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EVALUATION OF BUTTOCK PRESSURE DISTRIBUTION FOR SCIS

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Abstract: Pressure sore is a serious problem for patients with spinal cord injuries (SCI). Many kinds of pressure-relieving cushions have been developed to distribute the weight widely. In rehabilitation medicine, the selection of the wheelchair cushion and the adjustment of the cushion are very important problem for the medical staffs in prevention of pressure sore. In this paper, we calculate 6 parameters and represent the 6 parameters on the radar chart to evaluate the buttock pressure distribution. Using the radar chart, it become easy to select the best cushion and to adjust the air quantity of the air cushion. Moreover, it is useful for the SCI patients to study their posture on the wheelchair and the prevention of pressure sore.

Keywords: pressure measurement, pressure distribution, Tekscan, pressure sore, wheelchair cushion

1 INTRODUCTION

The pressure and the tolerance of tissue are big factors in developing the pressure sore[1]. Many kinds of pressure-relieving cushions have been developed to distribute the weight evenly and over the widest surface area of the body[2],[3]. In rehabilitation medicine, physicians and physical therapists (PT) assist the patients to select the wheelchair cushion and sometimes adjust the cushion if necessary. For physicians and PTs, it is very important to evaluate the pressure distribution of the cushion.

Many authors have reported about the evaluation of wheelchair cushions. They measured buttock pressure, however, most of them measured pressure only at a few sites on the buttock. These studies were concerned with the evaluation of wheelchair cushions with either the pressure value in a few points or the relative pressure distribution[4]-[6].

We measure the buttock pressure distribution of SCI patients using the Tekscan pressure measurement system. We reported that the air cushion was the best among the five cushions (the air cushion, contour cushion, gel cushion, Cubicushion, and urethane foam cushion)[7].

In this paper, we calculate 6 parameters to evaluate the buttock pressure distribution for SCI patients, and represent 6 parameters on the radar chart for the medical staffs to select and adjust the wheelchair cushions.

2 METHODS

Figure 1 shows the Tekscan "Big-Mat" pressure measurement system. Because a sensor seat consists of 48pixels x 43pixels, we can measure the buttock pressure at 2,064 points simultaneously with minimal error. This sensor seat is 2 mm thick and soft, so we can measure the pressure on soft objects such as cushions and beds. The error that is caused by creep characteristics is large. After sitting on the wheelchair cushions for 1 minute, we measure the pressure to reduce the error caused by creep characteristics of the sensor[7].

Figure 1 Tekscan pressure measurement system.

Three kinds of wheelchair cushions, the air cushion, solo cushion and jay2 cushion, are popularly used to distribute the weight evenly and over the widest surface area of the body (Figure2). The air cushion consists of many rubber air cells. The solo cushion's parts consist of urethane foam and the air pad. The adjustment is carried out to pull the air out of the air pad in the center area of the cushion. The jay2 cushion consists of silicon gel on the hard urethane foam. The silicon gel on ischial tuberosities is thick to distribute the pressure on these regions.

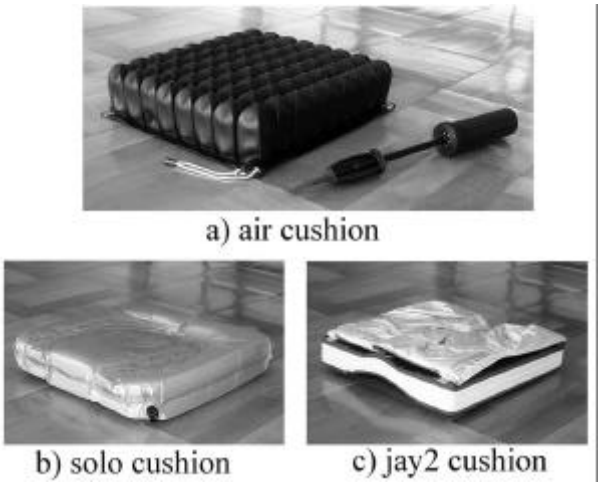


Figure 2 Three kinds of wheelchair cushions.

In rehabilitation medicine, the selection of the wheelchair cushion and adjustment of the cushion are important problems in the prevention of the pressure sore. It is necessary for the medical staff to evaluate the buttock pressure distribution of SCI patients. After measurement, we calculate 6 parameters to evaluate the pressure distribution, the sitting balance and the posture on the wheelchair. They are:

1. maximum pressure (M.P.)
2. contact area (C.A.)
3. high pressure area (H.A.) (more than 80g/cm^2)
4. tip rate (T.R.)
5. sitting balance (S.B.)
6. sitting position (S.P.)

