1. Introduction

Bedsores are lesions (sores) in the skin and adjacent tissue, caused by lack of oxygen in tissue due to compression of blood vessels supplying the area. Compression of blood vessels in the skin (i.e., the dermis) is achieved due to constant pressure, too long, at a certain area.

The result of compression vessels and reducing blood supply in that area is the cell death, skin damage and the formation of bedsores. In the early stages appear under the skin, and in later stages appear where the skin tissues are destroyed [2]. They were first described by Fabricius Hildamus researcher in 1593 as "gangrene" bedridden patients [3].

Wohlleben researcher in 1777 referring to bedsores, he called canker disease of decubitus ie, tissue necrosis caused by lying in bed [4]. According to studies conducted by researcher Thomson Rowling shows that pressure ulcers are found since the time of the Egyptians, being found in Egyptian mummies [5].

Pressures encountered at the contact surface between the skin and support surface (mattress) was applied for a long time can lead to tissue destruction [6], [7], [8].

Worldwide following percentages recorded in scarring about pressure sores:
- 95% of pressure sores occur in the back and lower body [9].
- 36% of cases are recorded in the lumbar and sacral
- 30% of cases are recorded in the hips, buttocks, heels
- 6% of cases occur in other parts of your body [10], [11].

2. Devices to prevent bedsores. Disadvantages

The current state of international research on the role developing devices for preventing and treating pressure sores is continuously growing.

Developed products fall into the following categories:
- mattresses, which are attached above the bed mattress,
- seat cushion, which is attached over the seat pan;

Alternating pressure mattress with honeycomb structure

Rooms are honeycomb mattress of PVC material and air are supplied alternately. Shows the dynamic character of attaching an electric pump that is designed to supply AC rooms mattress.

As shown below, the mattress is composed of 130 individual cells, and the sides are provided with alternative supply channels so that the power outlet is located inside the end of each row of rooms [9]. Rooms are parallel and are powered mattress on
occasions like this: when one line is loaded to the maximum pressure, the next line is loaded to minimum pressure.

Figure 2 – Antidecubitus dynamic mattress honeycomb

Supply of rooms is made through two hoses that are connected to the pump and mattress, as follows: cable is used to compress air mattress, air outlet and the other to change the cycle set.

Disadvantages:
- If used without an attached sheet over the mattress, is an environment for developing pressure sores due to persistence of moisture;
- Due to the nature of the material it is made the mattress, there is potential for friction and shear;
- Maintenance mattress is made with detergents, and if it deteriorates, it is necessary to vulcanization;
- Not be subjected to high forces on a small area.

The seat cushion is an automatic PK Airpulse used to treat and prevent bedsores. This device is applied over the wheelchair seat. The device is made of neoprene individual rooms that are air-powered alternative. Choose alternatively supply room because the main role is to change the interface points where pressure is high and to maintain blood flow [10]. Rooms are made of neoprene membrane and have different shapes as closely as possible to the body geometry.

As shown below, the sponge is inserted within the membrane and a connection that will make the air supply. Use sponge as intermediate material in order to support the weight.

Figure 3 - Rooms Airpulse PK cushion

Through automation, it will feed air chambers alternately to a comfort level, taking into account body weight. Alternation in power rooms, is to reduce the maximum pressure points arising from the seating area and pillow. The controller includes: micro-processor control unit, air pump, rechargeable batteries.

People who have used this product consisted of a number of disadvantages of the device.
- Difficulty in use, because the cables and components
- From the use of rooms it was found that resistance is poor, because the neoprene and foam comes out of shell
- Power supply doesn’t meet the cycles of use and fail very quickly
- A manual with detailed instructions with photos, detailed instructions for the required settings
- Foam is rigid
- Difficulty in posting swab to clean
- Do not provide ventilation skin product purchase costs are high.

3. Designing, dimensioning and making the dynamic seat cushion device driven by pneumatic muscles

As a preliminary stage of design and sizing, we started from the state of national and international research on medical devices in place to prevent and treat bedsores. Exprimental research shows that the products of this type is extended internationally, making it known in mattresses and in wheelchairs found to be limited by the functional. At national level there is no research about traversing the role of preventing bedsores or improving blood circulation. Although international research is developed, assessed by dynamic device users with pressure sores prevention role, it appears that the main disadvantages of the products are given by:
- The material used is neoprene that is, favoring wet sitting area
- Using the sponge, you feel as stiff to the touch and with less resistance while using the seat cushion
- Lack of ventilation seating area
- Limited information provided by the technical manual on how coupling device components and making settings
- Difficulty in posting cleaning swab
- Insufficient support for the pelvis
- Difficult to use automation
- Repairs and replacements provide any increased costs
- Batteries doesn’t meet the working cycles
- High purchase costs.

