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Huvudämnet klinisk medicinsk vetenskap
Examensarbete, 15 högskolepoäng
Vårterminen 2013

Energy consumption after spinal cord injury

Energiförbrukning efter ryggmärgsskada

Arbetsexemplar

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Sammanfattning/abstract

Syfte: Studier visar att personer med ryggmärgsskada (RMS) har en högre risk för hjärt-kärlsjukdom (CVD), däremot är rekommendationerna för icke-funktionshindrade personer är inte justerade för RMS -populationen. Syftet med studien var; att analysera energiförbrukningen i vila genom att mäta basalmetabolism (BMR) samt att analysera den metabola energiomsättningen i vanligt förekommande och standardiserade aktiviteter i Metabolic Equivalent of Task (MET).
Material-metod: Femton deltagare, tio män och fem kvinnor, med SCI Th7-12, AIS nivå A-B rekryterades. Vid mätning av BMR användes Jaeger Oxycon Pro och vid mätning av aktiviteterna användes Jaeger Oxycon mobile.
Resultat: Den genomsnittliga BMR för män var 1400 kcal/dygn och för kvinnor 1012 (kcal) / 24 h. Energiförbrukningen vid olika aktiviteter kan delas in i låg mellan och hög energiförbrukning. Låg energiförbrukning börjar vid 1,4 MET (titta på TV). Mellan-energiförbrukning vid 3,4 MET (handcykel långsam) och slutligen hög energiförbrukning 4,7 MET (armergometercykel 36W) till 6,2 MET (rulla utomhus träningstempo).
Slutsats: Denna sub -population av RMS har en genomsnittlig energiförbrukning som är 24% lägre än icke-funktionshindrade personer. Dessa resultat betonar vikten av en fysiskt aktiv vardag för att öka energiförbrukningen.

Objective: Studies have shown that the spinal cord injured (SCI) population has a higher risk of cardiovascular disease (CVD), although recommendations for able-bodied persons are not adjusted for the SCI population. The objectives of this study were; to assess the resting energy expenditure (REE) or basal metabolic rate (BMR) and the energy consumption in common standardized activities measured in Metabolic Equivalent of Task (MET).
Materials-Methods: Fifteen participants, ten men and five women, with SCI Th7-12, AIS level A-B were recruited. For measuring purposes the Jaeger Oxycon Pro was used to determine the BMR and the Jaeger Oxycon mobile for the activity testing.
Results: The mean BMR for men was 1400 kcal/ 24 h and for women 1012 (kcal)/24 h. The range of MET values for activities differed with the low energy expenditure starting at 1,4 MET (watch TV), for the middle energy expenditure at 3,4 MET (hand bike slow), and lastly for the high energy expenditure ranging between 4,7 MET (arm cranking 36W) to 6,2 MET (propelling outside exercise).
Conclusion: This SCI sub-population has a mean energy consumption that is lower than able-bodied persons. These results emphasize the importance of a physically active daily lifestyle to increase the energy expenditure.

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Introduction

I work as a physical therapist at Spinaliskliniken (Spinalis) in the spinal cord injury (SCI) unit at Rehab Station Stockholm. My working experience in this area includes ten years of hands-on management of persons with SCI. I have also been part of the Swedish task team that was involved in the planning, development and implementation of the first government rehabilitation unit for persons with SCI in Botswana. Whilst being abroad, in Botswana, I was made aware of the cultural differences, especially the lifestyle. We are all in agreement that physical activity and diet are main determinants of health and wellness, even more so for persons with SCI. Based on the lack of knowledge in this area, for persons with SCI, my study focuses on the energy expenditure in persons with SCI during rest and standardized activities. Some of the staff at Spinalis is specialized in therapeutic lifestyle prevention such as dietary, physical activity and psychological issues of motivation. The aforementioned target areas are of importance for the wellbeing of persons with SCI, however we have identified a lack of knowledge concerning evidence based clinical guidelines for physical activity and energy consumption.

