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Respiration Rate and Oxygen Intake by Change of Wheelchair Backrest Angle

Soo-young Chae, M.Sc., O.T.
Dept. of Rehabilitation Science, Daegu University
Hyuk-cheol Kwon, Ph.D., P.T.
Dept. of Rehabilitation Technology, Daegu University
Dong-hoon Jeong, Ph.D., P.T.
Jin-yong Kong, Ph.D., P.T.
Dept. of Rehabilitation Science and Technology, Nazarene University
Hyun-mo Koo, Ph.D., P.T.
Rehabilitation Technology Center, Nazarene University

Abstract

This study was purposed to provide basic informationon the correct application of a wheelchair's backrest angle by investigating the change in cardiopulmonary function according to backrest angle during propulsion. This study examined the effects of the wheelchair's backrest angle on the cardiopulmonary function by varying the angle to 0°, 10° and 20° with a propulsion velocity of 60 m/min. The experimental parameters were respiration rate, oxygen consumption rate and oxygen consumption rate/kg which were measured by a portable wireless oxygen consumption meter (COSMED, $K4b^2$). The results of the study were as follows: 1) There were no statistically significant differences in respiration rates due to changes in the wheelchair backrest angle ($p>.05$). 2) There were statistically significant differences in oxygen consumption rates due to changes in the wheelchair backrest angle ($p<.05$). 3) There were also statistically significant differences in the oxygen consumption rate/kg due to changes in the wheelchair backrest angle ($p<.05$). In conclusion, changes in the backrest angle of wheelchairs during propulsion influences oxygen consumption rates and heart rates, while respiration rates are not affected. Therefore, a training program for good seating and posture needs to be provided, and the wheelchair seating system should be equipped with the unadjustable-angle wheelchair to reduce the functional load on the cardiopulmonary system.

Key Words: Oxygen intake; Respiration; Wheelchair backrest angle.

Introduction

A wheelchair has different functions. It isn't just a transportation medium for disabled or elder people, who cannot move freely, but it also can serve as a tool to normalize muscle tension, decrease inhibition of pathologic reflex, promote facilitation of symmetrical posture, improve range of motion, recover one's skin condition, promote sitting tolerance, decrease fatigue, and improve the function of automatic nervous system if prescribed properly (Adrienne, 1994). However, in the case of false prescription, a wheelchair can cause several segmentation impediments such as scoliosis and kyphosis. Furthermore, in case of sitting a long time without any mitigation of pressure concentration, the result can be a pressure sore, which damages the skin tissue (Rosalind et al, 1998). During the construction of a wheelchair, the tilt angle of the seat and the backrest are closely related to the shear stress that occurs when the person sits down on the seat. That is, the backrest, which is reclined to the seat that is horizontal to the earth, has a tendency to push the hips forward. This position can have two results. First, it causes the

