Cardio-Pulmonary and Metabolic Functions and Exercise Tolerance in Patients with Spinal Cord Injury

Spinal Kord Yaralanmalı Hastalarda Kardiyo-Pulmoner ve Metabolik Fonksiyonlar ve Egzersiz Toleransı

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Summary

Objective: The aim of this study was to assess cardiopulmonary and metabolic functions and exercise tolerance in patients with spinal cord injury (SCI) in comparison with healthy subjects.
Materials and Methods: Twenty patients with paraplegia and fifteen healthy controls were included in the study. Fourteen patients were complete and six were incomplete according to the classification of the American Spinal Injury Association. Mean age of the patients was 31.31±8.17 years. The mean time since injury was 3.81±5.08 months. All subjects were considered either sedentary or minimally active and their upper bodies were not aerobically trained. Resting pulmonary functions were assessed spirometrically. Cardiopulmonary and metabolic responses to exercise were investigated with an electronically braked arm crank ergometry.
Results: There was a significant respiratory dysfunction in paraplegic patients. The mean peak oxygen consumption in the patient and control groups were 9.86±4.21 ml/kg/min and 14.27±1.59 ml/kg/min, respectively. Also, peak heart rate, peak minute ventilation, respiratory exchange ratio, peak power output values were lower in the paraplegic subjects than those in the healthy ones. As expected, healthy subjects reached significant higher values at peak exercise compared to the patient group (p range, <0.05 to 0.001).
Conclusion: In the present study, we determined that there was a significant respiratory dysfunction (60% in patients with SCI versus 1.3% in healthy controls, p<0.001) in the study population. Moreover, they had a decreased exercise tolerance and cardiopulmonary and metabolic responses to maximum exercise when compared to the healthy subjects. *Turk J Phys Med Rehab 2006;52(1):1-5*
Key Words: Exercise tolerance, spinal cord injury, peak oxygen uptake

Özet

Amaç: Bu çalışmanın amacı, spinal kord yaranmalı hastalarda, sağlıklı bireylerle kıyaslayarak, kardiyopulmoner ve metabolik fonksiyonlar ve egzersiz toleransını değerlendirmekti.
Gereç ve Yöntem: Yirmi paraplejik hasta ve onbeş sağlıklı kontrol çalışmaya dahil edildi. Amerikan Spinal Yaralanma Birliği sınıflamasına göre ondört hasta komplet ve altı hasta inkompletti. Hastaların ortalama yaşı 31,31±8,17 yıl idi. Ortalama hastalık süresi 3,81±5,08 aydı. Bireylerin tümü ya sedanter ya da minimal aktif ve vücut üst bölümü aerobik olarak eğitilmemiş olarak düşünüldü. İstirahat durumundaki akciğer fonksiyonları spirometrik olarak değerlendirildi. Egzersize kardiyopulmoner ve metabolik cevaplar elektronik frenli bir kol ergometresi ile araştırıldı.
Bulgular: Paraplejik hastalarda anlamlı bir respiratuar fonksiyon bozukluğu mevcuttu. Ortalama pik oksijen tüketimi, hasta ve kontrol grubunda sırasıyla 9,86±4,21 ml/kg/dak ve 14,27±1,59 idi. Ayrıca, paraplejik hastalarda, pik kalp hızı, pik dakika ventilasyon, solunum değişim oranı, pik egzersiz gücü değerleri daha düşüktü. Hasta grubuyla karşılaştırıldığında beklendiği gibi, sağlıklı bireyler pik egzersizde anlamlı olarak daha yüksek değerlere ulaştılar (p aralığı, <0,05 ile 0,001).
Sonuç: Bu çalışmada, spinal kord yaralanmalı hastalarda belirgin olarak respiratuar fonksiyon bozukluğu tesbit ettik (hastaların %60'ına karşılık sağlıklı kontrollerin %1,3'ü, p<0,001). Ayrıca, sağlıklı bireylerle bu hastalar karşılaştırıldığında maksimum egzersize azalmış kardiyopulmoner ve metabolik cevaplar ve egzersiz toleransına sahiptiler. *Türk Fiz Tıp Rehab Derg 2006;52(1):1-5*
Anahtar Kelimeler: Egzersiz toleransı, spinal kord yaralanması, pik oksijen tüketimi

Introduction

In recent years, life expectancy for individuals after spinal cord injury (SCI) has increased, but is presently still lower than that in the able-bodied population (1). Furthermore, cardiovascular morbidity and mortality are thought to be high in individuals with SCI because of their sedentary lifestyle, lack of aerobic fitness, and higher prevalence of other cardiovascular risk factors, including hypertension, hyperlipidemia, obesity, and diabetes (2).