Background

Historically, our knowledge of SCI is very ancient. Our first encounter with SCI tracks back almost 2500 years when "Edwin Smith papyrus" from Egypt described 48 cases of traumatic lesion to the spinal cord that probably occurred during the construction of the pyramids. There are also stories about spinal cord injured persons from various parts of the world and it is thought to be connected to times of war; from the Trojan war to second world war (Sonnetag VKH, 1996). Locally, approximately 120 persons sustain a traumatic SCI in Sweden each year and about 5000 people lived with SCI 2006 (Holtz A, 2006). The latest incidence is 19,4/million and the mean age for injuries in Sweden is 47 years and the male:female ratio is 3:1 and the most common cause of injury is fall (Divanoglou & Levi, 2009). Rates of SCI in Sweden are modest compared to other countries in Europe and the rest of the world (Hagen, Rekand, Gilhus, & Gronning, 2012).

Spinal cord injury and classification

A SCI is a condition that involves several major life changes. A SCI appears when there is trauma to the vertebral column that lead to soft tissue, bone and ligament damage, or due to systemic impairment. A SCI could be explained as an impairment of the pathways between the brain and the spinal cord, which could affect the segments below the level of injury. The motor and sensory impairment could either be complete or incomplete. The complete or incomplete paralysis is assessed by a standardized classification system called AIS (American spinal cord injury association Impairment Scale) that is based on clinical examinations of motor and sensory functions. An SCI is classified depending on the level of the spinal cord that is injured, which is examined by sensory testing per dermatome (pin prick and light touch) and muscle strength in key muscle groups. In cases where the injury is located to the cervical spine, it is often referred to as tetraplegia, compared to injury occurring to the thoracic, lumbar or sacral spine, which is called paraplegia. The latest AIS classification enables us to categorize the completeness of a SCI into 5 broad categories. This classification system allows us to standardize our reporting of clinical characteristics of persons with SCI. Terminology from American Spinal Cord Injury Association (ASIA) (Ditunno JF Jr; Marino, E., Haak, Hudson, & Priebe, 2003). Below is a brief description of the major definitions concerning the level and the completeness of injury to the spinal cord:

Tetraplegia:	Loss of motor control and/or loss of sensation due to an injury to the cervical spine, with a result of impairment in arms, trunk, pelvic organs and legs.
Paraplegia:	Loss of motor control and/or loss of sensation due to injury to thoracic, lumbar or sacral spine, with a result of impairment depending on level in trunk, pelvic organs, and legs.
Neurological level:	The most caudal segment of the spinal cord with both normal sensory and motor function bilaterally
Sensory level:	The most caudal level of the spinal cord with normal sensory function bilaterally.
Motor level:	The most caudal level of the spinal cord with normal motor function bilaterally.
Incomplete injury:	Lesion with partial preservation of sensory and/or motor function existing below the neurological level along with the sacral levels 4-5. Incomplete injury is called AIS B-D depending on the number of key muscles affected and their respective strength, and the preservations or impairment of the sensory level.
Complete injury:	lack of sensory and motor function in the lowest sacral segments. Complete injury is called AIS A in the neurological classification.

(DeVivo M. J, Black K. J, & L., 1993; Marino et al., 2003), (DeVivo M. J, Kartus P. L, Stover S. L, Rutt R. D, & R, 1989).

Associated conditions

The associated conditions are complications that are related to the level and type of lesion. It is often called secondary complications, and may include immobilization, pressure ulcers, urinary tract infections (UTIs), deep vein thrombosis (DVT) and respiratory disorders. Historically, the most common cause of death occurs from septicemia pneumonia and pulmonary emboli (DeVivo M. J et al., 1993), (DeVivo M. J et al., 1989).

