Time Pattern Study for a Dynamic-type Air Cushion

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Abstract—In this study, we explore and improve a dynamic-type air cushion system’s time pattern in inflation and deflation to achieve an optimal effect of pressure ulcer prevention and treatment. Via analysis and experiments, we found that a two-phase air cushion’s optimal, or best, time pattern, which provides its users the most comfort, has an identical inflation and deflation time for the individual phases with their operation durations complementing each other, and the time pattern with the individual phases’ inflation time being overlapped with each other ranks second in usage comfort. The time pattern with the two phases’ deflation durations being overlapped with each other ranks the lowest in usage comfort.

Keywords—Time pattern, dynamic, air cushion

I. INTRODUCTION

The probability of pressure ulcer occurrence increases with people’s age, and its treatment cost is rather high. How to effectively prevent and cure pressure ulcer has become a task the government, medical and academic communities all cannot ignore.

The main cause of pressure ulcer formation is due to an over 32mm internal pressure (weight) existing on the capillaries underneath the skin tissue, blocking the blood circulation wherein; if the situation persists for too long, the internal tissue will start dying outward. Hence, the dying of cell tissue is directly correlated with the exerted pressure’s time duration.

Many researchers in pressure ulcer adopted various kinds of rats to simulate human body [1]–[6] and also concluded that the pressure time and the formation of pressure ulcer is correlated. For example, Linder-Ganz, et al. utilized, in 2006, rats’ hind limbs and proceeded with experiments [1] to simulate human tissue under pressure. They found that if muscle tissue is put under high pressure for s short time (15 minutes to 1 hour), no series effect will occur; if, however, such pressure sustains for more than two hours, it will incur death in skin tissue [1].

If we can let muscle tissue gain rest in time, we can prevent the tissue death from occurring. At present, the most often-used pressure reduction products for sitting posture are static-type cushions, such as the types of ROHOTM, silicon, foam and so on [7]. They cannot gain rest time for the pressed muscle and can only delay the time for said muscle tissue death; the true solution that can release the mentioned shortcomings of the static-type cushions lies at using a dynamic type cushion to let the muscle tissue work in turn and, hence, rest in turn.

The purpose of the time pattern study for the dynamic type air cushion in pressure ulcer prevention and cure lies at raising the performance of said prevention or cure, viz. exploring the dynamic-type air cushion’s pressure-alternating time pattern in search of an optimal set of application parameters. The air cushion will divide the pressure alternation into two phases, Phass A and B; each phase is divided into two parts, i.e. inflation and deflation, so that when the muscle tissue corresponding to one phase is under the pressure of this phase’s inflated air tubes, the tissue corresponding to the other phase can receive the pressure reduction, viz. rest, from the deflated air tubes. Our main task is to locate the best ratio of the inflation duration to the deflation duration, i.e. the pressure alternating time pattern, to arrive at the optimal pressure-reduction effect.

We divide the time patterns into three types: For the first type, the ratio of the inflation duration to the deflation duration is 50:50, the second type, 25:75, and the third type, 75:25. Via actual tests, we will find out the time pattern for the optimal pressure-reduction performance.

II. THE TIME PATTERN OF THE DYNAMIC-TYPE AIR CUSHIONS

As mentioned, there are three types of time patterns for the dynamic-type air cushions:

For the first type, the two phases’ pressure-alternating does not overlap with each other, as shown in Fig. 1. Under such type, the muscle of the individual parts in the buttock will gain equal time in working and resting.

For the second type, the two phases’ inflation durations overlap with each other, as shown in Fig. 2. During the inflation overlapping time, the pressure the buttock muscle experiences is at the same effect as that of sitting on a static-type air cushion.