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Several studies emphasize low exercise capacity as a strong independent predictor of cardiovascular and all cause mortality (3,4). The value of cardiopulmonary exercise for prevention of cardiovascular disease is well documented (5). Therefore, measuring and assessing the cardiopulmonary functions of patients with SCI is important in evaluating their potential in daily life.

The aim of this the study was to compare cardiopulmonary and metabolic functions and exercise tolerance in patients with SCI and able-bodied subjects.

Materials and Methods

Subjects

Twenty patients with SCI (12 men, 8 women) and fifteen able-bodied controls (9 men, 6 women) participated in the study. All subjects were drawn from SCI patients who attended Ankara Physical Medicine and Rehabilitation Education and Research Hospital inpatient rehabilitation department. The exclusion criteria included chronic pulmonary and/or cardiac disease or clinical evidence of cardiac and/or respiratory disease. The criteria for recruitment of subjects for the study were: 1) sufficient upper torso and extremity nerve function and strength to accomplish arm crank exercise (ACE), 2) no previous history of cardiovascular or respiratory problems, and, 3) no medication that would influence metabolic or cardio-respiratory responses to exercise. Fourteen patients were complete and six were incomplete according to the classification of American Spinal Injury Association (ASIA). All of them had thoracic lesions (T6-T12). The mean time since injury was 3.81±5.08 months. Mean age was 31.31±8.17 years. All subjects were considered as minimally active and their upper bodies were not aerobically trained. Their full history was taken and a full examination was performed.

Radiological examination, resting electrocardiography (ECG), and routine laboratory measurements were performed in all patients and controls. All of the clinical and laboratory findings were assessed in the departments of internal medicine and physical medicine and rehabilitation before entry to the study.

Testing Procedure

Resting pulmonary function parameters including forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory flow rate 25-75% (FEF 25-75%), peak expiratory flow rate (PEF), vital capacity (VC), the ratio of FEV1 to FVC (FEV1/ FVC), maximum voluntary ventilation (MVV) were spirometrically assessed.

The patients were positioned during the arm crank ergometry test with crank axis located at the shoulder level at a distance that allowed for a slight bend in the elbow when the arm was extended. Cardiopulmonary exercise testing (CPET) was performed on an electronically braked arm crank ergometry (Sensormedics, Ergoline, YorbaLinda, CA, USA). A computerized gas analysis system collected and analyzed expired gases during exercise. The system consists of a mask, two-way breathing valve, a rolling seal spirometer, an oxygen analyzer, and a carbondioxide analyzer (Sensormedics, Vmax29, YorbaLinda, CA, USA). It was calibrated with known gas concentrations and volumes prior to each test. Heart rate (HR) and ECG were displayed throughout the cardiopulmonary exercise test. Capillary oxygen tension was measured by an oxygen photometer attached to the ear. Subjects were instructed to refrain from eating for at least 2h and from drinking for 1h to testing. All subjects were given instructions on how to signal the investigators when they reached fatigue. Incremental exercise test was used to determine maximum aerobic capacity. After stabilization and 3 minute warm-up period at 25 W, the load was increased at every 3 minutes until exhaustion.

Oxygen consumption (VO_2), carbondioxide exhaled (VCO_2), oxygen pulse (O_2 pulse), HR, minute ventilation (VE), respiratory rate (RR), respiratory exchange ratio (RER= VCO_2/VO_2), oxygen saturation (SaO_2) and power output (PO) level were recorded every 20 seconds during ACE test.

This protocol was approved by the ethical committee of the Ankara Physical Medicine and Rehabilitation Education and Research Hospital. Each patient gave an informed consent to participate in the study.