Another associated condition is spasticity. Spasticity is not homogenous among persons SCI, however, very little is known about who develops it and when it develops. In broad terms, spasticity is defined as an increased muscle tonus in both active and passive movements below the level of injury. Furthermore, it may be triggered spontaneously or by stimuli. It can also be triggered or increased from stimuli, which are due to pain below the level of injury. Apart from the negative consequences of spasticity, it could also be positive within the rehabilitation phased. Spasticity can be of assistance or help during transfers from wheelchair, dressing and standing/walking. The increased tonus can also have the opposite effect in transfers from wheelchair, dressing and standing/walking. Increased spasticity can also be warning sign from the body below the level of injury, indicating UTI, fracture or pressure soars (C. Skold, 1999). Studies have also shown that Botulinum toxin that reduces the spasticity on children with cerebral pareses lowers the level of energy consumption. On the other hand there is no such studies don in the SCI -population. So we can only assume that spasticity is closely related to energy consumption in the SCI – population. On a personal level, it is important to educate persons with SCI about spasticity and how it could assist them to identify the cause of problems that is responsible for their changing health status. For example, periods of increased spasticity could be indicative of ingrowing toenails or sunburn. There are different ways of assessing spasticity but the most common in rehabilitation of SCI is modified Aschworth scale, EMG and Penn.

Rehabilitation

The modern form of rehabilitation started 1944 at Stoke- Manderville National Spinal Center in England by the neurosurgeon Sir Ludwig Guttmann. He proposed a structured approach to the management of persons with SCI, with the main interventions of surgical management, antibiotics and intermittent catheterization during the acute phase (Guttman, 1976). He also introduced a systematic approach to the management of individuals with SCI, which is now recognized as the start of the development of modern evidence- based medicine and rehabilitation. Modern care of SCI demands a wide range of knowledge among different specialties such as rehabilitation medicine, urology, intensive care, orthopedics, neurosurgery, fertility and pharmacology (Goodman, 1994). The improvement of rehabilitation and medical care has affected the long time survival and has led to the development of age related health problems among the SCI population (Myers, 2007). To prevent health related problems one focus area in rehabilitation is exercise. Different forms of exercise are used such as weight training in gym, hand bike, circuit resistant training and propelling wheelchair indoors and outdoors.

CVD in the abled bodied population.

In Sweden, 38 % of all deaths are caused by CVD and it is further considered the leading cause of death, according to The Swedish National Board of Health and welfare, during 2011 (socialstyrelsen, 2013). CVD is the collective term for diseases affecting the circulatory system heart and/or blood vessels, arteries, capillaries and veins (Maton et al., 1993). Examples of diseases resulting from CVD include stroke, atherosclerosis, cardiomyopathy, coronary heart disease and myocardial infarction. Risk factors are divided into two categories, either non-modifiable or modifiable. Non-modifiable risk factors include, but are not limited to, age, gender and genetic factors. Modifiable risk factors may include tobacco/smoking, diabetes, hypercholesterolemia, obesity, hypertension, physical inactivity, sedentary lifestyle, stress and poor diet (Kelly, 2010). Atherosclerosis is the dominating cause of ischemic CVD. Since the devastating consequences of CVD have been determined, a standardised program is used to detect CVD risk factors. Below is a brief description of the screening program Metabolic Syndrome Definition by The US National Chelstorol education Program (NCEP) 2001 (Expert Panel On Detection, 2001).

On an individual level, if any three of the following factors exceed the normal recommended range, an individual is at risk of CVD. The factors include;
Central obesity: waist circumference ≥ 1,02 m (male), ≥ 0,88 m (female)
Dyslipidemia: Triglycerides (TG) ≥ 1.7 mmol/L
Dyslipidemia: High Density Lipoproteins -Cholesterol (HDL-C) < 0.456 mmol/L (male), < 0.57 mmol/L (female)
Blood pressure ≥ 130/85 mmHg
Fasting plasma glucose ≥ 6.1 mmol/L

Based on the risk factor equation, using the abovementioned factors, recommendations for CVD prevention has been made. The categories include;

A. -Physical activity, encourage individuals to take at least 30 minutes of moderate -physical activity/day.
B. -Diet, Reduce total fat and saturated fat intake
C. -Smoking cessation, everyone that smokes should be strongly adviced to quit smoking.
D. Weight control, persons that is over weigt or obese should be advised to lose weight by combination of fat reduction/energy diet and increase physical activity.