For the third type, the two phases’ deflation durations overlap with each other, as shown in Fig. 3. During the period the two phases all deflate, the buttock muscle experiences a pressure with an effect the same as that of sitting on a flat chair surface.
The time sequence of the dynamic-type air cushion is shown in Fig. 4, wherein T is the period, and \( T_{PHI} \) the inflation withholding duration. The duty cycle, \( \alpha \), is obtained by dividing the inflation withholding duration by the period, as shown in Eq. (1).

\[
\alpha = \frac{T_{PHI}}{T}
\]

The overlap coefficient, \( \gamma \), is obtained by dividing \( t_{a0} - t_{b3} \) by the period, as shown in Eq. (2). If the obtained value is zero, viz. no overlap in either inflation durations or deflation durations for the two phases, that will dignify a first type of time pattern. If the value obtained is positive, viz. an inflation overlap between the two phases, that is an indication of the second type of time pattern, whereas a negative represents a deflation duration overlap between the two phases and, hence, a third type of time pattern.

\[
\gamma = \frac{t_{a0} - t_{b3}}{T}
\]

A T working with various \( \alpha \) and \( \gamma \) will render various degrees of pressure reduction and comfort. We will test the three above-mentioned types of time pattern, viz. with various T’s, \( \alpha \)’s and \( \gamma \)’s, to locate the best type for the best comfortable performance for the test subjects via comparisons.

III. TEST METHOD

In the tests, we use cushions made of long air tubes modified from children’s swimming arm-ring floaters and other stripe-type air blades developed by us.

The period is set at either 2 or 6 minutes in this study, the duty cycle, 25%, 50% and 75%, and the overlap coefficient -50%, 0 and +50%; we also classify the comfort feelings of buttock into five categories: 1- Comfortable, 2- slightly painful, 3- somewhat painful, 4- very painful, and 5- acutely painful. The test subjects are informed the restrictions of experiment prior the tests; each subject sits on a type of cushion for 3 hours and records their buttock feeling in the mentioned five categories at each 15-minute interval until the end of the test.

The experimental restrictions in this study are: (1) No eating but drinking is allowed; (2) No movie watching or watching any items that will entice the subject; (3) No phone conversations for more than 3 minutes; (4) No leaving the seat; (5) No sleeping; (6) Both the inside and outside underwear and pant must be loose and the same cloth must be used for the multiple experiments.

IV. TEST RESULTS

According to the questionnaires filled in by the subjects as shown in Table I, the subject’s buttock felt acutely painful approximately 1 hr after the test when no cushion was used and the subject sat directly on a flat wooden chair surface.

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TABLE I The test result comparisons
(1- Comfortable; 2- Slightly painful; 3- Somewhat painful; 4- Very painful; 5- Acutely painful.)
As shown in Table 1, the test subject with the first type of time pattern under a period of 6 minutes and using the arm-ring-floater-made cushion felt comfortable within the first 15 minutes but slightly painful after 30 minutes; at 1 hr and 30 minutes, the subject felt very painful and, afterwards, drifted between very painful and slightly painful. When the period is 2 minutes, the first type of time pattern can provide better degree of comfort. The test subject all felt comfortable within the 3 hrs during the test, while with the second type of time pattern, the subject’s buttock felt slightly painful after 2 hr and 30 minutes; with the third type of time pattern, the subject’s buttock felt slightly painful after 2 hrs.

V. DISCUSSIONS AND CONCLUSION

We discover in this study that the first type of time pattern provides the highest degree of comfort, for this type renders a relatively longer rest time for the muscle during each period than that of the other two types.

The second type of time pattern is second in comfort degree felt by the test subject. According to the test subject, the portion felt slightly painful lied at the spine-end muscle. We assess that since the two phases’ inflation durations overlapped, portion of the pressure supported by the buttock muscle was transferred to all buttock surface muscle, resulting in a shortened rest time for a portion of the pressed muscle and a sense of incurred pain.

The third type of time pattern is the least in comfort degree felt by the test subject in this study. The subject sensed a pain, according to the questionnaire, after 2 hr and 15 minutes during the test. We assess that the cause is due to that when both phases were deflated, the buttock touched the bottom, like sitting on a flat chair without the protection of any cushion.

The factors that affect a sitting posture pressure include many, as Defloor et al. reported in 1999 during their experiments on said pressure [8], which indicates that said pressure is the least when the chair back tilts slightly backward with lower legs putting on a flat platform. Such sitting posture is not suitable in a working environment, so it was not adopted in this study.

Other factors such as the volume, height and length of the cushion and the time pattern are all related to the effectiveness of pressure ulcer prevention or cure, which remain to be investigated in future studies.

REFERENCES