing elements hinder the skin's ability to maintain its health. It poses a significant threat to patients that have limited mobility. A new patented mattress design and alternative suggested designs aimed to reduce pressure are investigated in this paper for their performance in decreasing pressure. A simulation using Ansys finite element analysis (FEA) is carried out for comparison. Three-dimensional models are designed and tested in the simulation for a mattress and human anthropometric segments (Torso and Hip). All designs are carried out in SolidWorks. Results show that the original design can redistribute the pressure and decrease it up to 17% less than the normal mattress. The original design shows better ability to decrease the absolute amount of pressure on the body. However, increasing the surface area of the movable parts results in less pressure applied to the body parts. Thus, this work suggests changing the surface area of the cubes from 25 to 100 cm2 .

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Keywords:

bedsores; pressure ulcers; immobility

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الملخص باللغة العربية:

قرح الفراش، والمعروفة أيضًا بقرح الضغط، هي جروح ناجمة عن قوة خارجية (ضغط) على أجزاء الجسم، وبالتالي تمنع إمدادات الدم من إيصال العناصر المطلوبة إلى أنسجة الجلد. العناصر المفقودة تعيق قدرة الجلد على الحفاظ على صحته.

إنه يشكل تهديدًا كبيرًا للمرضى الذين لديهم قدرة محدودة على الحركة. يتم في هذه الورقة دراسة تصميم مرتبة جديد حاصل على براءة اختراع وتصميمات بديلة مقترحة تهدف إلى تقليل الضغط لأدائها في تقليل الضغط.

تم إجراء محاكاة باستخدام تحليل العناصر المحدودة Ansys (FEA) للمقارنة. تم تصميم واختبار نماذج ثلاثية الأبعاد في محاكاة المراتب والقطاعات البشرية (الجذع والورك). - يتم تنفيذ جميع التصاميم على برنامج Solidworks .

أظهرت النتائج أن التصميم الأصلي يمكنه إعادة توزيع الضغط وتقليله بنسبة تصل إلى ١٧% أقل من المرتبة العادية. يُظهر التصميم الأصلي قدرة أفضل على تقليل مقدار الضغط المطلق على الجسم. ومع ذلك، فإن زيادة مساحة سطح الأجزاء المتحركة يؤدي إلى تقليل الضغط المطبق على أجزاء الجسم. وبالتالي فإن هذا العمل يقترح تغيير مساحة سطح المكعبات من ٢٥ إلى ١٠٠ سم٢.

الكلمات الدالة: ألم السرير؛ قرحة الضغط؛ الجمود

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Introduction:

Bedsores, also known as pressure ulcers, are wounds that pose a significant threat to the wellbeing of limited mobility patients by the pressure influence on normal blood circulation. The pressure reduces the amount of oxygenated blood cells loaded with nutrients to the skin surface under pressure . Data show that 70% of bedsores patients are 65 years old and older. Moreover, the younger population with a severe or chronic illness accompanied by neurological impairment are more prone to developing bedsores due to the lack of movement. Bedsores are classified according to their severity into four stages starting with stage I where skin is intact with non-blanching redness. Stage II is when the skin starts to open as an ulcer; stage III is when the skin starts losing full thickness tissue with visible subcutaneous. The last stage, Stage IV, is when there is a full-thickness skin loss with visible muscle and bone. extrinsic. While intrinsic factors are hard to manage mechanically due to the fact they lie within the body, extrinsic factors are often dealt with mechanically. There are multiple ways in which health practitioners can screen patients for pressure ulcers; since the early 1960s, risk assessment scales have been developed and used. Among the most famous scales are Braden and Norton scales. These scales are 5 and 4-point scales to screen patients in order to prevent pressure ulcers from developing. The Braden and Norten scales are methods that medical practitioners use to get a prediction whether a patient is at risk of developing pressure ulcers and