The tip rate, sitting balance and sitting position are calculated from the top five projection. Figure 3 shows the 2-D representation of the buttock pressure distribution and the horizontal top five projection (TFP_x). $TFP_x(i)$ is the average value of the top 5 data that are picked up among the data *f(i,1), f(i,2), ……., f(i,n)*. Figure 4 shows the horizontal top five projection (TFP_x), the vertical top five projection (TFP_y) and an approximate gauss curve around the maximum point of TFP_x. The tip rate (T.R.) is defined by

$$T.R.=a/2b \quad (1)$$

We define the length between the maximum point of TFP_x and the back end of the buttock as the sitting position (S.P.). TFP_y-R is the value of the maximum right point in TFP_y and TFP_y-L is the value of the maximum left point in TFP_y. The sitting balance (S.B.) is defined by

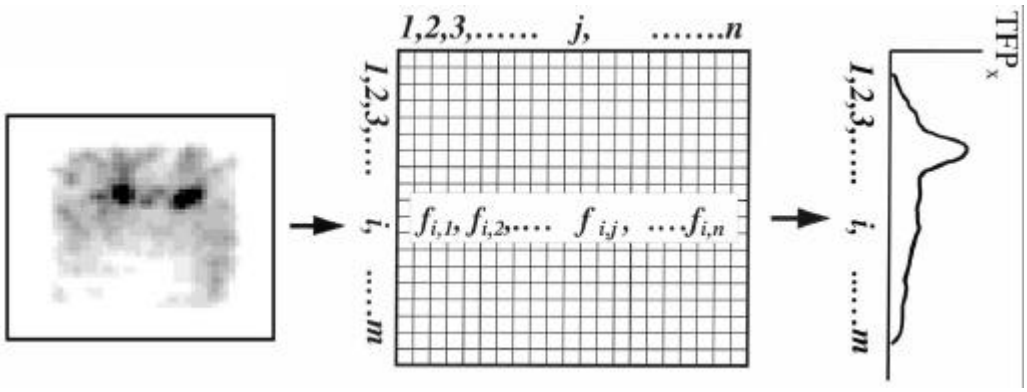


Figure 3 2-D representation of buttock pressure distribution and horizontal top five projection.

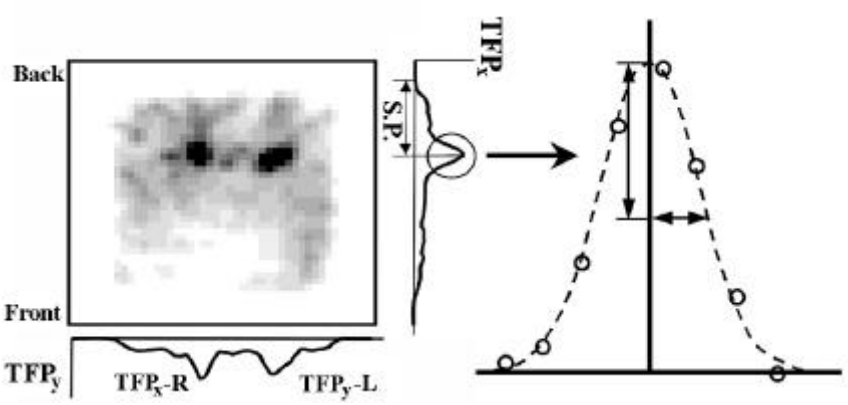


Figure 4 Horizontal Top Five Projection(TFP_x) , Vertical Top Five Projection (TFP_y) and an approximate gauss curve around the maximum point of TFP_x.

$$S.B.= |TFP_y\text{-}R - TFP_y\text{-}L| / (TFP_y\text{-}R + TFP_y\text{-}L)\times 100 \quad (2)$$

Figure 5 shows the radar chart that is the hexagonal representation of the 6 parameters. In this figure, an inner perfect hexagon shows the means of each parameter of 25 SCI patients using the air cushion. Each parameter is put on each axis after normalization with standard deviation of each parameter with 25 SCI patients using the air cushion.

The medical staff can understand the position and the approximate size of a high pressure area from the 2-D representation of the pressure distribution and the exact size of a high pressure area from H.A. on the radar chart. The T.R. shows the concentration of the pressure. When the SCI patient who has large T.R. and M.P., medical staff has to adjust the quantity of air in the air cushion carefully. The medical staffs and SCI patients recognize the sitting position from S.P. and the sitting balance from S.B. When the SCI patient has large S.P., he sits on the wheelchair in a shallow position. When S.B. is large, the medical staff has to assist the SCI patients to hold the posture carefully.

