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KINEMATIC SYNTHESIS OF A MEDICAL BED FOR DECUBITUS ULCER PATIENTS

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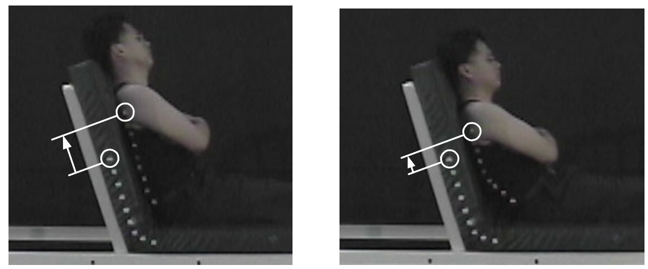
ABSTRACT

A decubitus ulcer or bedsore is a pressure-induced ulceration of the skin occurring in persons confined to bed for long periods of time. Reduction of pressure over bony prominences is of primary importance to prevent and cure bedsores. For this purpose, specially designed mattresses can be used and/or the patient should be turned frequently to avoid ischemia of soft tissue. In addition to pressure, other principal factors causing bedsore are friction and shear forces. In this paper, we designed a new 5 degree of freedom bed mechanism that can be used to change the posture of pressure ulcer patients, which generates 7 motions including backrest elevation, kneerest elevation, lounge position, left and right rotation, trendelenberg and reverse trendelenberg motion, and straight elevation. Particularly, we focused on the synthesis of a backrest and seatrest assembly that can reduce sliding between the bed and the patient.

METHODS

Decubitus ulcers are localized areas of tissue damage or necrosis that develop due to pressure over a bony prominence. If the patient is immobile or remains in the same position for extended periods, the tissue dies due to insufficient blood circulating through the area. Other terms referring to the same phenomena are pressure ulcers, pressure sores, and bedsores. In addition to pressure, risk factors of decubitus ulcers include shear and frictional forces (Wiechula, 1997). For the prevention of ulceration, these risk factors should be made not to act on the vulnerable anatomical locations, such as the sacrum, great trochanter, and hip (Hunt, 1993). A widely accepted practice for the prevention of decubitus ulcers is frequent repositioning of patients. The US Agency for Health Care Policy and Research (AHCPR) recommends that any individual in bed who is assessed to be at risk for developing pressure ulcers should be repositioned at least every two hours (AHCPR, 1992). Similarly, the European Pressure Ulcer Advisory Panel (EPUAP) recommends that any individual who is assessed to be at risk of developing pressure ulcers should be repositioned if it is medically safe to do so, and that when repositioning patients, to do so in such a way as to minimize the impact on bony prominences (EPUAP, 1998).

Fig. 1 Initial position of motion analysis



(a) With legs fixed **(b) With legs unfixed**

Fig. 2 Motion anayses when backrest is lifted

In this study, through motion analyses shown in Figs. 1 and 2, we have found that conventional hospital beds have two problems if they are used for pressure sore patients. The first problem is sliding action between the bed and the patient when the backrest of the bed is in lifting motion. This sliding action would cause excessive friction to the patient's body and may cause or even worsen the sores (Dinsdale, 1974). The second problem is, when the backrest is lifted, the patient slides down along the bed surface due to gravity. These can be explained with the aid of Figs. 1 and 2. In the initial position shown in Fig. 1, the markers attached to the body and the mattress are in line vertically. After the backrest is rotated, the two markers which were initially at the same vertical position are separated along the bed surface as shown in Fig. 2. Figure 2(a) shows the motion analysis with the legs fixed. This proves that there exists sliding action between the bed and the user. Kinematically, it can be said that this sliding action occurs because the rotation centers of the backrest and user's motion do not coincide. Hence, in order to reduce this phenomenon, the rotation center of the backrest should be placed near the ration center of the human body when the torso is lifted by the backrest. Figure 2(b) shows the motion analysis with the legs unfixed. Comparing Figs. 2(a) with 2(b), it can be seen the patient slides down along the bed surface if the lower body is not fixed. This phenomenon occurs due to the weight of the patient, and may cause friction and shear forces not only to the upper body of the patient, but also to the lower body.