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not ways to prevent the development. The Braden scale takes into account the sensory perception, activity, mobility, moisture, nutritional status, and shear. Furthermore, the Norton scale takes into account the general physical condition of patients, and their mental state, activity, mobility, and incontinence. According to the wound healing society [8], the process starts with the Pressure Ulcer Risk Screening (PURS) where all patients must undergo an assessment by a registered nurse to identify whether they are at risk of developing pressure ulcers. If identified, patients undergo a plan for prevention that includes dressing and pressure relief. Guidelines recommend three stages for the prevention of bedsore among patients, including screening where all patients with known risk factors such as age, sex, race are vetted for risk factors. Risk assessment is used to assess how likely the patient would develop the bedsores. Finally, wound management is used at a later stage where the ulcer has already been developed. Bedsore wound management and prevention has been under the scope of researchers and scientists; due to this fact, multiple solutions have been developed. Mechanical or pneumatic tools emerged to aid healthcare practitioners such as mattresses and overlays that are divided into different design cells filled with gas or water cushions designed on anatomical bases and wedges to support limbs; or a combined dynamic system of electrical sensors and mechanical components. According to Marchione et al. 2023, the most used techniques to prevent and manage pressure ulcers are by monitoring pressure. Although many other techniques monitor blood flow, pressure distribution remains the main focus when it comes to pressure ulcer risk

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factor monitoring . Given that the extrinsic risk factors of developing pressure ulcers are pressure, friction, and shear, the effect of these risk factors on the skin can be recreated using simulation techniques such as finite element analysis (FEA). The use of such a technique provides researchers with the ability to apply multiple scenarios without the chance of harming human participants, while at the same time, providing relatively high accuracy results that can be reliably considered. Simulation studies have been previously used in many biomedical studies . A new patented mattress was designed to minimize the chance of developing bedsores among bed-ridden patients. The proposed design offers a cheap and effective solution to manage bedsores in prone patients. This study aims to investigate whether the proposed new design is able to effectively reduce the risk of developing bedsores. The study is divided into two parts; first, studying the pressure distribution using multiple simulation scenarios namely full support (with no pressure distribution) and with supported pressure distribution (removing some support elements). Second is studying the effectiveness of slight design modification on these scenarios.

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Materials and Methods

Mattress Design Model Preparing

The mattress design three-dimensional drawing in Figure 1 is based on the patent measurements [18] developed using SolidworksTM 2013. The patent design has two major components, one is the main mattress that is similar to any typical mattress, design-wise, with a width of 90 cm, length of 190 cm, and depth of (14 cm), and a cavity that spans the width of 50 cm, length of 110 cm, and depth of (7 cm), as shown in Table 1. The second component of the patented design is the removal cubes that are 5 × 5 × 5.8 cm.

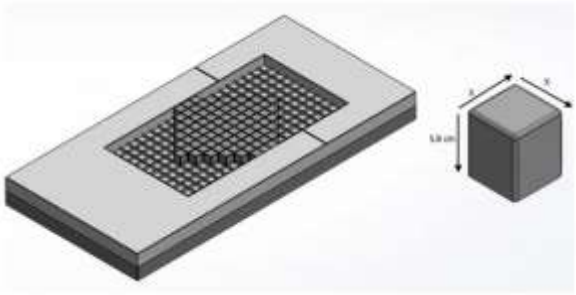

Figure 1. (left) Mattress Model Isometric view. (right) Isometric view of the cube model with its dimensions.

Human Body Models

The human body anthropometric models, shown in Figure 2, are designed to be the test tool placed on the mattress. The models' measurements were adapted from Ronald L Huston [20] human anthropometric data. The area of interest in this paper is the upper body separated into two segments, namely torso and hip. These parts have the biggest surface area, providing the test with a clear contact pressure to form a result heat map on the models. The two segments are designed to assemble the upper body as torso and hip, as shown in Figure 1.

