Comparison of Electric and Manual Wheelchairs Using an Electrocardiogram

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Abstract

Electrocardio-vuscular activity modulates physical activity depending on work load as well as work environment. Activity of electrocardiogram (ECG) may be associated with physical load of moving for people with mobility handicaps in use of wheelchairs. The aim of this study was to investigate the relationship of ECG activity with physical load of wheelchair users with or without electric motor system as well as being exposed to difficult access for high pavement above ground level in crossing main road. Ten voluntary students participated in the study. R-R interval times of heart beats were continuously recorded for each session of manual or electric wheelchairs. Experimental road conditions included the places where there was a 0cm to 5cm drop or steep step at both sides of the road. We conclude that electric wheelchairs can provide stable driving for their users under conditions where there are differences in height between sidewalk and road, which are common obstacles for the users of wheelchairs, and furthermore electric wheelchairs can also prove effective in reducing the physical load on their users.

Keywords

electric wheelchair, manual wheelchair, R-R interval time, physical load, curb

1. INTRODUCTION

As part of the transport problems that have arisen with the diversification of lifestyle in recent years, old people as well as handicapped people with mobility are more and more involved in social activities, but the environment for the transportation for these people has not been sufficiently prepared. Especially, barriers on roads obstruct transportation by wheelchair. The height of curbs on sidewalks and big slopes on the road become barriers for easy transportation. This situation increases difficulties and anxiety for those using wheelchairs, and it could cause traffic disasters. This paper compares the heart beat rates of wheelchair drivers between when operating electric and manual wheelchairs and for different curb heights between sidewalk and road, and it studies the efficacy of electric wheelchairs.

2. METHOD

Electric and manual wheelchairs were used in this experiment. In five different situations where the curb height was against the operation of wheelchairs, R-R interval time of heat beats, perceived rating as an index of physical load and time required were measured.

Table 1 shows the main features of the electric wheelchair. As shown in Figure 1, the direction of the wheelchair was controlled by the use of a joystick. The manual wheelchair is a type of the Japanese Industrial Standard (JIS), which is shown in Figure 2.

Table 1 Specifications of the electric wheelchair

Model/Type	EMC-101 OE
Drive system	Front-wheel power-steering, rear-wheel direct-driven system.
Braking system	Braking system by motor generator and magnetic break.
Control system	Eclectic control system in all directions by the use of a joy stick.
Wheel	220mm-diameter front-wheel and 388mm-diameter rear-wheel.
Motor	30-minutes rated output 24V 220W x 2
Size	Length 1070mm x width 600mm x height 900mm
Weight	83kg (including batteries)
Speed	Low: 2.5km/h, Middle: 4.5km/h, High: 6.0km/h
Actual hill-climbing	10 degrees
Step climbing	50mm
Minimum turning radius	850mm

Fig. 1 Electric wheelchair with joystick

Fig. 2 Manual wheelchair

The experiment was conducted over five different curb heights between sidewalk and road; a range of 0cm to 5cm difference in height. As Figure 3 shows, the wheelchair crossed the road from one sidewalk to the sidewalk on the other side. The road had one-lane. The width of the road was 10m in total from A1 to A3, and the width of the sidewalk was 1.8m.

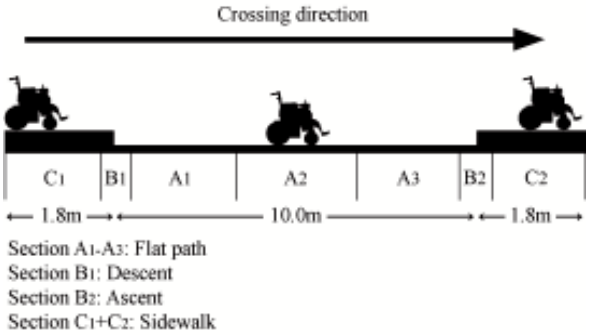

Fig. 3 Sectional view of setting in the experimental road

2.1 Experimental procedure

The experiment was conducted of the random combination of two types of wheelchairs and five setting conditions consisting of the differences in curb height. However, the experiment involving a 5cm curb height was not possible using the manual wheelchair, so only four conditions were used with the manual wheelchair. After the users' heart rate was measured while they were resting (under conditions while their eyes were closed), ten trials of road-crossing under each condition were conducted.