We studied the weaknesses of existing devices and analyzed alternative electro-pneumatic device to achieve a dynamic seat cushion type driven by pneumatic muscles to prevent bedsores. Pneumatic device design involves:
1. Selection and sizing of pneumatic muscles
2. Sizing cushion fabric
3. Sizing the three compartments for placing antidecubitus fur
4. Sizing the two compartments for introducing pneumatic muscles
5. Scheme design automation electro-pneumatic device
6. The suitable air supply, reduced overall.

To demonstrate the functional benefits of pneumatic muscle devices are superior to existing rooms neoprene sponge inside, I realized experimental research on pneumatic muscle in the laboratory, where we analyzed changes in length depending on the supply pressure.

We studied the degree of shrinkage and elasticity of the pneumatic muscle membrane DMSP-10-250N; membrane length = 245 mm, nominal diameter = 10 mm in the relaxed state. We conducted experimental research on the stand for successive supply pressure of 1 bar ÷ 4.5 bar.

Following investigations, it appears that, in supply pressures between 1 bar ÷ 2 bar, the average variation of pneumatic muscle length is 3%, and the supply pressure between 2.5 bar ÷ 4.5 bar, the average length variation pneumatic muscle is 14.53%. From experimental research, we concluded that pneumatic muscles behave advantageous when supplied with air and can be integrated easily into the role such a device to prevent bedsores.

Because of the pneumatic muscle need to support different categories of body weight, we choose type of DMSP-20-520N, with an external diameter of 20 mm and the force of 520N and we found to be most appropriate. We chose to integrate the two pneumatic muscles into the cushion as it will eliminate the disadvantages encountered in existing devices that is insufficient support in the pelvis. Thus, a muscle will fully support the pelvis and the second will support full thigh. According to the current state of research, existing devices do not provide full support points for the seat, pneumatic muscles to function efficiently, we sized shrink membrane length of 500 mm.

As Figure 4 the air supply will be done via an adapter side, to avoid discomfort during the utilization of the pneumatic device, easier integration into the cushion, efficient device because the free ends will tend to come downtown, to the area seating.

![Figure 4 - Arrangement of adapters in pneumatic muscles](image)

The cushion is made up of five sections, two of them are occupied by pneumatic muscles, three of which are filled with antidecubitus fur that is designed to support and take the muscle force when they are compressed, making an optimal microclimate for the user.

I sized the three compartments for introducing antidecubitus fur and two compartments for introducing pneumatic muscles, as shown in Figure 5. To cushion size, we considered is the active surface area of seating, so by using the device, the entire circumference to be supported and ventilated, to allow development of bedsores.

![Figure 5 – Size of seat cushion to prevent bedsores](image)

The seat cushion is made of cotton so the skin can breathe and not disturbed because of chemicals used in other products.

Figure 6 presents sizing channels for pneumatic muscles given the maximum contraction of the diaphragm, so that a maximum supply pressure, the muscles do not break room where they were introduced.

![Figure 6 - Arrangement of pneumatic muscles in the seat cushion](image)

In Figure 7, was chosen as the intermediate material, antidecubitus fur, the role of efficiency: support area seating, comfort, ventilation area. The antidecubitus fur will be placed in three rooms and has the

![Figure 7 - Layout cushion coat antidecubitus fur in rooms](image)
supporting role when the pneumatic muscles are contracted and relaxed by eliminating friction, shear, pressure on the exposed area. Direct contact with skin gives a massage of the skin, stimulates and supports evacuation and moisture vaporization (goose feather effect) [11]. Flora will support the seating area and will perform ventilation, because according to the characteristics, flora height is 24 mm. Support is made of polyester fabric, which allows moisture to reach the pneumatic device consisting of pneumatic muscles and antidecubitus fur to prevent bedsores.

In Figure 8, once the pneumatic muscles and antidecubitus fur strips were introduced into the seat cushion the links are made for air supply. Over the seat cushion device is expected to be attached antidecubitus fur that prevent bedsores.

4. Design and achieve of the automation

Compared with existing pneumatic devices for patients in wheelchairs, where the patient needs and air supply, a manual pump for the device we have established a scheme that offers patients flexibility of use by simply driving two pneumatic timers. Automation scheme has the following form

To describe the functioning of the pneumatic dynamic device driven by pneumatic muscles, we used Fluids software that allows modeling and simulation of device behavior [12].

