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The effects of patient positioning in wheelchairs on cardiac and metabolic function

Efectele poziţiei pacientului în scaunul cu rotile asupra funcţiei cardiace şi metabolice

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Abstract

Background. Limited information is available on patient wheelchair mobility positioning and the effects on cardio-respiratory function. Proper sitting posture can be a key determinant on a patient's cardio-respiratory function during activity, as physiologic demands can be affected based on the patient's assumed sitting position.

Aims. The study aimed to determine the effects of a solid seat insert and lumbar postural roll on cardiac and metabolic function in patients diagnosed with stroke.

Methods. A total of 7 subjects propelled a wheelchair 300 feet during two separate trials: sitting in a sling wheelchair seat (SWS); and using a solid seat insert with lumbar support (Modified). Data was collected using the Physioflow Cardiograph and Oxycon Mobile Systems at four distinct time points during each trial.

Results. At the end of the trial, cardiac output (SWS: 5.9±0.5 L/min vs. Modified: 6.5±0.8 L/min), ejection fraction (SWS: 57.9±22.9% vs. Modified: 59.3±20.6%), myocardial contractility (SWS: 165.9±112.2 ohm/sec/m2 vs. Modified: 178.7±113.6 ohm/sec/m2), and heart rate (SWS: 90.5±13.6 bpm vs. Modified: 93.5.±15.6 bpm) were higher during the Modified positioning, although not significantly. Oxygen consumption was similar between trials (SWS: 6.7±1.4 mL/kg/min vs. Modified: 7.5±2.5 mL/kg/min).

Conclusions. In subjects diagnosed with stroke, a modified wheelchair sitting posture could create a more beneficial physiological position responsible for enhancing the cardiac function and increasing oxygen utilization, an indicator of cardio-respiratory fitness. Although, the trials were not statistically significant, the depicted trend is the incipient evidence that patients with stroke can benefit from modified wheelchair positioning.

Keywords: wheelchair, positioning, cardiac function.

Rezumat

Premize. Literatura ne oferă puţine informaţii privitoare la poziţia pacienţilor cu handicap în scaunul cu rotile, şi la efectele acesteia asupra funcţiei cardiorespiratorii. Postura adecvată în scaun poate reprezenta un determinant cheie al funcţiei cardiorespiratorii a pacientului în timpul deplasării, dat fiind că cerinţele fiziologice pot fi influenţate de poziţia pe care el o adoptă.

Obiective. Studiul şi-a propus să determine efectele plasării unui suport solid (placă) sub perna scaunului cu rotile şi a unui rulou în zona lombară asupra funcţiei cardiace şi metabolice, la pacienţii cu accident vascular cerebral.

Metode. Un număr de 7 subiecţi au parcurs distanţa de 300 picioare (un picior are 0,3048 m) în două condiţii; într-un scaun cu rotile standard (SRS), respectiv într-unul modificat (SM), prin plasarea unei plăci de lemn sub perna de sub şezut, şi a unui rulou în zona lombară. Datele au fost colectate cu ajutorul cardiografului Physioflow şi al sistemului mobil Oxicon, în patru momente distincte ale testărilor.

Rezultate. La sfârşitul deplasărilor pe distanţa menţionată, debitul cardiac (SRS: 5,9 ± 0,5, faţă de SM: 6,5 ± 0,8 l/min), fracţia de ejecţie (SRS: 57,9 ± 22,9, faţă de SM: 59,3 ± 20,6%), contractilitatea miocardică (SRS: 165,9 ± 112,2, faţă de SM: 178,7 ± 113,6 ohm/sec/m2) şi frecvenţa cardiacă (SRS: 90,5 ± 13,6, faţă de SM: 93,5 ± 15,6 bătăi/min) au fost mai mari, deşi nesemnificativ, atunci când s-a utilizat scaunul modificat. Consumul de oxigen nu a fost influenţat de poziţia pacientului în scaun; SRS: 6,7 ± 1,4, faţă de SM: 7,5 ± 2,5 ml/Kg/min.

Concluzii. La pacienţii cu accident cerebral vascular modificarea poziţiei în scaunul cu rotile ar putea avea efecte fiziologice favorabile, ce ar putea conduce la îmbunătăţirea funcţiei cardiace şi creşterea consumului de oxigen, indicatori de încredere ai capacităţii de efort. Deşi rezultatele noastre nu au evidenţiat modificări semnificative statistic în acest sens, tendinţele constatate pot constitui dovezi incipiente încurajatoare că pacienţii respectivi ar putea beneficia de perfecţionările scaunului cu rotile propuse de noi.