A wristwatch type of portable heart rate equipment S810 (Polar Electro Oy) was used for measuring heart rates. While the R-R interval time continued, a measure of the heart rate was fed from the transmitter in the heart rate induction electrode to the memory in the wristwatch receiver in order to record the rate.

2.2 Subjects

Ten male post-graduate and under-graduate students volunteered to participate in the experiment. The subjects were all healthy, and none of them had any physical problems with their upper limps, backs and hips. Their averaged age was 23.2 years old from 21 to 31 years old. Their average body height was 173.8cm from 166 to 183cm, and their average body weight was 63.4kg with from 50 to 72kg.

3. RESULTS

The speed and time needed for crossing the road and the heart beats were analyzed on three different sections of the experimental road as shown in Figure 3. The manual wheelchair could not ascend a 5cm curb.

3.1 Crossing speeds at the different levels

Figure 4 shows crossing speeds at difference levels from the road respectively in electric and manual wheelchairs. The average speed on flat section from A1-A3 was 4.3km/h for electric wheelchairs and was 3.9km/h for manual wheelchairs. The former type thus crosses the road faster.

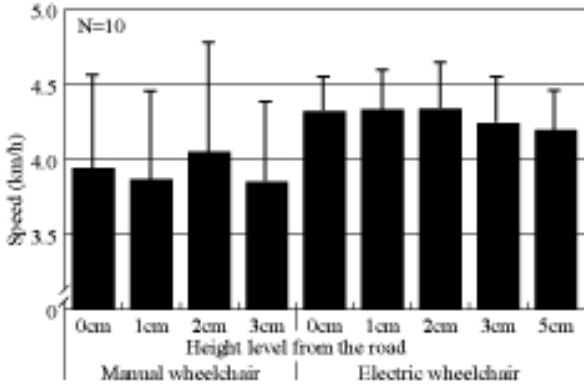

Fig. 4 Crossing speeds at the different levels

3.2 The time taken at the different height levels

Comparing the time taken for crossing the sections C1-C2 in Figure 3, it took an average time of 12.4sec by electric wheelchair and 14.6 sec by manual wheelchair. Figure 5 indicates that the crossing time of a manual

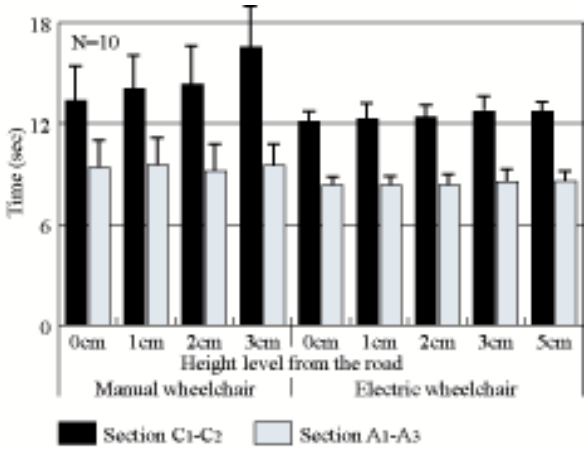

Fig. 5 Time needed for two sections

wheelchair was the longest at a 3cm curb height. And it took longer to ascend than to descend under the experimental road conditions. It was shown that with electric wheelchairs there was no difference in the time taken under all conditions.

In crossing the sections A1-A3, the average time needed for an electric wheelchair was on average 1.0 sec shorter than for a manual wheelchair. There was almost no difference of time needed for driving on a flat road in both types.

3.3 Comparison of R-R interval times of heart beats at difference in level from the road

Figure 6 shows a comparison of the average R-R interval time between electric and manual wheelchairs for the five different heights. The R-R interval time during using both different types of wheelchairs decreased in the section B1-B2. In particular when the wheelchair was ascending the curb, the difference was recorded as 125msec.

