BED DESIGN WITH MECHATRONIC SYSTEM TO DECREASE PRESSURE ULCERS

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Abstract – Pressure ulcers are one of the biggest problems for bedridden elderly people, who have to lie for a long time on bed with inactivity. It is important to have information regarding the type of care needed by bedridden elderly people (BEP) when they lying on their bed, in order to prevent them from pressure ulcers. A pressure ulcer is a localized wound to the skin or underlying tissue, usually over a bony prominence, as a result of unrelieved pressure or pressure in combination with shear and/or friction. These skin injury causes pain, related risk for serious infection, and increased health care utilization. In order to prevent from these sores, the position of elder people should be replaced at least once in an hour. This task is usually done by a caregiver who is usually the other element of the couple (husband or wife). Regardless of the needs, they desire comfort in their daily life, as well as more efficient and integrated systems for health and social care. Nowadays, there is an increase on the availability of assisted devices that can be used at home, decreasing the constant requirement for health professional assistance.

The main objective of this study is to propose a conceptual solution consisting on the development of a bed design in order to be able to care of older people’s skin problem, reduce the pressure on the bony prominence, nonetheless protect fragile elders and maximizing their quality of life. This design aims to create solutions with the help of mechanic and mechatronic systems, to reduce pressure on bony prominence and better conditions of life for the elderly or disable people. The new design consists of a cam-flower mechanism system. With the help of independent movable of subsets on this system, the pressures on bony prominence can be reduced and the contact surface can be protected. Each independent subset of the cam-follower mechanism can be initiated by the rotation movement of a motor and it can be used as a concept of a “massage bed”. In this way it allows a safety design structure, to be able to take care of older people with disabilities in order to live more safe and comfortable in their bed.

Keywords – wellbeing, assistive mechatronic system, welfare technology, pressure ulcers, bed sores.

1. Introduction

In the coming years, the world will be witnessing a considerable demographic shift up. Increased life expectancy and decreased birth rates have lead to a rapidly growing elderly population and a declining labour force. According to the United Nations, the elderly will make up 37% of the European population by 2050 [1]. This will be a significant increase of 20% from the year 2000. Disease and disability become more prevalent with older ages, and as a consequence people often require more attention and health care. Ambient Assisted Living Technologies, have lead to home health care becoming the preferred method of care for the elderly and disabled. In order to make an independent lifestyle possible without sacrificing the quality of care, alternative methods to traditional home care must be considered. The use of sacrificing technology in the home is one such alternative [1].

One way to address this problem is to rely more on assisted living technology, known as welfare technology or welfare-based societies, in the homes of the elderly and disabled. These technologies ensure greater independence by allowing users to accomplish tasks they may not usually be able to do on their own [2,3]. Welfare technology can also create a safer living environment. This study has as main purpose the development of a bed design with special functionalities in order to be able to care of older people’s skin problem (pressure ulcers) in order to improve the users’ quality of daily life. The specific skin problems can be denominated as pressure ulcers, also known as pressure sores, bedsores or decubitus ulcers, and are a dominant health problem for people who is disable and spend long periods of time in bed [4]. Pressure ulcers usually occur over bony prominences such as hips or heels. Many causes have been identified as contributing for the development of pressure ulcers, while pressure related to time is believed to be the most significant [5]. Pressure ulcers are painful for patients and increase time.
recovery. Furthermore, pressure ulcers are also very costly for the caregivers [6]. It is important that - when bedridden elder are in position of lying down - pressure must be distributed homogenously and it is mostly provided by bed. There are modules of making distinct movement concerning bedridden elders. The amount of time required for different activities is proportional to the number of times that a patient must be repositioned every day; it is necessary to change their position at least every two hours to avoid skin problems [7-9]. For the better caring it is needed to reduce pressure by distributing it over a larger contact area. These situations can be finished with the use of appropriate mattress structures that distribute the pressure uniformly over the surface.