Cuvinte cheie: scaun cu rotile, poziție, funcția cardiacă.

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Introduction

Cerebral Vascular Accidents are one of the leading causes of severe long-term disability in the United States. Each year 795,000 people in the United States experience a new or recurrent stroke (Go et al., 2014). In addition, an estimated seven million Americans older than 20 years of age have had a stroke (Go et al., 2014). Due in part to an aging population and improvements made in cardiac disease identification and treatment, it is likely that there will be an increase in the number of patients diagnosed with stroke in the next 10-20 years (Alberts, 2003).

Many stroke survivors rely on wheelchairs during and after their acute recovery. Wheelchair cushions for patients with stroke are used to facilitate normal posture (In Hee & Sang Young, 2011). The posture of the body and normal spinal curvature are both affected by the seating surface, as pelvic position is a critical and highly influential contributing factor to normal spinal alignment. The thoracic spine, in combination with the rib cage, biomechanically serves as a stable support structure for the heart and lungs (Mauriciene et al., 2009). Through proper body positioning, the thorax has an increase in anatomical space allowing the lungs to expand fully, establishing a clear, fundamental connection between body positioning and effective breathing. The main posture affected by the conventional sling-seated wheelchair is that of excessive thoracic kyphosis, a biomechanical imbalance brought on by prolonged periods of time in one flexed postural position (Price, 2013). Patients of post-stroke status may be positioned in a wheelchair for an extended length of time, which could hinder their cardio-respiratory function. The main responses monitored for change during exercise rehabilitation - even with wheelchair propulsion - are: heart rate, cardiac output and performance of practical functions, all of which affected by the posture of the body (Soo-Young, 2012). Therefore, it is essential for patients to receive proper wheelchair positioning to optimize cardio-respiratory function, furthermore impacting recovery through an increased ability to participate in rehabilitation regimens to promote functional mobility.

Past research has attempted to identify efficient outcome measures in patients of post-stroke status utilizing different seat positioning. These studies focused on functional reach in elderly patients seated in sling wheelchair seats (SWS) versus those in a wheelchair with a solid seat insert (Amos et al., 2001). Limited information is available on patient wheelchair mobility positioning and the effects on cardio-respiratory function. Proper sitting posture can be a key determinant on a patient's cardio-respiratory function during activity, as physiologic demands can be affected based on the patient's assumed sitting position. The present study investigated whether cardio-respiratory function improved in patients of post-stroke status through correction of posture and restoration of proper thorax biomechanics while performing functional wheelchair propulsion.

Hypothesis

We hypothesize that in patients post-stroke, correction of posture and restoration of proper thorax mechanics while performing functional propulsion of the wheelchair will result in improved cardio-respiratory function.

Materials and methods

Research protocol

a) Period and place of research

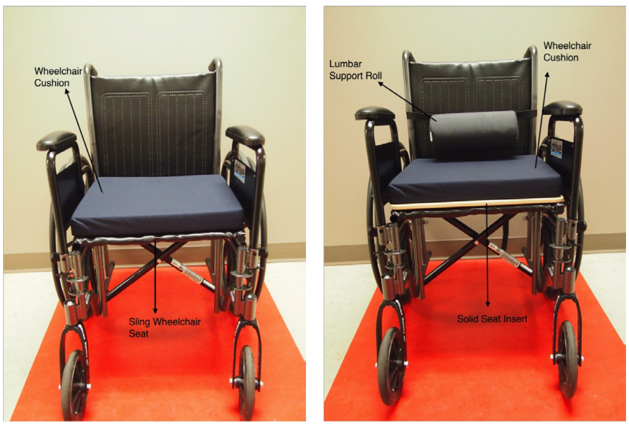
The subjects were patients at Carilion Roanoke Community Hospital Inpatient Rehabilitation, a facility with physical therapy, occupational therapy and speech-language therapy.

b) Subjects and groups

Three males and four females of post-stroke status, aged 53 to 72 years, volunteered to be in the study. In order to qualify for the study, patients must have had a primary diagnosis of stroke, be over the age of 50, and have a Functional Independence Measure (FIM) score of greater than or equal to five, with locomotion/wheelchair mobility. Individuals were excluded if they did not have proper decision making capacity as noted in the social worker, physician, or other clinician's notes within the medical record. Individuals were also excluded if they had existing co-morbidities including chronic obstructive pulmonary disease, asthma, or congestive heart failure. The study was approved by Carilion's Institutional Review Board and all subjects provided written informed consent.