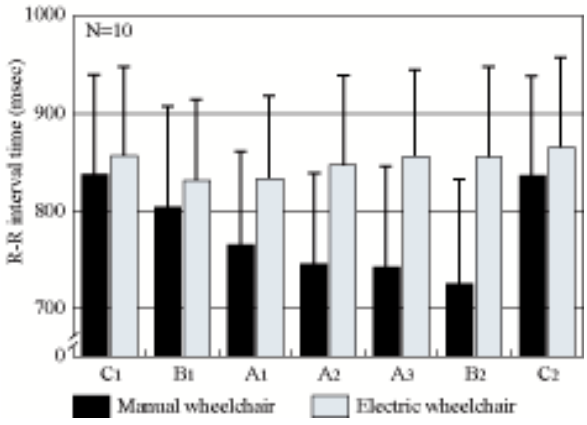

Fig. 6 R-R interval times of heart beats

As shown in Figure 7, the average R-R interval times of heart beats for the section C1-C2 were: 0cm=896.0, 1cm=869.8, 2cm=847.5, 3cm=817.5, 5cm=822.7msec. In spite of the difference in height between road and sidewalk, the R-R interval time was shorter when descending the curb than when ascending. The heart rate of the user also increased.

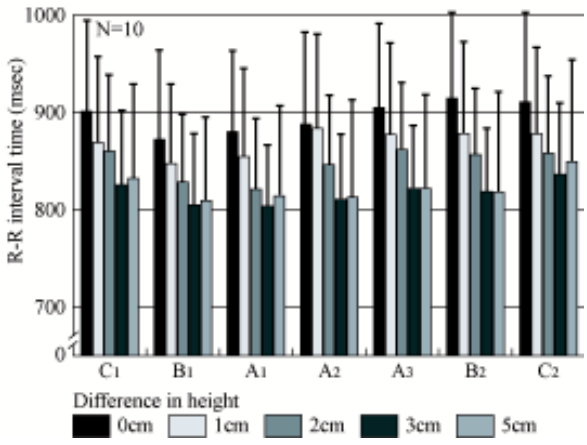

Fig. 7 R-R interval times for using an electric wheelchair

As Figure 8 shows, for using a manual wheelchair, R-R interval times got shorter as the curb height became greater, and the heart beats of the driver also increased. The R-R interval time was shortest when the gap in height was 3cm, and when the wheelchair was ascending it showed the shortest R-R interval time of 682msec. For the section C1-C2, the heart rate of the user increased when the wheelchair descended the curb and moved to the flat section A1-A3; and the heart rate was constant until the user ascended the curb.

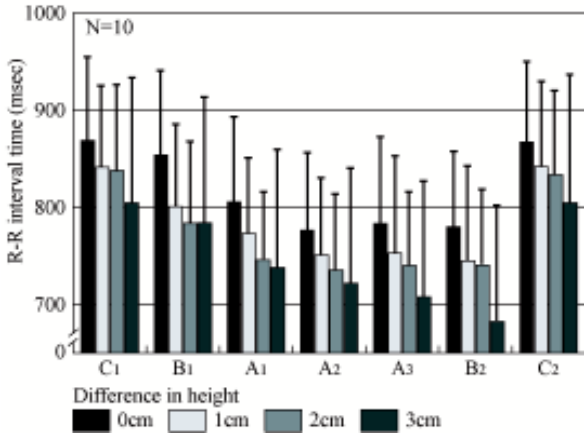

Fig. 8 R-R interval times for using a manual wheelchair

Figure 9 shows the R-R interval time when ascending and descending. With a manual wheelchair, the R-R interval time is shorter when it is ascending than when it is descending; and the user's heart rate increased. The differences of R-R interval time when driving up and down were: 0cm=73.9, 1cm=56.0, 2cm=42.7, 3cm=101.4msec; and the biggest difference was at 3cm. With an electric wheelchair, the R-R interval time was longer when ascending, and the heart rate of the user

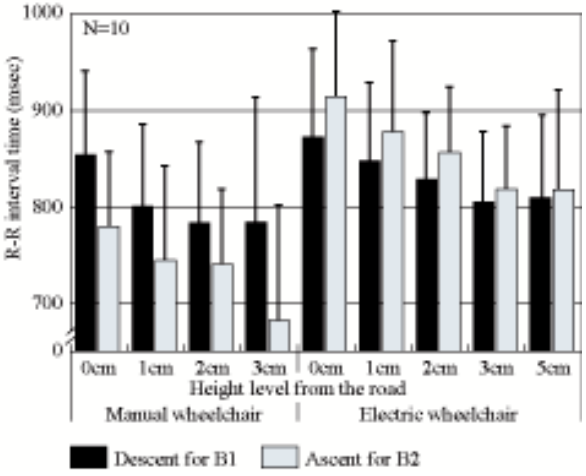

Fig. 9 R-R interval time of ascending and descending different heights

decreased. The differences of R-R interval time when ascending and descending were: 0cm=42.2, 1cm=30.8, 2cm=28.3, 3cm=13.6, 5cm=8.6msec. As the difference in height between road and sidewalk became larger, the difference of the R-R interval time became smaller. This is because the physical load on the users of wheelchairs increases on descending when the difference of the height from the road becomes larger. Comparing between electric and manual wheelchairs, a difference was found in the shift of the physical load in relation to the R-R interval time.