This project will develop a new bed design with a mechatronic system that is able to detect the areas where the pressure is concentrated and thus prevent the development of pressure ulcer improving the quality of life of users.

This paper is organized as follows: next section states the analysis problem domain and its requirements to understand the solution included in the paper. Further section includes the design and technical details of proposed concept. Final section outlines the most important conclusions and future work.

2. Analysis of problem domain

Pressure ulcers occur when tissue is compressed under pressure. The interface pressure exceeds the pressure of the capillary veins, leading to the weakening of the local blood circulation and finally, to ischemic necrosis [10] - to the death of cells of the body in a localized area. Predisposing factors are classified as intrinsic (e.g., limited mobility, aging skin, comorbidities, poor nutrition) or extrinsic (e.g., pressure, friction, shear, moisture) [6]. The pressure tolerance varies for each person. However, the threshold value of 32 mmHg has been used in several researches as a reference. Any load greater than 32 mmHg is harmful because it exceeds capillary pressure in blood vessels [11].

The areas where the pressure is too high can be detected with pressure mapping system and the pressure can be relieved. The pressure level is reduced by moving the pressure away from critical areas to more tolerant areas, that is, the single peak pressures are eliminated. The pressure can also be reduced by distributing the pressure over a larger contact area. This can be done with appropriate mattress structures that distribute the pressure uniformly over the surface. Pressure mapping systems are therefore designed mainly for commercial applications, such as mattress designing and manufacturing. However, such a system is not necessarily suitable for physiological measurements [11]. Karki and Lekkala [11] investigated the pressure distribution on the surface with and without mattress when the bedridden elderly or disable is lying. Figure 1 shows the example of pressure map of a person lying on a sensor array with no mattress and with a thin mattress.

The unit of pressures is mmHg. Any load greater than 32 mmHg is marked in the pressure maps with yellow and orange colour. The satisfactory pressure values are drawn with different shades of green colour. Pressures less than 3 mmHg were neglected due to the noise.

According to Karki and Lekka’s [11] the advantage of using proper mattress can be seen clearly. It helps to distribute pressure more homogenously. However does not protect bedridden elderly or disable people from pressure ulcers entirely. Even though using thin mattress, the patient needs to change their position once in a while. In this study, it is intended to reduce the frequency of this operation, reducing problems for the patient, as well as the caregiver’s effort.

3. Proposed concept

The presented study has, as main purpose, the development of solutions to healthcare related to lying. It is important that - when bedridden elder are in position of lying down - pressure must be distributed homogenously being mostly provided by bed. There are modules of making distinct movements concerning bedridden elders.
The amount of time required for different activities is proportional to the number of times that a patient must be repositioned every day (every two hours as previously referred).

In this study, the dimensions of the bed are chosen according to continental Europe standards from UK National Bed Federation Guidelines for a single bed [12]. The dimensions of the proposed bed (considered on this study) are 900 x 2000 mm. It has 8 x 8 individual parts and all these parts are independent, in order to move individually. To allow small movements, this bed was designed with a camshaft concept which is known mostly in automotive engineering. The main purpose of using a camshaft is to reduce the number of motors required. In this project of new bed system, the mechanical part is composed by 8 camshafts. Figure 2 shows the designed camshaft to compose the main part of the mechatronic system. The camshaft performs independent movable of subsets on this mechatronic system - the pressures on bony prominence can be reduced and protect contact surface with the skin.

![Figure 2: Designed camshaft.](image-url)

The function of each independent subset of the cam-follower mechanism is initiated by the rotation movement of a motor placed at the bottom of the mattress. This system can be used not only to skin care but also as a “massage bed”. It allows a safe design structure to be applied in the structure of beds able to take care of older people with disabilities improving their safety and comfort. The proposed concept can be seen in Figure 3. The top of the structure was designed with the form of elliptical using beech material on the top. And elastic material was chosen for using under the elliptic part, because it has low Young’s module. Hence, according to body’s position, related part will be deformed easily and it provides homogenous pressure distribution.