In this research, we have synthesized a backrest and seatrest assembly that can reduce the both sliding phenomena, and this assembly is used in a newly designed 5 degree of freedom bed mechanism that is capable of 7 motions including backrest elevation, kneerest elevation, lounge position, left and right rotation, trendelenberg and reverse trendelenberg motion, and straight elevation.

RESULTS

In order to reduce the sliding action between the bed and the patient when the backrest of the bed is in lifting motion, the rotation center of the backrest must be located near the rotation center of the

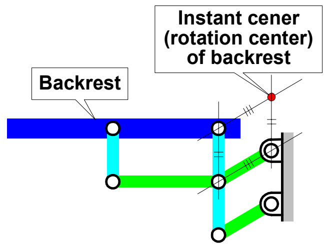


Fig. 3 Backrest mechanism and its rotation center

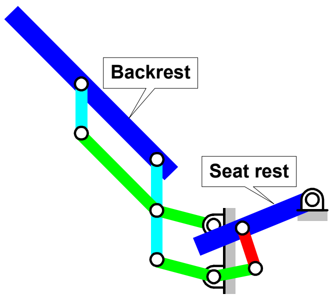


Fig. 4 Backrest and seatrest assembly

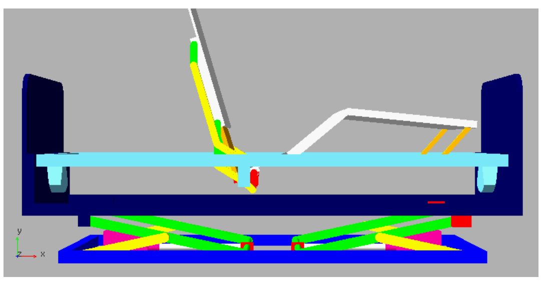


Fig. 5 3-D model of new bed mechanism

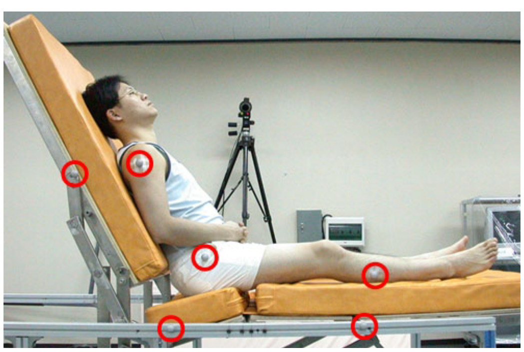


Fig. 6 Motion analysis of new bed mechanism

human body. When the backrest lifts the upper body of the patient on the bed, the rotation center of the human body can be assumed to be at the hip joint (Zatsiorsky, 1998). Figure 3 shows the backrest mechanism designed in this research. The instant center (Erdman et al., 2001) of backrest motion with respect to the frame of this mechanism is stationary; the backrest always rotates about the stationary instant center. In the design of this mechanism, we synthesized the proportion of the mechanism so that the instant center of backrest motion locates near the hip joint. In order to prevent the patient from sliding down along the bed surface due to gravity, the seatrest is designed to be lowered as the backrest is lifted as shown in Fig. 4. Figure 5 shows the developed medical bed mechanism modeled by ADAMS software (MDI, 2002). Figure 6 shows the result of motion analysis of the bed mechanism designed in this study. As shown in Fig. 6, the sliding is greatly reduced compare to the case of Fig. 2.

DISCUSSION

A new medical bed mechanism that reduces the slidng action between the bed and the patient has been designed. The dimensions of the backrest mechanism depend on the thickness of mattress, because a change in mattress thickness results in a height change of the patient's hip joint.

The bed mechanism is designed to function well with at least two separated mattresses as shown in Fig. 6, one piece on backrest and the other on the rest of the bed. A specially designed mattress, such as an air-inflated mattress, can be used with this bed mechanism. However, modification of kinematic structure may be required if used with an one piece mattress.

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