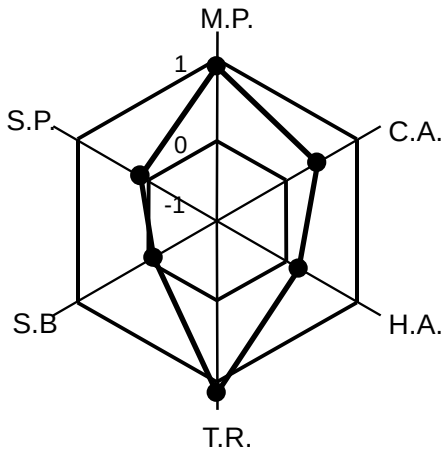


Figure 5 The Hexagon Radar Chart.

3 SELECTION OF CUSHIONS

It is the important problem for medical staffs to select the wheelchair cushion among the 3 cushions in Figure 2. Figure 6 shows the 2-D representation of the pressure distribution and the radar chart of 2 SCI patients using the 3 kinds of wheelchair cushions. Patient A is a female (C_7 SCI level) and her weight is 45.0kg. Patient B is a male (Th_{12} SCI level) and his weight is 48.0kg. In Patient A, the contact area of the 2-D representation of the pressure distribution is large in all cushions. The 3 parameters (M.P.,H.A. and T.R.) are small in all cushion. The pressure distribution and the 3 parameters of Solo cushion is especially better than other 2 cushions. The pressure distributions of patient A vary slightly among the 3 cushions and are similar to the pressure distribution of healthy subjects. In patient B, the 2-D representation of the pressure distributions are different among the 3 cushions. The buttock pressure of patient B is narrowly supported by ischial tuberosities and not supported by both thighs. The pressure on coccygeal regions where some SCI patients develop the pressure sore is large. Such pressure distribution is observed in some SCI patients but isn't observed in healthy subjects. The M.P., H.A. and T.R. of the air cushion are smallest among the 3 cushions.

In this way, 2 types of distributions were observed. One is that the weight is supported widely and the contact area is large (patient A) and the other is that the weight isn't supported on both thighs and contact area is small (patient B). When patients who have the latter type of pressure distribution use solo cushion or jay2 cushion, the weight is concentrated on ischial tuberosities and the maximum pressure is large. We think the reason for this is the posture of the SCI patient.

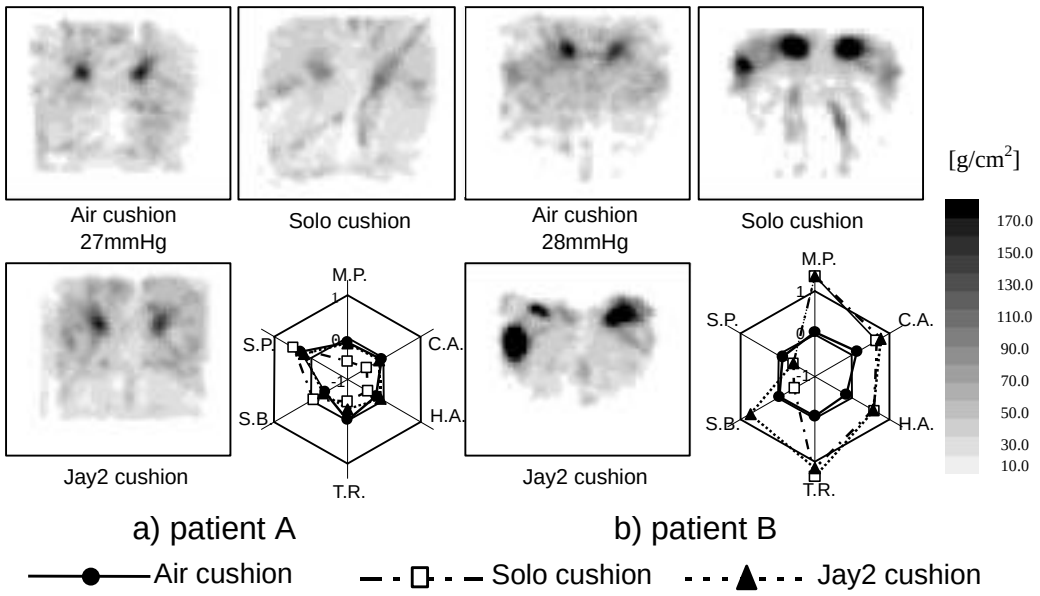


Figure 6 2-D representation of pressure distribution and radar chart using 3 cushions.