Statistical analyses

Data were analyzed using the Statistical Package for Social Sciences (SPSS) (SPSS, Chicago, Illinois, USA.) Descriptive statistics were performed for all variables measured. Demographic and clinical data were compared between the groups with the use of non-parametric Mann-Whitney U test for continuous variables. The Chi square test was used to analyze differences between the groups for categorical variables. The level of statistical significance was set at $p<0.05$ for all tests.

Results

Table 1 shows subject characteristics for patients with SCI. No significant ST change for a positive test was observed in the maximum cardiopulmonary exercise test.

Table 1: Characteristics of the study subjects

Characteristics	Patients	Controls	p values
Number of subjects	20	15	
Age (years) (mean±SD)	31.31±8.17	30.73±7.86	p>0.05
Sex (Male/Female)	12/8	9/6	P>0.05
BMI (kg/m^2) (mean±SD)	24.44±3.96	24.77±2.31	p>0.05
Lesion level	T6-T12	NA	
Time since injury (months) (mean±SD)	3.81±5.08	NA	
ASIA (complete/incomplete)	14/6	NA	
FIM score (mean±SD)	96.05±4.03	NA	

(ASIA: The American Spinal Injury Association, FIM: Functional Independence Measure, BMI: Body Mass Index, NA: Not applicable)

There were no differences between the groups with regard to age, sex, and body mass index. The mean resting spirometric values in paraplegic and healthy subjects are shown in Table 2.

Spirometric restrictive ventilatory defect (VC less than 80% and FEV1/FVC higher than 80) was observed in five patients and generalized airway obstruction (FEV1/ FVC less than 70%, PEF and FEF 25-75% less than 75%) was present in four patients. Mixt respiratory dysfunction was present in three patients. Statistically significant differences were determined between the groups in FVC, FEV1, FEF 25-75%, PEF, MVV and VC values. When compared with the controls, all these values were decreased in the patient group.

Cardiopulmonary and metabolic values obtained at maximum exercise are provided in Table 3. The peak values of VO_2, O_2 pulse, HR, VE, RR , RER, SaO_2, PO, exercise time, systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined to be lower in the SCI patients than those in the healthy subjects.

Discussion

Individuals with SCI are at increased risk of chronic respiratory symptoms and added disability. Respiratory muscle paralysis not only restricts maximum inflation of the lungs but it also impairs the ability to cough. Obstructive pulmonary dysfunction is also of concern, not only because airways may collapse or be clogged by mucus, but also because they may be especially susceptible to constriction (6).

Our results generally corroborate the findings of previous studies recorded in the literature (6-9). Most of our patients had significant restrictive, obstructive or mixed respiratory dysfunctions. Our paraplegic subjects averaged only a slight percent below the predicted values for FVC and FEV1 and essentially most of them fell within the normal range for the reference population. However, their mean PEF was significantly below 100% predicted, supporting the presence of ineffective cough.

Table 2: The mean±standard deviation resting spirometric values in paraplegic and healthy individuals

	Patient group	Control group	P values
FVC (L)	3.51±0.71	4.10±0.83	p<0.05
FEV1 (L)	2.70±0.66	3.43±0.58	p<0.05
VC (L)	3.46±0.76	4.10±0.86	p<0.001
FEF 25-75% (L/sec)	2.83±1.14	3.95±0.88	p<0.05
PEF (L/sec)	4.6±1.29	6.98±1.55	p<0.001
MVV (L/min)	104.8±24.94	126.8±14.6	p<0.001
FEV1/FVC (%)	78.6±13.51	83.8±5.87	p>0.05

(FVC: forced vital capacity, FEV1: forced expiratory volume in one second, VC: vital capacity, FEF25-75%: forced expiratory flow rate 25-75%, PEF: peak expiratory flow rate, MVV: maximum voluntary ventilation)

Table 3: The mean±standard deviation cardiopulmonary and metabolic values obtained at peak exercise in paraplegic and healthy subjects