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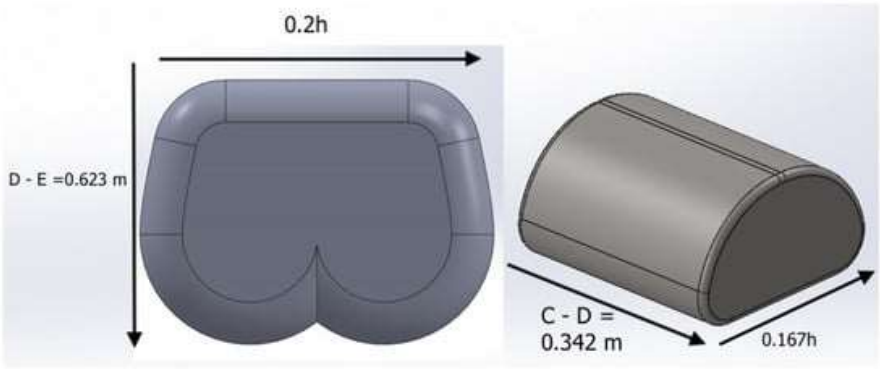

Figure 2. (**left**) Hip model bottom view. (**right**) Isometric view of torso model. Dimensions adapted from Huston anthropometric data.

Study Design and Simulation

Instead of using pressure sensitive sensors, the simulation in this study was conducted Using ANSYS workbench finite element analysis to evaluate the contact pressure risk factor. To simulate a real case scenario, the analysis is set with the following boundary conditions:

1. Gravitational acceleration (g) = 9.81 m/s2.
2. Fixed support under the mattress.
3. Unstructured triangular mesh.
4. Minimum mesh size = 1 mm
5. Maximum mesh size = 1 cm

The Von-Mises provide results in three streams:

1. The pressure distribution on the whole system (inclusive of body part and mattress). This allows for investigating how the movable parts behave under pressure.
2. The pressure distribution on the torso model independently. This allows for the investigation of the effect of cube removal on the torso.
3. The pressure distribution on the hip model independently, which allows for investigating what happens to the hip when the arrangement of the cubes is changed.

Results

All results from the simulated force (bodyweight) are presented in .Full support refers to the mattress while all parts are intact. Supported

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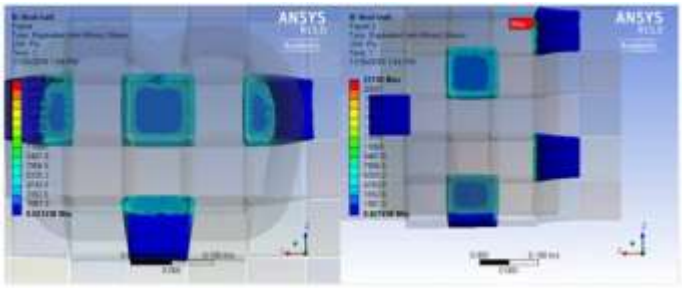
pressure distribution refers to the mattress after the removal of some movable parts (the parts supporting the maximum pressure point). The number of parts removed differs for each body segment and ranges from one to five parts.

Discussion

This paper presents a simulation of consistent application of force (bodyweight) on a semi-rigid surface (mattress). The simulation mimics the case of a bed-ridden patient who is unable to move his/her upper body parts, and thus, is prone to bedsores.

The original patented design, performed well as the original design. It was able to decrease the maximum pressure by 17% and 12% on the hip and torso consequently. These values show better performance compared to Cube A design that showed only a 0.7% and 1.71% on the hip and torso consecutively. Cube B design also showed a reduction of 10% and 14% for the hip and torso consecutively.



Conclusions

A new mattress design is investigated for the use of bedsores management among bedridden patients. The design was recently granted a patent from the Saudi patenting office . Consisting of two parts, this mattress uses the concept of lean design to enable pressure distribution, and hence, blood circulation and supply to prone body areas.

This paper uses FEA to simulate the effect of upper body weight on the mattress in three scenarios with varying designs. The aim is to investigate whether the proposed design variation is able to effectively reduce the risk of developing bedsores. The original design shows better ability to

decrease the absolute amount of pressure on the body. However, increasing the surface area of the movable parts shows that less pressure is applied to the body parts.

In conclusion, although the original design allows for decreasing the amount of pressure by rearranging the parts, the higher the surface area, the lower the pressure. Thus, this work suggests changing the surface area of the cubes from 25 to 100 cm2. Further research is required to investigate whether alternative movable parts' shapes can enhance the performance of pressure distribution around the edges of the

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