Evaluation of EMG for Electric Wheelchair Designs for Disabled People

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Abstract

Electric wheelchairs that are in use have heavy weight and are difficult to maneuver in the home. Therefore, a study to establish simple movement in the home of people who have difficulty with walking because of advanced age was designed and developed. In this study, the following points were examined with 5 physically unimpaired people: (1) levels of back and arm muscle activity at the time of sitting/standing movement with various seat heights, and (2) a comparison of the muscle load of the arms during the operation of a manual wheelchair and an electric wheelchair. In the results, for the ergonomic design of a wheelchair for people having difficulty walking and who cannot use the muscular strength of lower limbs, the height of the seat of the wheelchair should be set to around 42-44cm without lowering it. Also, the useful support of the arms at the time of sitting/standing from the wheelchair should be given attention.

Keywords

electric wheelchair, manual wheelchair, electromyogram, physical load

1. INTRODUCTION

Vehicles have become electromotive, moving silently with superior control characteristics and power. The development of electric vehicles is performed with regard to such points. In addition, if wheelchairs become electromotive, they will provide comfort and wider mobility. However, electric wheelchairs that are in use have the following faults concerning general use: (1) heavy weight and difficult to fold and store, (2) incongruous design compared with domestic furniture, (3) difficult to maneuver in home.

Therefore a study to establish simple movement in the home of people who have difficulty with walking because of advanced age was performed, and a chair named "Mobile Chair" was developed. The development purpose is the electronic assistance of a chair in the home which facilitates easier movement for people who have difficulty walking, whose number is predicted to increase with old age. [Masuzawa et al., 2005] When a person who has difficulty walking sits down on a chair, they cannot use the big muscular strength of the lower limbs which are necessary for physical support, therefore, there tends to be an excessively heavy load demanded from their backs and arms. The height (the height from the floor) of the seat is a basic and an important ergonomic design factor because it is necessary to reduce the muscle load of the back when using a fixed chair and to find the height adjustment range of the seat. Therefore, an EMG was used as a method of evaluating physical load. The EMG has been studied as an evaluation method of reducing physical load systematically in various fields. [Kroemer and Grandjean, 1997; Ikeda et al., 2007]

In this study, the following points were examined: (1) levels of back and arm muscle activity at the time of sitting/standing movement with various seat heights; (2) a comparison of the muscle load of the arms during the operation of a manual wheelchair and an electric wheelchair

2. METHOD

2.1 Measuring with an electromyogram

As shown in Figure 1, sensors were attached to four places, on the left and right of the trapezius (shoulder) and back muscles (the fourth lumbar vertebrae area). The electromyograph was recorded on a memory card at sampling time 500Hz with a microminiature electromyograph muscle tester pro by Mega Electronic Com-

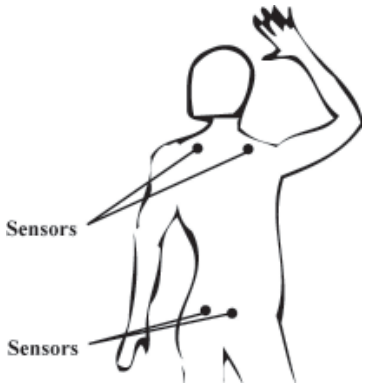

Fig. 1 Electrode sensor positions

pany. The average muscle activity was measured after RMS processing and analyzed with Acknowledge 3.7 MP100P software (Biopac System Co).

2.2 Procedure of measurement

In order to measure the muscle activity of back and upper arms at seven different heights from the seat, a commercial office chair was used. The seat height from the floor was set at seven conditions, 39cm, 40cm, 42cm, 44cm, 46cm, 48cm, and 51cm. As shown in Figure 2, each cycle of action consisted of standing position - sitting position - standing position, and the cycle was repeated four times with the office chair, manual wheelchair and electric wheelchair.

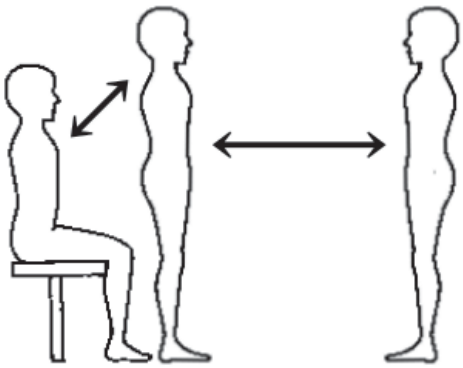

Fig. 2 Cycle of action

2.3 Subjects

The volunteer subject group consisted of six people. The average age was 23.7 years old (sd = 4.6, range = 21-33), average height 171.5cm (sd = 6.9, range = 161-180), average weight 64.8kg (sd = 9.2, range = 52-80). (Table 1)