c) Tests applied

The study was experimental and tested patients from a sample of convenience. Subjects performed two trials of wheelchair propulsion, each trial covering 300 feet in total length. Methods of wheelchair propulsion varied, as patients were allowed to move the wheelchair using upper and lower extremities. During the first trial, patients propelled a wheelchair in a normal sling seat with a wheelchair cushion (Fig. 1a). During the second trial, a solid seat board insert was placed under the wheelchair cushion and a lumbar postural support roll (Modified) was placed at the curvature of the patient's lumbar spine (Fig. 1b). All patients participated in the same testing procedure. Initially, the goal was to test patients in random fashion with the normal seat or the modified one; however, due to variability in the physical functioning of the patients, assistance was not available at the beginning of the testing.



a **b**

Fig. 1 – Sling wheelchair seat compared to modified positioning.

Prior to testing, each patient had the blood pressure and oxygen saturation recorded. The collected variables included oxygen uptake (VO_2), carbon dioxide production (VCO_2), oxygen uptake per kilogram (VO_2/kg), stroke volume (SV), heart rate (HR), cardiac output (CO), ejection fraction (EF) and myocardial contractility (CTI).

Patients were instructed to propel their wheelchair 150 feet in a straight line down a hallway, while a research team member followed with a cart containing the testing equipment. Upon reaching the 150-foot marker on the floor, the patient performed a turn to the right and propelled their wheelchair 150 feet back to the original starting position. The total distance propelled by each patient was 300 feet. The patient then rested for approximately ten minutes to allow for the blood pressure and oxygen saturation values to return to normal. Nursing employees provided assistance with a brief sit-to-stand transfer to allow a research team member to place the solid seat board insert and lumbar postural roll into the patient's wheelchair. The patient was then instructed to propel the wheelchair in the same manner as the first trial, with the added solid seat insert and lumbar postural roll.

The Physioflow Cardiograph System (Manatec Biomedical, Paris, France) is a non-invasive device used to hemodynamically monitor patients at rest and during motion. The Physioflow Cardiograph System consists of six non-invasive electrodes that are placed on the anterior portion of the patient's chest wall and left anterior-lateral neck. Before placement of the six electrodes, the patient's skin was removed of hair, abraded, and sterilized with an alcohol pad to ensure a good signal. The electrodes were then placed on the patient in the designated areas outlined by the manufacturer. Once a good signal was established via the Physioflow Cardiograph software, the patient was asked to remain still and quiet for approximately 30 seconds to allow for adequate calibration of the system. The PhysioFlow® emits high frequency (75 kHz) and low-amperage (1.8 mA) alternating electrical current on the thorax. This concept and methodology have been validated at rest and at exercise (Charloux et al., 2000), during maximal progressive exercise (Richard et al., 2001) and at rest, in emergency room and intensive care unit trauma patients (Shoemaker et al., 2006). The Physioflow was validated against the direct Fick method. Mean differences between cardiac output (CO) values obtained by the direct Fick method and the Physioflow device are not significantly different during rest (0.04 l/min), submaximal exercise (Charloux et al., 2000) (0.29 l/min), or maximal incremental exercise (Richard et al., 2001) (0.58 l/min). The direct Fick method is highly correlated with the Physioflow during rest (Charloux et al., 2000) ($r = 0.89$, $n = 40$), submaximal exercise (Charloux et al., 2000) ($r = 0.85$, $n = 40$), and maximal exercise (Richard et al., 2001) ($r = 0.94$, $n = 50$). High correlations in the SV ($r = 0.84$) and CO values ($r = 0.98$) between the direct Fick and impedance cardiography methods have been reported during maximal cycling exercise in young, fit men (Teo et al., 1985).

The Oxycon Mobile System (Carefusion; San Diego, California) is a non-invasive device used to measure metabolic values. The Oxycon Mobile System consisted of a flexible facemask (Hans Rudolph, Kansas City, MO) held in place by a head harness, which covered the patient's nose and mouth. The mask was attached to a bidirectional rotary flow and measurement sensor to determine the volume of inspired and expired air. A sample tube running from the mask to the analyzer unit delivered expired air for the determination of oxygen and carbon dioxide content (Rosdahl et al., 2010). The Oxycon Mobile System was calibrated per manufacturer specifications before testing of each patient, and a breath-by-breath analysis was conducted for each wheelchair propulsion trial. The Oxycon Mobile System has been shown to provide reliable and valid measures during activity (Trost et al., 2012). When compared to the Douglas Bag Method, which is the gold standard in gas analysis, the VO_2 and VCO_2 collected with the Oxycon Mobile System were deemed reliable in sedentary, moderately trained, and professionally trained individuals during cycle ergometer testing (Rosdahl et al., 2010; Trost et al., 2012).

d) Statistical processing

Using SPSS version 18 software (IBM; New York, NY), simple descriptive statistics and an analysis of variance procedure were performed to determine differences in the two types of wheelchair seating options. A two way repeated measures ANOVA was performed to determine any differences between the groups at different time points. An alpha level of 0.05 (two-tailed) was used to determine statistically significant data.