Both thighs aren't in contact with the wheelchair cushion when the lower legs are longer than the length between the position of the footrest and the wheelchair seat. This situation can be observed in the patient who sits on the wheelchair in shallow position or when the patient's lower legs are too long for the wheelchair. In some SCI patients who sit in the middle position, the pressure distribution of the Solo cushion is better than the other 2 cushions. On the other hand, the air cushion is useful for SCI patients who have small contact area and small pressure on both thighs. Thus, using the radar chart, it become easy to select the best cushion for each SCI patient.

4 ADJUSTMENT OF AIR CUSHION

Recently in our rehabilitation center, most SCI patients use the air cushions because of the pressure distribution and easy adjustment using the air pump (Figure 2). Figure 7 shows the relation between the contact area and the air pressure in cells, the maximum pressure and the air pressure in cells with a healthy subject. It is seen that the maximum pressure and the air pressure have a proportional relationship, whereas the contact area and the air pressure have an hyperbolic relationship. Thus, the weight is distributed evenly and over the widest surface area when the quantity of air in each cell is small. However, the maximum pressure becomes large because of bottom up, when the quantity of the air is small. Because the influence of the air pressure on the pressure distribution is large in the air cushion, it is one of the important problem for the medical staff to adjust the air quantity of the air cushion.

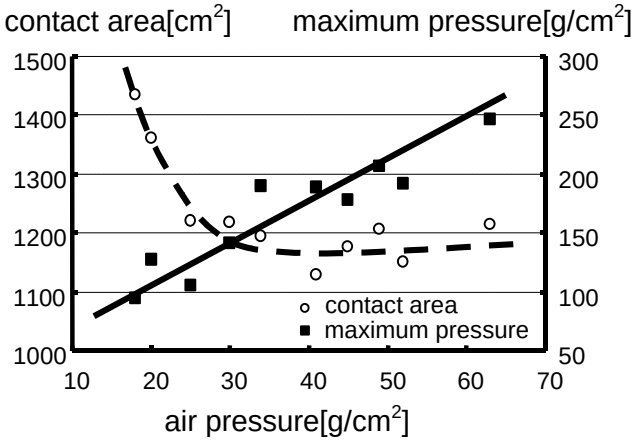
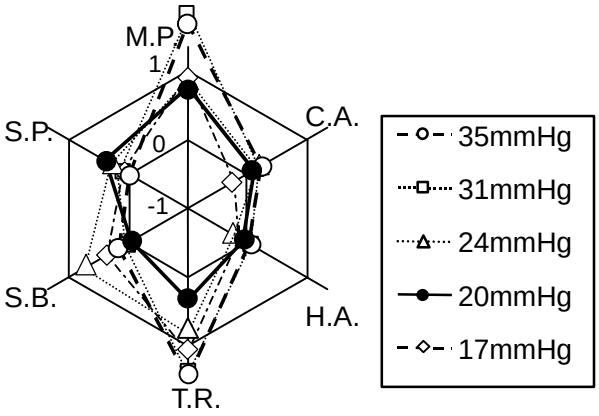


Figure 7 Relation of contact area and air pressure, maximum pressure and air pressure.

Figure 8 shows the results of the adjustment of the air cushion. It is the radar chart of a SCI patient with 5 type of the air cushions. The 5 type of the air cushion have small quantity of air in cells (17mmHg), a little small quantity of air (20mmHg), middle quantity of air (24mmHg), a little large quantity of air (31mmHg) and a large quantity of air (35mmHg). Because the air cushion

had large quantity of air, the air in cells was pulled out by a physician, then the air pressure in cells changed from 35mmHg to 17mmHg. As the results, the M.P. and H.A. of the air cushion with a little small quantity of air became smaller than other type of the air cushion. The air cushion with a little small air quantity is thought to be good for this SCI patient. We think that the radar chart of small quantity of air becomes larger than a little small quantity of air, because of the bottom up. In this way, we believe that the radar chart is very useful for the medical staff's adjustment of the air cushion



Patient C female 44.0kg C_8

Figure 8 The radar chart under adjustment of the air in cells of the air cushions.