Table 1 Subject information

Subject no.	Age	Height	Weight	Dominant hand
(1)	23	174cm	80kg	Left
(2)	21	169cm	65kg	Left
(3)	22	161cm	52kg	Right
(4)	33	168cm	65kg	Right
(5)	21	180cm	67kg	Right
(6)	22	177cm	60kg	Right

2.4 Manual and electric wheelchair

Figure 3 to Figure 6 shows the four wheelchairs which were used. The direction of the electric wheelchair shown in Figure 5 was controlled by the use of a joystick. The manual wheelchair shown in Figure 6 was a Japanese Industrial Standard (JIS) type.

Fig. 3 Prototype no. 1

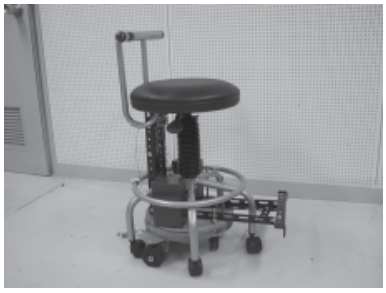

Fig. 4 Prototype no. 2

Fig. 5 Electric wheelchair

Fig. 6 Manual wheelchair

3. RESULTS

3.1 Muscle activity of back and arms at the time of sitting/standing

As shown in Figure 7, muscle activity of the back indicated different physical loads depending on the height of the seat at the time of sitting/standing. Between the seat heights 40-44cms, there was no difference in the right and left muscle activity, and especially 42cms

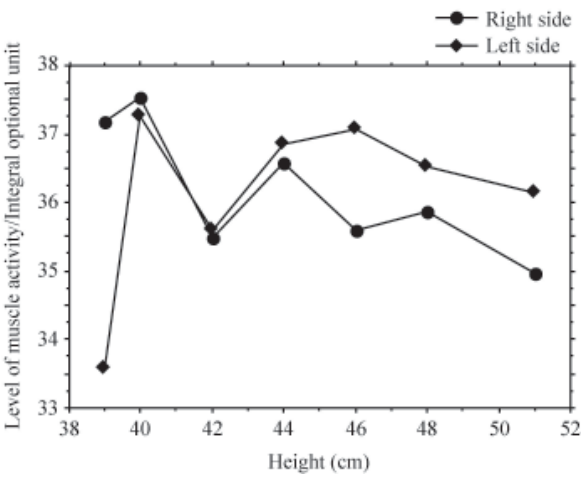

Fig. 7 Comparison of the seat height and back muscle activity

showed the lowest level of muscle activity. On the other hand, both seat heights over 44cms and under 39cms showed a difference in the muscle activity between right and left. However, the more the seat height was increased, the more the muscle activity decreased.

In Figure 8, the relationship between several seat heights and the muscle activity of the shoulder trapezius is shown. When the shoulder was raised and the arms were raised forward or to the side, the trapezius (shoulder) became active and as the angle increased, the level of muscle activity also increased. The muscle activity of the trapezius at the time of sitting/standing was different depending on the seat heights, and under 44cms, the muscle activity was 50% less than for 46cm. There was no difference in the muscle activity between right and left.

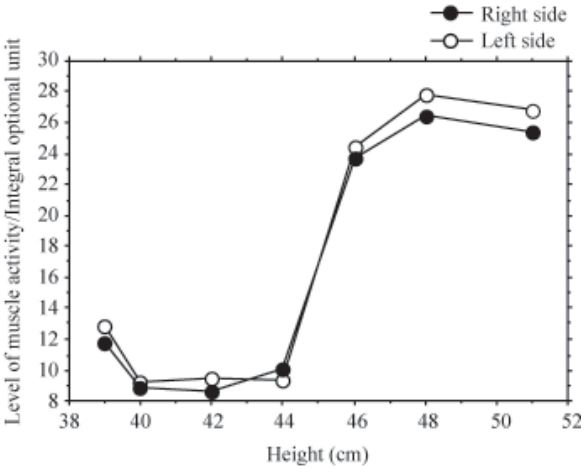

Fig. 8 Comparison of the seat height and trapezius (shoulder) activity

3.2 Muscle load of three electric wheelchairs and one manual wheelchair

The corresponding muscle load of back and trapezius, when operating three electric wheelchairs and one manual wheelchair, was compared. When the shoulder is raised and the arms are raised forward or to the side, the trapezius muscle activity increases. When the shoulder is raised to an angle exceeding 30 degrees, it is said that pressure on the shoulder causes a circulation obstruction. Therefore, there is strong concern that the driving posture of a wheelchair is connected to forcing an unnatural posture. An improvement of the posture, to avoid a second obstacle, and a wheelchair which can provide comfortable operation is necessary.