Corresponding author: Soo-young Chae robin3938@daum.net

increase of the pelvis posterior tilting and kyphosis of lumbar and second, it generates shear stress and weight concentration in the parts of the ischial tuberosity, coccyx, and the sacrum. Namely, the backrest's tilt angle can provide the user with safety and comfort, but it has to be taken into consideration that tissue problems can occur because of excessive pressure concentration on the sacrum, coccyx, and part of buttock. Therefore, an appropriate seating and positioning is an essential factor for the functional ability, skin preservation, and increase of independence (Sprigle et al, 2003). A lot of researches have been done concerning the fact that people, who are living a life depending on a wheelchair due to innate or posterior reasons, have inferior physical abilities than those without disabilities because of a limited range of physical actions. A sedentary lifestyle causes psychological percussions such as a decrease in heart-lung abilities, a lowered self-concept due to a decrease of movement ability, an increase of dependency on other persons in everyday life, a decrease of acculturation ability (Glaser and Davis, 1990). Therefore an effective and consistent cardiopulmonary capacity is supposed to provide sufficient oxygen to tissues, remove CO_2 , and show appropriate reactions to various metabolic demands. In this aspect, physical activities are the frequent physiological stimuli. One's cardiopulmonary capacity, which is measured to evaluate the patient's functional abilities, reacts depending on the level of physical activities (Byun, 1994). The main index of evaluating the cardiopulmonary capacity is the maximum inhalation of oxygen, respiratory quotient, and heart pulse beat (Astrand and Rhyming, 1954). Generally, the experiment tools to calculate the main index of the cardiopulmonary capacity, by measuring the maximum inhalation of oxygen, are the treadmill, bicycle ergometer, and the arm ergometer, among which the treadmill, which regulates the stress of exercise by controlling speed and recline, is the most frequently used measurement tool. The sitting posture is one of the variables affecting the cardiopulmonary capacity during the wheelchair propulsion. Currently, the majority of wheelchair users modify their wheelchair to improve its level of comfort and usage. The backrest's angle of the wheelchair is applied differently referring to the type of disability. While Pierson et al (1976) claimed that the lung capacity in a sitting posture is superior to that in a standing posture, Kang (1988) claimed that the lung capacity in a lying posture is superior to that in a standing posture because the total lung volume decreases by about 500 ㎖. In conclusion, it can be said that the change of posture changes the cardiopulmonary capacity. The studies concerning the cardiopulmonary capacity of wheelchair users so far have been very dynamic. That is, while many cardiopulmonary capacity studies that are based on the propulsion speed or method have been accomplished, there has been a shortage of studies concerning the change of cardiopulmonary capacity based on the physical posture (wheelchair's backrest tilt angle). Therefore, studies concerning the change of inhalation of oxygen and the respiratory quotient, based on the backrest's tilt angle, are needed.

Methods

Subjects & Study Period

This study's subjects were twenty-two healthy students in their twenties, who are attending D University in Daegu. None of them has had experiences with respiratory system sickness or musculoskeletal system disorder and none familiar with the use of wheelchairs.

General Characteristics

The subjects who participated in this study were healthy adults, and their average age was 23.73 years (21～26 years), their average weight was 67.6 ㎏ (52～85 ㎏), and their average height was 174.5 ㎝ (163～180 ㎝) (Table 1).

Measurements

After receiving an agreement of the study subjects to participate in the study, its procedure was explained to them, and they were given time to retain a psychologically relaxed condition to adapt to the experiment atmosphere. Then the oxygen inhalation and respiration rate were measured for one minute. The subjects propelled a wheelchair for ten minutes at a constant speed of 60 m/min, while having a different backrest tilt angle (0°, 10°, and 20°). The oxygen inhalation and the respiration rate's change was measured based on each backrest's tilt angle. To assure that fatigue didn't influence the measurement results in any way, the experiments were executed over a period of 1~3 days. To measure the oxygen inhalation and the respiration rate, a portable wireless metabolic system, the $K4b^2$ was used. The $K4b^2$ can execute measurement by being fixed onto the subject's breast or back with an x-band. The ventilation and gas analysis can be carried out by sticking a gas and flux sensor at the front of the mask's ventilation exit and connecting it to the main system. The data was received by connecting the receipt antenna, which is positioned inside 5 meters distance, to the main computer with a RS-232 cable. At the first rest, the oxygen inhalation and respiration rate was measured for one minute and after the physical activity started the data was collected for 10 minutes.

Data Analysis

The average and standard deviation of the oxygen inhalation and respiration rate during times of rest and physical activities changed according to the backrests' tilt angle at the moment of the wheelchair propulsion. This average and standard deviation were acquired with help of the SPSS version 12.0 for Windows and were used for the analysis. When the subjects were resting a measurement was executed each minute, while during physical activities a measurement was executed every ten minutes according to the change of the backrest's tilt angle. After that the average value was calculated and used for the analysis. To find out the relationship between the wheelchair's tilt angle and the cardiopulmonary capacity, a one-way repeated measure ANOVA was processed. To verify the statistical equivalence, the equivalence standard α was set at .05.