	Patient group	Control group	P values
VO_2 peak (ml/kg/min)	9.86±4.21	14.27±1.59	p<0.001
VO_2 peak (L/min)	0.638±0.261	1.068±0.67	p<0.001
O_2 pulse (ml/beat)	10.09±4.46	15.10±5.70	p<0.05
HR peak (bpm)	149.47±9.59	170.46±8.27	p<0.001
HRR (bpm)	38.10±10.67	18.80±5.42	p<0.001
VE peak (L/min)	43.72±19.33	50.87±13.02	p>0.05
RR (bpm)	35.26±8.94	40.66±6.94	p<0.05
BR (%)	42.79±17.82	40.28±10.10	p>0.05
VD/VT Rest	0.54±0.07	0.35±0.04	p<0.001
VD/VT Peak	0.36±0.08	0.18±0.04	p<0.001
RER	1.07±0.13	1.18±0.53	p<0.05
SaO_2 (%)	87.42±3.90	92.6±2.09	p<0.001
PO (Watt)	31.21±12.83	60.80±12.40	p<0.001
Exercise time (min)	15.76±7.64	34.13±8.72	p<0.001
SBP (mm Hg)	138.42±12.47	162.67±7.03	p<0.001
DBP (mm Hg)	83.16±7.67	91.67±8.38	P<0.05

(VO_2max: maximum oxygen consumption, O_2 pulse: oxygen pulse, HR: heart rate, HRR: heart rate reserve, RR: respiratory rate, BR: breathing reserve, VE: minute ventilation, VD/VT: The ratio of physiologic space to tidal volume, RER: respiratory exchange ratio, SaO_2: oxygen saturation, PO: power output, SBP: systolict blood pressure, DBP: diastolic blood pressure)

Peak oxygen consumption has been traditionally identified as the major indicator of aerobic capacity and fitness. Peak external power output is a second important indicator of performance. The peak VO2 and PO values have been reported to be lower in paraplegic subjects than those in healthy controls due to reduced active muscle mass and increased adipose tissue in paraplegia (8-12). Moreover, Zoeller et al. (13) reported that in this population, greater muscular strength is associated with greater aerobic power and endurance.

It has been reported that there was a reduced cardiac output, lower stroke volume and mean exercise systolic and diastolic blood pressure in paraplegic subjects. These lower physiologic responses were explained by the loss of central sympathetic vasomotor outflow and the loss of a muscle pump below the level of injury, inducing a venous pooling of the blood (8,11,12,14-16).

The VE at peak exercise has also been reported to be lower in paraplegic subjects than that in healthy controls by many authors, and is thought to be related to an impaired innervations of some of the respiratory muscles (8,12,18).

The RER value is an important respiratory variable as it provides information regarding the proportion of energy derived from various food stuff at rest and submaximal exercise. RER values that are less than 1.0 at peak exercise generally signify inadequate effort or poor motivation on the part of patient. An RER value of 1.15 to 1.20 during exercise has been suggested a subsidiary evidence that a true VO2 max has been attained (19).

It has been determined that the RER values obtained from paraplegic patients were lower than the value of 1.20 at the maximum exercise (12,20,21).

In the present study, VO2 peak, HR peak, VE peak, RER, PO peak values were lower in paraplegic subjects. As expected, healthy subjects reached significant higher values at maximum exercise compared to the patient group.

It has been reported that an elevated VD/VT response to exercise may be the only gas exchange abnormality. An increase in VD/VT reflects increased inefficiency of ventilation and is often referred to as wasted or dead space ventilation (22). The VD/VT values recorded in this study were increased in most of the patients. These findings suggest that there may be a gas exchange abnormality in paraplegic patients.

It has been shown that training of the arms in healthy subjects increases VO2 max and decrease ventilatory requirement at identical work rates (23). Many authors observed significant improvements in specific upper extremity performance tests after upper extremity training in comparison to a control group (24,25).

It has been determined that upper extremity exercise training program provides cardiorespiratory and strength benefits in persons with paraplegia. The increased peak oxygen consumption, exercise time, and peak power output during arm testing had been found after the training program (26,27).

Conclusions

In the present study, we determined that there was a significant respiratory dysfunction in paraplegic patients. Also, they had a decreased exercise tolerance and cardiopulmonary and metabolic responses to maximum exercise when compared to the healthy subjects.

These findings suggest that ventilatory and upper extremity training program should be considered early after the injury to avoid cardiopulmonary problems and deconditioning in patients with SCI.

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