Figure 10 shows the R-R interval times and time taken when ascending the curb. In the case of manual wheelchairs, the higher the curb, the shorter the R-R interval times. Also, time taken become longer. However, in the case of electric wheelchairs, the higher the curb, the shorter the R-R interval times but there was no difference in the time taken.

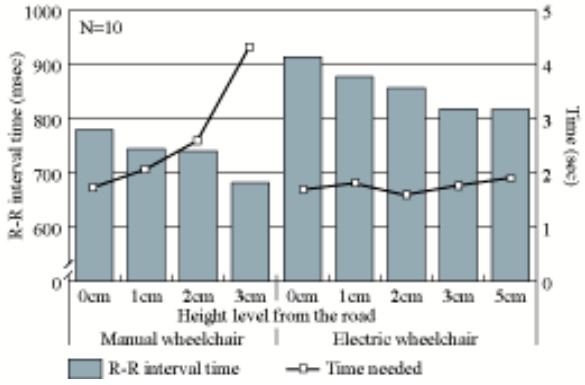

Fig. 10 R-R interval time and time required when ascending to a height level

4. DISCUSSION AND CONCLUSION

Electric wheelchairs can be controlled simply by the user operating the joystick. However manual wheelchairs are operated by the power of the users' arms, so there is additional physical load on their upper limbs and shoulders. Also in keeping the static sitting posture, load always accumulates in the back and hip and becomes a secondary problem to the users.

The averages in the process shown in Figure 6 are 857.2msec and 783.7msec for the electric and manual wheelchairs respectively. The electric wheelchair causes less physical load than the manual wheelchair, and this can reduce the accumulated load. However, as it is shown in C1 and C2 in Figure 7 and 8, which indicate the every 2-minutes state of rest, as the difference in height increases, the R-R interval time of C1 and C2 at the rest becomes shorter. This is because as the users drive the wheelchairs more, the higher the difference in heights become, the slower the body recovers from the load.

The manual wheelchair could not ascend a 5cm curb, but the electric wheelchair could ascend this height. The users of manual wheelchairs were asked if they had an experience of not being able to go to where they wish to go because of the difference in heights between sidewalk and road, 37% of them answered "happened very often", and 23% answered "happened often." [Tokuda et al., 2001] For this reason, the electric wheelchair which is less likely to be affected by the curb height is effective for expanding the users' field of activities. But, though it is effective for overcoming the problem of different heights, if the difference between sidewalk and road becomes higher, the load on the body also increases as it is shown in Figure 7. This is because the body suffers from the load in exchange of ascending the difference.

This experiment conducts a comparative evaluation of the degree of physical load between the users of electric wheelchairs and manual wheelchairs. The measurement of R-R interval time is used throughout this experiment and is fundamental to it. As a result of these measurements, it becomes clear that the electric wheelchair displays a greater efficacy in cutting the user's physical load than when the manual wheelchair is used. This becomes especially clear when the user of the wheelchair ascends a range of different curb heights. It also becomes clear that the electric wheelchair can move at a constant speed irrespective of these differences in height. Based on the results of comparing R-R interval times shown in the above paper, we conclude that electric wheelchairs can provide stable driving for their users under conditions where there are differences in height between sidewalk and road, which are common obstacles for the users of wheelchairs, and furthermore electric wheelchairs can also prove effective in reducing the physical load on their users. Taking into consideration the fact that the ratio of the physical load changes depending on the difference in curb heights, it is clear that an overall improvement in traffic conditions for wheelchair users is necessary.

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References

Tokuda, K., et al., Research and Study for Transportation Safety of Wheelchair User, *Annual Report of Research and Study 2000*, 32, 2001 (in Japanese).

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