![Figure 3: Conceptual of bed design.](image-url)

The functions of the system have been chosen in order to allow two different modes of function. The first one provides to distribute the pressure homogenously with the aid of separated elastic parts. (see Figure 4).

![Figure 4: An illustration of the use of the mattress with the proposed design.](image-url)

In order to provide vertical movement of each row eight motors was used. The about motor that is responsible of cam movement to verify control laws and compensation methods for the accurate torque control of D.C. the motors used has a torque of 750 oz-in (12 VDC) and load speed of 10 rpm. In order to obtain accurately reproduced torque signals the motors have been developed it may also mean the torque load that causes the output rotational speed of a motor to become zero to cause stalling. Due to their mass, the design of mechanisms that utilize these actuators are severely restricted. The objective of the research involving this to improve the system to create of different way to movement and care of skin’s problems.

![Figure 5: Measurements of cam-followers movements](image-url)

The value of the distance presented in Figure 5 represents distance between surfaces that touch the mattress. It’s in initial position to provide the movement in contact with the part of down in the mattress and also the patient, when this cam-follower works, the height parts changes with elevations and decline with two different levels of surface. The objective of this mechanical part is to obtain different situations and levels of movements. In this work the measure of height the superior part in contact of mattress is the 9 mm. It’s demonstrated in the Figure 5, where is possible identify of differences between both levels.

To understand why this system is important, it is necessary to understand all problems related with permanent position of the patient in bed. The movement of cam followers need to be soft and slowly because of skin restricts movements. Is important measures results about velocity and accelerations when the mechatronic system works, the Figures 6 and 7 show the results of such on operation with the simulation that was applied a motor (coupled with a mechanical reductor) with 10 rpm of angular velocity to move of cam followers. In this case, it was desired to determine the effect that surface finish and cam manufacturing technique had on cam performance. This study was done to determine what information could be obtained from the analysis of
simulated measured acceleration and velocity of the value in a modern overhead camshaft bed system.

The other function purpose of this design is to give movement within 2 hours, with 10 minutes duration in each session of movement, where each part can move independently - this movement is provided by the cam-follower mechanism. This mechanism is positioned under each elliptic part and transforms rotation movement into a linear movement. During one rotation of the cam mechanism, vertical distance of elliptic part changes from 0 to 9 mm. When cam’s widest point goes up/down the elliptic part goes up/down providing the desired movement (see Figure 8).

With the proposed design the spine keeps straight when the patient lay on, as it can be seen in Figure 8. Besides, it provides an uniform pressure - there will be no excessive pressure on any bony areas. Using this kind of bed mattress, for distributing pressure uniformly, pressure ulcers risk can be decreased. However, if the patient is not repositioned every 2 hours, it is inevitable to start pressure ulcers appearance. That is the reason why the cam-follower mechanism was used in this design. When the mechanism starts moving it provides a small massage motion to the body in order to change pressure points. In this manner this proposed design may reduce the number of caregivers to only one.

4. Conclusion

This paper proposes a conceptual design of a mechatronic bed system. It consists on the use of a cam-follower mechanism that can distribute the pressures between bony prominence and contact surface with the help of independent movable subsets. This design is a system with demands in comfort, accessibility, safety and easiness of use, on the context of healthcare of bedridden elderly people. The use of an elastic ring under elliptic parts of the subset provides uniform pressure distribution decreasing the pressure points accordingly and so reducing the possibility of occurrence of pressure ulcers. The functionalities provided promote two modes of operation, where it is possible to control the type of the rotation of the cam-follower mechanism. It is delivered a small motion in order to change patient’s pressure points instead of changing its position. The function of the mechatronic system works each independent subset of the cam-follower mechanism initiated by the rotation movement of a motor - it can be used as a “massage bed” as well. With this system we expect to contribute to the improvement of quality of daily life of bedridden elderly people. Future work, will consider the physical implementation of this system as well as its integration with other systems under development by the research team.

5. References