CVD risk factors in SCI –population.

Recent studies aiming to explore the need of cardiovascular disease prevention at Rehab Station Stockholm SCI unit, has shown that the SCI population is at higher risk of myocardial infarction, more than eight times higher in prevalence as compared to the general population. The studies also showed higher prevalence of risk factors of CVD, further the prevalence for each risk factor were: dyslipidaemia (83%), overweight (70%), hypertension (39%) and diabetes (10%) in the SCI population (Wahman K, 2011.). Research has also shown that a sedentary lifestyle is an essential risk indicator for cardiovascular health in the general population (Expert Panel On Detection, 2001).

Persons with complete SCI lose the ability to voluntary control the muscles in the lower extremity, which predisposes them to a sedentary lifestyle. In an evidence based review article from 2012 the authors described the available evidence for: Dyslipidaemia, chronic inflammation, glycaemic control and blood pressure irregularities in the SCI population (Cragg, Stone, & Krassioukov, 2012).

Dyslipidaemia: after a SCI there is evidence that the levels of Low Density Lipoprotein (LDL) is increased and that High Density Lipoprotein (HDL) levels are reduced compared to the abled- bodied population (D'Agostino et al., 2008).

In the abled-bodied population increases in LDL and decreases in HDL is a risk factor for CVD events and many of these individuals need pharmacological interventions to reduce their CVD risk (Stone, 2011).
Chronic inflammation: Atherosclerosis is believed to be an inflammatory process that is linked to CVD in the abled-bodied population (Ross, 1999). In the SCI population chronic inflammation can also be linked to urinary tract infections and therefore obstructs the process of identifying episodes of chronic inflammatory (Frost, Roach, Kushner, & Schreiber, 2005; Wang et al., 2007).
Glycaemic control: Hyperglycaemia often leads to diabetes and/or metabolic syndrome and is documented to be associated with CVD (D'Agostino et al., 2008). After an SCI there is a higher prevalence of abnormal glycaemic control or impaired glucose control relative to the abled-bodied population (Bauman W.A, 1994).
Blood pressure irragularities, orthostatic hypertension (OH): As described earlier in the background, OH is defined as a drop in systolic blood pressure of 20 mm Hg or more, or in diastolic blood pressure of 10 mm Hg or more. In the abled-bodied population the link between OH and an icreased risk for CVD is documented in a cohort study in elderly (Verwoert et al., 2008). In a study among SCI individuals the experience of OH was estimated to 57% of the cohort (Cariga, Ahmed, Mathias, & Gardner, 2002).

The role of physical activity in preventing CVD

Apart from the use of pharmacological agents, evidence suggests that physical activity counteracts or delays the cause of the common CVD risk factors. Which the National Board of Health and Welfare recommends, they advice at least 30 min of moderate physical activity per day (Socialstyrelsen, 2008).