Results

1. Change of the respiration rate according to the wheelchair's backrest tilt angle

Concerning the wheelchair's propulsion, the change of the respiration rate according to the wheelchair's backrest tilt angle is reflected in table 2. While there was a change ($p<.05$) in the respiration rate based

Table 1. The general characteristics of the subjects

General characteristics	No. of subjects	Mean±SD	Range
Age (years)	22	23.7±1.80	21~26
Weight (㎏)	22	67.6±10.23	52~85
Height (㎝)	22	174.5±5.13	163~180

Table 2. Change of the respiration rate according to the wheelchair's backrest tilt angle (N=22)

Division	Sum of square	Degree of freedom	Mean square	F value
Respiration rate	3,490.47	1	3,490.47	65.11*
Respiration rate × Angle	301.22	2	150.61	2.81

*p<.05

on the time (during rest, after 5 minutes of physical activity and after 10 minutes of physical activity), it could be observed that the respiration rate didn't change according to the tilt angle of the wheelchair.

2. Change of the oxygen inhalation according to the wheelchair's backrest tilt angle

Concerning the wheelchair's propulsion, the change of the oxygen inhalation according to the wheelchair's backrest tilt angle is reflected in Table 3. There was a change ($p<.05$) in the oxygen inhalation based on the time (during rest, after 5 minutes of physical activity and after 10 minutes of physical activity) as well as a change according to the tilt angle of the wheelchair ($p<.05$).

3. Change of the oxygen inhalation/㎏ according to the wheelchair's backrest tilt angle

Concerning the wheelchair's propulsion, the change of the oxygen inhalation/㎏ according to the wheelchair's backrest tilt angle is reflected in table 4. There was a change ($p<.05$) in the oxygen inhalation/㎏ based on the time (during rest, after 5 minutes of physical activity and after 10 minutes of physical activity) as well as a change according to the tilt angle of the wheelchair ($p<.05$).

Discussion

Recently many studies related to wheelchair propulsion have been attempted. For example, studies have been undertaken concerning the oxygen inhalation at times of maximal physical activities (Keyser et al, 1999), which can be compared to the measurement of a normal person's fatigue at the time of wheelchair propulsion. Studies have also been done of interrelatedness between a disabled person's upper limbs' muscle strengths and cardiopulmonary endurance (Song, 2001). However, these study approaches were aiming at cardiopulmonary endurance according to the method of wheelchair propulsion and the overall use of a wheelchair, whereas studies concerning the change of the backrest's tilt angle and the cardiopulmonary capacity have been insufficient so far. Therefore this study's focus is to present a backrest tilt angle that helps effective wheelchair propulsion by examining the change of the cardiopulmonary capacity based on different backrest tilt angles. In general, the wheelchair propulsion experiment was carried out on a wheelchair ergometer and the experiment time didn't exceed one minute. This experiment can have limits in providing reliable data concerning the cardiopulmonary capacity in proportion to the

Table 3. Change of the oxygen inhalation according to the wheelchair's backrest tilt angle

Division	Sum of square	Degree of freedom	Mean square	F value
Amount of oxygen inhaled	4,269,596	1	4,269,596	358.27*
Amount of oxygen inhaled × Angle	120,776	2	60,388	5.07*

*p<.05

Table 4. Change of the oxygen inhalation/㎏ according to the wheelchair's backrest tilt angle (N=22)

Division	Sum of square	Degree of freedom	Mean square	F value
Amount of oxygen inhaled/㎏	992.32	1	992.32	297.26*
Amount of oxygen inhaled/㎏ × Angle	25.05	2	12.53	3.75*