Results

Six of the seven patients (age 65±7.4 years, height 167.1±9.9 centimeters, and weight 80.3±24.1 kilograms) were included in the study for data analysis because, in one patient, mask leakage caused abnormal data collection.

Cardiac data

A repeated measures ANOVA revealed no statistically significant differences ($p>0.05$) in cardiac values across time points between the SWS and Modified positions. There were few variables demonstrating a trend towards improvement with the Modified seating position, namely stroke volume, ejection fraction, myocardial contractility, cardiac output and heart rate. The majority of these differences were seen after 300 feet of wheelchair propulsion (Table I).

Table I

Cardiac variable for SWS and Modified positioning at the end of trials.

Indicator	SWS	Modified	p
SV (mL)	69.2±9.2	73.5±14.6	0.5
EF (%)	57.9±22.9	59.3±20.6	0.9
CTI (ohm/sec/m^2)	165.9±112.2	178.7±113.6	0.7
CO (L/min)	5.9±0.5	6.5±0.8	0.1
HR (bpm)	90.5±13.6	93.5±15.6	0.4

Legend: SWS - sling wheelchair seat; SV - stroke volume; EF - ejection fraction; CTI - myocardial contractility; CO - cardiac output; HR - heart rate.

Metabolic data

Repeated measures ANOVA revealed no statistically significant differences ($p>0.05$) in metabolic values across time points between the SWS and Modified. However, oxygen consumption per kilogram of body weight, oxygen consumption, and carbon dioxide production in the Modified seating position demonstrated a trend towards improvement. The majority of these differences were seen after 300 feet of wheelchair propulsion (Table II).

Table II
Metabolic variables for SWS and Modified positioning at the end of trials.

Indicator	SWS	Modified	p
VO_2 (mL/min)	525.3±167.5	567.3±127.3	0.6
VO_2/kg (mL/min/kg)	6.7±1.4	7.5±2.5	0.5
VCO_2 (mL/min)	503.5±104.5	571.5±124.4	0.3

Legend: SWS - sling wheelchair seat; VO_2 - oxygen consumption; VO_2/kg - oxygen consumption per kilogram; VCO_2 - carbon dioxide production.

Discussions

The aim of this study was to investigate whether different wheelchair seating surfaces, SWS vs. Modified, could have an effect on cardio-respiratory function during wheelchair propulsion in patients undergoing rehabilitation following a stroke.

Cardiac findings

Hemodynamic variables were not different based on the type of posture the patients were asked to adopt during wheelchair propulsion. In a study about the spine sagittal curves, Mauriciene et al. (2009) found that thoracic kyphosis was negatively correlated with cardiovascular parameters. In theory, the slumped wheelchair position could be similar to a kyphotic abnormality and references to the literature should allow valid comparisons between the current results and previous published research. Current subjects tested did not experience any difference with seating mainly because of the clinical status and advanced age. Patients of post-stroke status commonly have primary residual neurological deficits and secondary deficits that collectively contribute to low cardiovascular capabilities post-stroke (Jin et al., 2013). In addition, an aged body will cause a decrease in elasticity and compliance of the cardiovascular system, resulting in an increase in resistance of blood being pumped by the myocardium to peripheral systems. The myocardium must work harder to overcome the ensuing resistance to blood flow, potentially causing myocardial hypertrophy, typically of the left ventricle (Stern et al., 2003). The left ventricle becomes inefficient at pumping blood as a result of increased size, which predisposes elderly individuals to a loss of cardiac adaptability at increased workloads.

Looking at specific cardiac variables, no significant differences in heart rate between the two different types of wheelchair seating were found. Mauriciene et al. found no significant differences in heart rate of subjects 15-18 years of age with thoracic kyphosis when compared with similar control subjects (Mauriciene et al., 2009). This finding supports the results of the present study, as thoracic kyphosis may not cause a heart rate change, albeit an older population was tested. Biomechanically, the thoracic spine and rib cage provide a stable support structure for the heart and lungs, thus the heart may not have a direct biomechanical link to thoracic kyphosis as the autonomic nervous system primary controls heart function.