So far, the use of a sedentary lifestyle has been a synonym for physical inactivity, meaning that persons failed to achieve the recommendations for physical activity instead of using of a sedentary lifestyle as a synonym for muscular inactivity. Research has shown that a sedentary lifestyle or muscular inactivity, independent of other physical activity, increases the risk for CVD and premature mortality in the general population (D. W. Dunstan, Thorp, & Healy, 2011; Hu et al., 2001; Jakes et al., 2003). The causality is independent of BMI. A recent study from Australia showed that for every additional hour of muscular inactivity increased the risk of CVD with 26 % in women, independent of other moderate to high intense exercise. On the contrary, 30 min of physical activity could decrease the risk of CVD with 28% (D. W. S. Dunstan, J. Owen, N. Armstrong, T. Zimmet, P. Z. Welborn, T. A. Cameron, A. J. , Dwyer, Jolley, & Shaw, 2005). One study have shown that an obese person could increase the energy expenditure by 350 kcal just by standing for two hours instead of sedentary, compared to a person in with a BMI in the normal range (Levine, 2005). There is no current research that proves underlying physical and molecular effects of a sedentary lifestyle. (D. W. S. Dunstan, J. Owen, N. Armstrong, T. Zimmet, P. Z. Welborn, T. A. Cameron, A. J. et al., 2005). Studies on rats observed that those who were limited to muscular immobility had a lower lipoproteinlipas (LPL) level than the rats in the control, which were able to stand and walk (Hamilton, Etienne, McClure, Pavey, & Holloway, 1998; Hu et al., 2001). The studies also showed that immobilized rats had a lower concentration of HDL high-density lipoproteins and a lower uptake of triglycerides in skeletal muscles. Furthermore, results from the study showed that rats that were standing compared to rats that did more intense physical activity did not have significantly lower levels of LPL. This indicates that the contraction from the muscle might be equally important as the intensity of the physical activity.

Treatment and prevention of CVD in SCI.

Recent research studies describe pharmacotherapy to improve the fasting dyslipidaemia, post-prandial lipaemia and vascular inflammation (Cowan & Nash, 2010). However, pharmacotherapy is not the only available treatment for persons with SCI. Persons with SCI may already be pharmacologically managed; for example spasticity, pain and urinary tract infections(Cowan & Nash, 2010). Therefore, alternative treatment for this group should be non-pharmacological, where exercise is the first alternative. Other important treatments that need to be addressed are directed towards lifestyle interventions such as smoking cessation and dietary modifications.

The SCI population generally has a low physical activity level and a higher incidence for overweight (Noreau, Shephard, Simard, Pare, & Pomerleau, 1993). To achieve weight loss for an abled-bodied individual, it requires an energy expenditure of over 2000 Kcal extra per week. This is around 250-300 Kcal extra during a day and equal to 20-30 min of running (Donnelly et al., 2009). As a health promotion campaign the Swedish general public health recommended physical activity for cardiovascular care (Socialstyrelsen, 2008). Even though an individual do not lose 200-300 Kcal extra every day, exercise has proven to have additional positive health effects other than losing weight, especially on vascular inflammatory processes (Selvin & Erlinger, 2007). We can assume that persons with SCI have a lower Basal Metabolic Rate (BMR) because of the loss of muscle mass due to paralysis. For that reason we assume that it is harder to accomplish 200-300 Kcal extra per day in the same amount of time. Also it is difficult for clinicians to give well-informed recommendations on physical activity due to a lack of knowledge in the field of physical activities and in SCI unique metabolic equivalent of task (MET). The MET value is expressed as the energy cost of physical activities and 1 MET to be considered equivalent to resting metabolic rate (RER) or basal metabolic rate (BMR).

Thus, recommendations for physical activity used in the general population are not fully applicable for this group. There is one systematic review aimed at providing evidence based physical activity guidelines (Ginis & Hayes, 2011; Hicks et al., 2011). The result from the study suggest that persons with SCI should engage in at least 20 min of moderate to vigorous aerobic activity and strength training exercises consisting of three sets of at least 8-10 repetitions, twice a week. Their conclusion was that recommendations are not related to reducing risk for CVD, but the program could help improving muscular strength and cardiovascular endurance. There is only one study done that tries to measure the MET values during activities for persons with SCI (Collins et al., 2010). The limitations in Collins study were that they had almost all SCI levels and AIS. This resulted in few participants on each level of injury and some levels of injury only consisted of men. Further studies are needed to measure the resting energy expenditure and common activities to contribute to a better understanding on how to create evidence based clinical guidelines for physical activity after SCI.