*p<.05

change of the backrest tilt angle at times of propulsion. In addition an obvious critical point especially was to provide an environment comparable to that of a wheelchair user propelling the wheelchair in everyday life. Vanlandewijck et al (1994) stated that, compared to the wheelchair ergometer, the wheelchair treadmill's propulsion effect occurs through the movement of the body and arms. The inertial force that is exercised in the user's system is utilized in the propulsion and this kind of inertial force adopts an important role in increasing the dynamic effect at the moment of the wheelchair propulsion. Latin and Elias (1993) assumes that the use of the wheelchair treadmill is providing a more exact measurement value than the use of the wheelchair ergometer concerning the examination of the stress of exercise. Therefore, this study provides the most similar environment comparable to the real wheelchair propulsion, and an experiment on a wheelchair treadmill, which improved the dynamic effect, was executed. The reason for that experiment was to examine the cardiopulmonary capacity in proportion to the change of the backrest tilt angle. Without any consideration for the physical differences of the subjects, the same wheelchair (Daesae, Korea) was used for all subjects. The change of the cardiopulmonary capacity can vary according to the wheelchair seat's height, the footrest height, the diameter of the wheel, and the distance between the wheelbases. After that, to execute a study, one must consider where the backrest tilt angle and the distance between the wheelbases can be modified according to the subject's physical characteristics. According to Kim (1999) the main focus of the ventilation ability caused by physical activities is the cardiac output amount and ventilation, while for the real performance the influence of the posture was included. In addition, important decision factors in the ventilation ability are the amount of maximum oxygen inhalation and the heartbeat. The analysis of the respiration rate according to the backrest's tilt angle at the time of propulsion was as followed: 25.961 beats/min at 0°, 24.797 beats/min at 10° and 25.698 beats/min at 20°. These results reflected that the respiration rate according to the backrest tilt angle didn't change significantly. When the respiration is in a stable condition, inspiration occurs if one's diaphragm and the external intercostals shrink and the abdomen slacken. In contrast to that expiration occurs if the external intercostals of the diaphragm slacken or the abdomen shrinks and the ribs and the lungs' elasticity go back to its normal form. The expiration and inspiration each occur 10 to 25 times per minute.

However, Brooks et al (1984) states that during physical activities, according to the type of breathing, the influence can be different. In the case of inspiration, the sternocleidomastoid and internal intercostals are additionally mobilized, so that the respiration can rise up to 40 to 45 times/minute.

The analysis of the amount of oxygen inhalation at the time of the wheelchair propulsion based on different backrest tilt angles had the following results: 547.503 ㎖/min at 0 degrees, 522.437 ㎖/min at 10 degrees and 474.7 ㎖/min at 0 degrees. These results reflect the amount of oxygen inhalation according to the backrest tilt angle decreased from 547.503 ㎖/min at 0 degrees to 474.7 ㎖/min at 20 degrees. Moreover, the analysis of the amount of oxygen inhalation/㎏ according to the backrest tilt angle showed following results: 8.16 ㎖/㎏/min at 0 degrees, 7.845 ㎖/㎏/min at 10 degrees, 7.145 ㎖/㎏/min at 20 degrees. These results reflect the amount of oxygen inhalation/㎏ according to the backrest tilt angle decreased from 8.16 ㎖/㎏/min at 0 degrees to 7.145 ㎖/㎏/min at 20 degrees. Jeong (1991) states that the amount of oxygen inhalation is the index of the body's aerobic power. Moreover it reflects the oxygen transportation and oxygen consumption system's synthesized power. It isn't only showing the inspiration's superiority and inferiority, but also that according to the superiority and inferiority the coronary circulation, endo/exocrine system, digestive system, and muscle tissue change. Byun (1994) reported that at a condition of rest, the amount of oxygen inhalation in the supine was 3.64 ㎖/㎏/min, while in a standing condition it was 4.53 ㎖/㎏/min, showing that in a lying condition the amount of oxygen inhalation was lower than in a standing condition.

Conclusion

This study targeted twenty-two healthy students in their twenties without any cardiopulmonary disease experience or any problems with the musculoskeletal system in the upper limbs or the nervous system. The study also measured changes in the cardiopulmonary capacity according to the change of the backrest's tilt angle during the 10 minutes the wheelchair was propelled at a speed of 60 m/min. Referring to the above mentioned results, the change of the backrest tilt angle at the moment of propulsion didn't affect the respiration rate, but affected the amount of oxygen inhalation. Therefore it can be derived that changes in the cardiopulmonary capacity are caused by the sitting posture. To reduce the burden on the cardiopulmonary capacity at the time of propulsion during everyday life, a rehabilitation program to secure a right sitting posture will be introduced. Moreover it is considered that a wheelchair seating and positioning system is needed when a wheelchair without adjustable backrest tilt angle is used.

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