Cardiac output did not change with variations in wheelchair seating surfaces. Fukuda et al. (2012) conducted a study that analyzed cardiac output response to exercise in individuals with Chronic Heart Failure on a lower extremity ergometer that mimicked the action required to mobilize a wheelchair. They found that stroke volume was significantly responsible for cardiac output response due to stroke volume reaching a plateau at the low intensity exercise (Fukuda et al., 2012). Their study did not have participants perform a functional task, but rather a simulated exercise routine based on physical demands similar to those required for wheelchair propulsion with the lower extremities. The present study did not investigate the differences between seating surfaces at peak workload intensities, although it did collect measurements during functional wheelchair propulsion. Different target populations and variations in workload intensities between our study and that of Fukuda et al. may explain why we did not find any significant difference in stroke volume between seating surfaces. Findings in the present study do indicate that stroke volume tends to increase during wheelchair propulsion at 300 feet with the Modified position compared to the SWS. This suggests that the myocardium, specifically the left ventricle, could be more capable of pumping blood to the peripheral system during times of increased workload when erect posture is required.

Huonker et al. (1998) studied the effects of ejection fraction across sedentary individuals with paraplegia, trained individuals with paraplegia, and able-bodied individuals. The study concluded that ejection fraction was not significantly different among the individuals during a wheelchair ergometer exercise test (Huonker et al., 1998). These results coincide with the findings from the current study. Although not statistically significant, ejection fraction and myocardial contractility tended to be higher in the present study immediately after 300 feet of wheelchair Modified position propulsion. In flexed, kyphotic posture, the heart is under the dominance of parasympathetic activity, which will cause a weakened atrial contraction (Tsuchie et al., 2011). The decreased atrial force of contraction could impact the ventricular filling and cause a decrease in contractility via the Frank-Starling mechanism (Shiels & White, 2008). One standard clinical measurement of heart contractility is the ejection fraction, a variable usually expressed as stroke volume divided by end-diastolic volume. Postural adjustments made while seated in a wheelchair have the potential to increase ejection fraction and restore a normal stroke volume.

Metabolic findings

The Modified position tended to show higher values for VO_2, VO_2/kg, and VCO_2, when compared to the SWS. Tsai et al. (2007) investigated changes in respiratory function across three wheelchair types. The study found that there were no significant differences in VO_2 across the wheelchair propulsion types in patients of post-stroke status (Tsai et al., 2007). Similarly, the present study found that VO_2 did not significantly change with modification of seating posture; however, the results did imply that immediately after 300 feet of wheelchair propulsion, VO_2 and VO_2 per kilogram tended to be higher with the Modified seating position. This suggests that patients of post-stroke status that are wheelchair users may benefit from a Modified sitting position to increase oxygen consumption. An increase in oxygen consumption may cause further oxygen saturation to tissues that require oxygenation at increased workloads, including the myocardium. The Modified position may induce cardiovascular adaptations that could translate into a greater amount of oxygen being circulated in the cardiovascular system, which can be more efficiently delivered to tissues that metabolically and mechanically require it (Trost et al., 2012). With increased oxygen consumption, partial pressure of carbon dioxide in the blood increases as a waste product of normal cellular metabolism. When carbon dioxide (CO_2) is retained in the lungs, respiratory acidosis may ensue and be further exacerbated by CO_2 that cannot be adequately expired during exercise (Smolka et al., 2014). This mechanism is supported by the trended increase in VCO_2 in the Modified seating position found immediately after 300 feet of wheelchair propulsion.

Limitations of the study

Patients were selected from a sample of convenience, and from a single rehab facility in rural southwest Virginia. The sample size was small due to a limited availability of patients during the testing period. Another limitation could be that the baseline spinal curvature was not measured in the SWS or Modified positions. This could provide further information on subject responses to wheelchair modification due to pre-existing spinal curvature abnormalities. Lastly, more definitive differences could have been attained if locomotion had been longer than 300 feet.

Conclusions

1. The current research did not provide significant evidence linking wheelchair seating surfaces and cardio-respiratory function. However, this does not represent a specific, conclusive result and is not meant to suggest differences do not exist between wheelchair seating surfaces, as the present study did find cardiac and metabolic non-statistical differences across certain time points - particularly directly after increased workload demands.

2. Patients of post-stroke status who use a wheelchair as their primary means of mobility may benefit from a Modified position to further enhance cardio-respiratory function.

Conflict of interest

The authors have no conflicts of interest to disclose.

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