Aim

The overall aim of this study was to map the energy consumption in persons with SCI, paraplegia .
More specifically, the objective of the study were to assess the;

1. The basal metabolic rate (BMR)
2. The energy consumption in common standardized activities.

Method

Study design

The design of the study is two folded; firstly, the basal metabolic rate is descriptive and cross-sectional, with the purpose to document the nature through systematic collection of data at one point in time, and to give a close to reality description of the BMR. Secondly, the objective addressing the energy consumption during the activities was explorative in nature. In general, explorative studies allow researchers to gain multiple perspectives on outcomes that are both well contextualized or that emerge as a result of unexplained phenomena. So that the researcher could get a deeper understanding and a base for hypothesis generating for further studies (D. Polit, 1996).

Participants and sample size

The inclusion criteria was set as follow: persons with motor complete SCI AIS A-B level Th7-Th12, with absent or minimal spasticity, as measured with Penn; participants living with the injury for at least five years or more; those residing in Stockholm area and those recruited from Spinalis SCI unit at Rehab Station Stockholm. We decided to set the inclusion criteria for spasticity to minimal or absent so that we could preclude higher energy consumption because of heavy spasticity. Spasticity was assessed with Penn, which is a self reported muscle spasm frequency scale that clinically measures spasticity (Penn, 1988). In the described subpopulation approximately 40 persons match the inclusion criteria, of which 40 % presents the sample size for this study (Th7-Th12 AIS A-B). The selection process was carried out through a list of persons in this sub-population that was contacted via a phone call. When the researcher had five women and 10 men that matched the inclusion criteria and reflect the incidence for mean age and male:female ratio. The selection process ended and all participants got an information letter and a letter of consent (supplement 1) Eligible participants were contacted between February to May and August to September 2012 to participate in the study. Due to the exploratory nature of the study, 15 participants deemed sufficient to control for main characteristics such as age, gender, and neurological level.

Table 1. Main characteristics of participants as Range, mean and ± SD.

	Women	**Men**
Sample size	5 (15)	10 (15)
Age (years)	45,2 (23-68)	42,7 (32-59)
Height (cm)	165,4 ± 4,7	180 ± 9,3
Weight (kg)	55,9 ± 8,5	76,1 ± 9,6
Level of injury		
Th7	2	0
Th9	0	3
Th10	0	2
Th11	1	2
Th12	2	3

Data collection

The data were collected at two different institutions. The BMR data were collected at Åstrandslaboratoriet, Idrottshögskolan Stockholm and the activity data at Rehab Station Stockholm. All data were collected between May and September 2012. In clinical settings the most suitable approach to measure energy expenditure is open circuit indirect calorimetry (Haugen, Chan, & Li, 2007). Two systems were used: the Jaeger Oxycon Pro for BMR and the Jaeger Oxycon Mobile for measuring the standardized activities. Both systems are open –circuit indirect calorimetry where the participant breathes in a ventilated hood or mask system. During the aforementioned procedure the respiratory gases are measured. Differences in Oxygen (O_2) consumption and carbon dioxide (CO_2) release levels are measured from inspired and expired air during rest and steady state exercise.

Equipment

For BMR, as measures by Jaeger Oxycon Pro, a gas volume sensor and a Nafion sampling tube for exhaled air was connected to the hood. The sensor is connected to the calibration receiver and a personal computer. Data were processed with the PC-software (JLAB,Carefusion Germany 234 GmbH, Hoechberg, Germany) for display and evaluation. The same measurement procedure was followed for Jaeger Oxycon Mobile, except the gas volume sensor and Nafion sampling tube is connected to the face mask, with the transceiver equipment carried on the back of the participant (weight 950g). The data from the participant were sent telemetrically to the receiver, which was connected to the personal computer. Both systems was switched on 30 min prior to data collection and calibrated with high-precision gas from a tank. Calibration was performed immediately before each testing using built-in automated procedures.

For weight measures a scale were used and heart rate monitor for measuring the heart rate.