5 INSTRUCTION OF SITTING POSTURE

It is one of the important problem for medical staffs to instruct the SCI patients to hold the posture on the wheelchair. Figure 9 shows the radar chart when the medical staff instructed the SCI patients to hold the posture on the wheelchair evenly. When the pressure is evenly concentrated on both ischial tuberosities, the S.B. become small. On the other hand, when the S.B. is large, the medical staff has to assist the SCI patients to hold the posture on the wheelchair evenly. When the medical staff instructs the SCI patient to hold the posture on the wheelchair evenly and the SCI patient studies the sitting posture on the wheelchair well, the pressure is concentrated on the both ischial tuberosities evenly. Then the S.B., the M.P., the H.A. and the T.R. become small in figure 9. The maximum pressure changed from 179.1g/cm^2 to 130.0 g/cm^2. In this way, we can recognize the effect of the medical staff's instruction of the SCI's sitting posture on the wheelchair using the radar chart. We believe that the radar chart is very useful for the medical staff's instruction of the SCI patient's posture on the wheelchair. Moreover, using the radar chart, we can evaluate the SCI's study of the posture on the wheelchair.

6 CONCLUSION

In rehabilitation medicine, the selection of wheelchair cushions, adjustment of cushions and instruction of the SCI patient's posture are important problems to prevent the pressure sore. In this paper, we calculated the six parameters and represented the six parameters on the radar chart to evaluate the buttock pressure distribution of SCI patients. It is useful for the medical staffs and SCI patients, because they can easily understand the pressure distribution, sitting position and sitting balance with the radar chart.

We measure the buttock pressure distributions of SCI patients on 3 kinds of wheelchair cushions using the Tekscan pressure measurement system. As the results, because the best cushions vary in patients, it is difficult for the medical staffs to select the best cushions for each SCI patient. Using the radar chart, it become easy to evaluate the pressure distributions of cushions and select the best cushion for each SCI patient.

Many SCI patients use the air cushions because of the pressure distribution and easy adjustment. In the air cushion, the

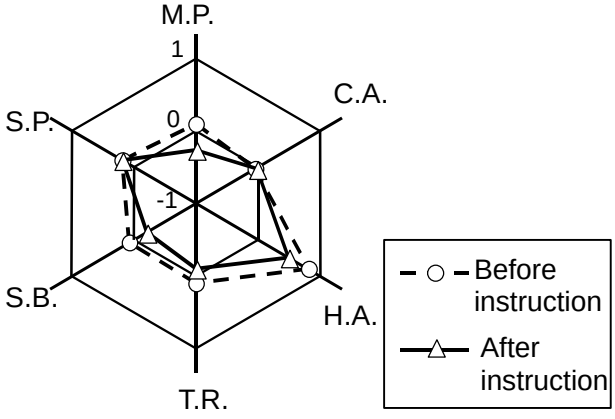


Figure 9 The radar chart after instruction of the posture on the wheelchair.

adjustment of the quantity of air in cells is one of the important problem for the medical staffs because the influence of the air quantity in cells on the pressure distribution is large. The medical staffs can adjust the air cushion to each SCI patient using the radar chart. Moreover, the medical staffs can instruct the SCI patient to hold the posture evenly and SCI patients understand their posture on the wheelchair. It is useful for SCI patients to study their posture on the wheelchair and the prevention of pressure sore.

REFERENCES

[1] Kosiac,M, Etiology and pathology of ischemic ulcers, *Arch. Phys. Med. Rehabil.*, **40**(1959) 62-69.
[2] A.Tokuhiro, A study of the incidence of the pressure sore in rehabilitated paraplegic patient, *Jap. J. Trauma. Occup. Med.*, **38** (1990) 538-541
[3] K.Fujiie, A questionnaire on pressure sore with spinal injuries, *Rehabilitation Engineering R&D S.C.I.*, (1992) 123-133.
[4] T. Inoue, A. Nakajima and T. Aoyama, The pressure relieving effects of the wheelchair cushion in Royal Perth Rehabilitation Hospital, *Jap. J. Trauma. Occup. Med.*, **38** (1990) 582-587.
[5] R. Palmieri, G. T. Haelen and George Van B. Cochran, A comparison of sitting pressure on wheelchair cushions as measured by air cell transducers and miniature electronic transducers, *Bulletinn of prosthetics research*, **17** (1980) 5-8.
[6] Terry K. K. Koo, F. T. Mark and Y. L. Lee, Posture effect on seating interface biomechanics: comparison between two seating cushions,*Arch. Phys. Med. Rehabil.*, **77** (1996) 40-47.
[7] Y. Tanimoto, H. Takechi, H. Nagahata and H. Yamamoto, The study of pressure distribution in sitting position on cushions for patients with SCI, IEEE Transactions on Instrumentation and Measurement, **47** (5) (1998) 1239-1243.
[8] L. Henderson, S. H. Price, M. E. Brandstater and B. R. Mandac, Efficacy of three measures to relieve pressure in seated person with spinal cord injury, *Arch. Phys. Med. Rehabil.*, **75** (1994) 535-539.

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