Figure 8 – Dinamic device seat cushion driven by pneumatic muscles

Figure 9 – Automation of the pneumatic system
1. Air Compressor; 2 Distributor 3/2 N/I (normally closed) with manual action; 3. Timer 1 left muscle; 4. Timer right muscle 2; 5. Distributor 5/2 N/I (normally closed); 6. Distributor 3/2 monostable N/I (normally closed); 7. Pneumatic muscle number 1; 8. Pneumatic muscle number 2

In Figure 8, the pneumatic muscles and antidecubitus fur strips were introduced into the seat cushion, the links are made for air supply. Over the seat cushion device is expected to be attached antidecubitus fur that prevent bedsores.

Figure 10 - Power to set the system pressure

In Figure 10, is symbolized by the blue line closed, how is the air supply system. From the compressor (1) connection hole feeds. A distributor of 3/2 NC (2) and connecting hole No. 1 distributor valve (6).

Figure 11 – Power to set the left timer

In Figure 11, is presented the realization of power left timer (3). Channel no. 2 of the distributor 3/2 NC (2) is made of two timers and power distributor 5/2. The air entering the distributor 5/2, is eliminated by channel no. 2 and focused on the timer left (3) and the pneumatic muscles through pneumatic distributor channel 3/2 NC (6). By adjusting the throttle path is established pneumatic supply slow muscles (7 and 8) and thus contraction.
By switching the right timer channel (4), air is channeled to be removed slowly from pneumatic muscles. With this setting, pneumatic muscles will relax to its original length. Elimination slow air by adjusting the throttle is right for the timer, which allows adjustment of the outlet channel opening.

In Figure 12, the air in the pneumatic muscles causing contraction, returning the system, the distributor 3/2 (6) and left timer (3). Timer causes a switch left in the dealer channel 5/2 (5), designed to deflect air removal through a longer and slower circuit.

Figure 12 - Switching timer channels for air is released through right

In Figure 13, the air in the pneumatic muscles is removed and flows slowly. By adjusting the throttle, the timer releases air through the right channel.

Figure 13 - Removing slow air pneumatic muscles

By switching the right timer channel (4), air is channeled to be removed slowly from pneumatic muscles. With this setting, pneumatic muscles will relax to its original length. Elimination slow air by adjusting the throttle is right for the timer, which allows adjustment of the outlet channel opening.

In Figure 14, the right timer (4) is determined from the distributor switching channels 5/2, thus bringing it to its original position. This switching power resumes principle of pneumatic muscles by left timer (3) and the distributor 3/2 NC (6).

5. Experimental research
To determine the pneumatic device functionality, we achieved FluiLab, experimental studies on the relationship between body weight, recovery time and hence the frequency of loading and unloading pneumatic muscles.

For experimental research, we used the wide range of body weights as follows: 60 kg, 80 kg, 100 kg, 120 kg. Subjects were placed in turn on the device was powered dynamic pressure of 3 bar and 4 bar.

The graphs obtained in FluidLab are presented in Figures 15 ÷ 22, where the abscissa is the time in which the determinations are made, and the ordinate is the pressure at which the power is made for the dynamic seat cushion device driven by pneumatic muscles.

Figure 15 - Frequency of load discharge pressure of 3 bar for 60 kg

Figure 16 - Frequency of load discharge pressure of 3 bar for 80 kg
6. Experimental results. Conclusions. Future directions of research

In experimental research, we obtained the following data:

According to experimental results contained in Figure 24 indicates that during the discharge load 60 kg, 80 kg, 100 kg, 120 kg to 4 bar food, ranging from 4.104 sec to 4.762 sec, and with increasing body weight during needed to make a charge cycle is higher and stable discharge.

In Figure 25 and 26 are the results of calculation of loading frequency discharge supply 3 bar and 4 bar. Is found according contained, the frequency decreases with increasing body weight, resulting in slower emptying of pneumatic muscle between cycles.
The most important conclusion follows from the comparative analysis of the results for the supplying 3 bar and 4 bar, where it is found that although it retains the same categories of body weight for experimental research, frequency of discharge charge cycles, decreases with increasing pressure, which means that the dynamic pressure of 4 bar type device is functional and economic cushion in terms of low air consumption because of the reduced frequency.

Another conclusion obtained experimental data, is that weight does not influence greatly the loading unloading cycles but pressure.

To provide flexibility in using the device, we achieve automation cushion smaller scale and will fit in a closed box in order to minimize gauge, eliminating the existing hoses currently stand.

We will also replace the existing compressor with a reduced overall compressor for comfort in use and transport.

We will study the contact pressure at the interface between the user and seat cushion actuated by pneumatic muscles..

7. References


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