Figure 9 shows a comparison of the muscle activity according to the right and left back muscles at the time of sitting/standing of four wheelchairs. The results show that the muscle activity of the back was greatest for the manual wheelchair which has the lowest seat, greater for the electric wheelchair, and lower for the prototype wheelchairs which have higher seats. No difference

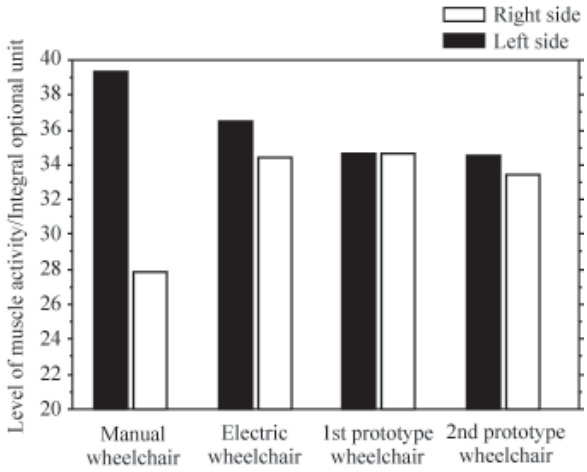

Fig. 9 Comparison of right and left back muscle activity in four wheelchairs

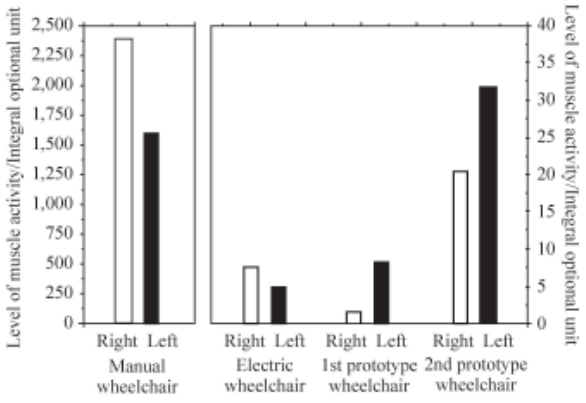

Fig. 10 Comparison of trapezius (shoulder) activity during operation of four wheelchairs

between right and left back muscle activity could be seen, except for a manual wheelchair. There is a twist of the back muscles at the time of sitting/standing for a manual wheelchair, therefore, it may be said that a greater burden on the back is easily increased.

Figure 10 shows the comparison of arm muscle activity during the operation of four wheelchairs. The result of EMG for the manual wheelchair exceeded 300 times of the electric wheelchair, and therefore, indicates the biggest muscle load.

4. DISCUSSION AND CONCLUSION

As shown in Figure 7, a difference between the right and left back muscles and the arms at the time of sitting/standing was observed. In addition, as the seat height was increased, the muscle activity decreased. These results suggest that there is no twist of the back muscles during sitting/standing action at each seat height from 40-44cms, however, there is a positive twist at a seat height above 45cms. Also, as the seat height increased, the distance between the sitting/standing positions was decreased, therefore, the muscle load was also decreased. It can be thought that a seat height of 42cms is a possible guide to decrease the muscle load on the back at the time of sitting/standing.

As shown in Figure 8, the results of muscle activity of the shoulder trapezius at various seat heights suggest that a chair with a lower seat height required no muscle support from the arms when sitting/standing, and also, when the seat height was higher, sitting/standing required support from the arms.

As shown in Figure 9, the muscle activity of the back was greatest at the lowest seat height of a manual wheelchair. There is a twist of the back during sitting/standing action with a manual wheel chair, therefore, the physical load of the back is easily increased. Figure 10 shows the greatest results of muscle load with a manual wheelchair. The stick operation of the electric wheelchair and the prototype no. 1 used hand and finger action, therefore, there was little arm-raising load. However, with prototype no. 2, which can be operated without both hands, it was necessary to twist the back and use strength to push the operation bar, therefore, in order to keep the balance of the upper body posture, operation action was required. It can be thought that this indicates a connection with an increase of muscle load.

For the ergonomic design of a wheelchair for people having difficulty walking and who cannot use the muscular strength of lower limbs, the seat height of the wheelchair should be set to around 42-44cm without lowering it. Also, the useful support of the arms at the time of sitting/standing from the wheelchair should be given attention.

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