Assessment procedure

Basal metabolic rate -assessment

Before BMR testing, all subjects were fasting (8h) overnight and the testing was scheduled between 07:30 and 09:00 a.m. The expired gases were measured using a ventilated hood for 30 minutes with the person lying down in supine. The first 20 min of assessment procedure was to receive steady state BMR, whereas the last 10 min was used to measure the lowest steady Vo2 recorded and used as the BMR. Latter the mean oxygen uptake ($mL \cdot kg^{-1} \cdot min^{-1}$) and the BMR in ($Kcal \cdot min^{-1}$) were calculated from the Vo2 value.

Standard physical activities -assessment

The standardized physical activities were sitting and watching television, sitting by a desk and work with computer, carry out housework (setting table, standardized track), propelling a manual wheelchair indoors in self-imposed slow pace, biking hand bike slowly and exercise pace indoors on a stationary bike, propelling a manual wheelchair outside on asphalt in slow and exercise pace, double poling ergometer exercise pace, arm ergometer 18 Watt 36 Watt, gym/strength exercise, and circuit resistance training. For the standard physical activities, the participants performed standardized work for 5-7 min. The systems were calibrated and verified with reference gases and room air before the start of each test. The procedure prior to the testing included the familiarisation of standardized information for each participant regarding the activity. Secondly, the fitting and acclimatization of the gear was allowed. Tire pressure was also check before the activities. After the equipment was fitted for each participant, the investigator gave the standardized verbal information again and a demonstration of how the activity should be performed. For the activities that had an instruction about pace, the investigator used the standardized instruction and Borg RPE scale (supplement 2) (B. G. Borg, 1994; G. A. Borg, 1982), walking pace Borg 10-11 fairly light/light and exercise pace Borg RPE 13-14 somewhat hard. For gym activities, the instruction was to select a weight that the participant was able to perform at least 10 repetitions for a specific movement. The participants were also given the instruction to perform the gym exercises at a controlled pace. All the activities were assessed until each participant reached a steady state. This state varies among the participants, but all activities were performed for at least 5 min. After each exercise the participants were instructed to rest quietly for at least 5 min. To visualize the MET values in this study our values will be compares the data to the abled –bodied population as described by the energy expenditure compendium by (Ainsworth, Haskell, & Bassett, 2000)

Data collection was carried out under clinical and laboratory conditions. Under each activity the following data were collected; heart rate (via heart rate monitor beats / min), oxygen uptake by Jaeger Oxycon Mobile 2, VO_2 ($ml \cdot min^{-1}$), $mL \cdot kg^{-1} \cdot min^{-1}$ and energy expenditure in calories per kilo, $Kcal \cdot min^{-1}$, measured weight self reported body height. Energy consumption was calculated in MET values from the VO_2 (ml · min^{-1}) from each participant then calculated as a mean value that represents the SCI MET.

Data Analysis

All data were analysed with SPSS version 21 and Excel spread sheet (Microsoft Excel, Microsoft Corp., Seattle.) BMR data were analyzed with JLAB, Carefusion (Germany 234 GmbH, Hoechberg, Germany) used as the BMR. The average of the steady state measures <3% in variation was accepted for each participant. All data were transferred into SPSS for initial analysis, thereafter transferred to Microsoft Excel for further analysis. Mean and ±SD were used to characterize the sample and to determine the average energy expenditures. Energy expenditure values for activity testing were determined by breath-by-breath values of pulmonary gas exchange. The values used to determine the steady state during the activities was only calculated from values collected during the performance of each activity. The steady state values were collected from the last 2 min of the 5 min spent during each activity, transformed into output of 15 sec intervals. The average of values was calculated in Microsoft Excel, with the mean and SD for the selected data points representing the individual energy expenditure for each activity.

Ethical conduct

The study was reviewed and approved by Stockholm regional ethical committee, with the assigned reference number 2011/1989-31/1. The research participants were informed both verbally and in writing. The information sheet included the protected of the participant's identify and assured them of anonymity during the reporting of the results. All participants were over 18 years and gave informed written consent.

Results

BMR results are presented in table 2. It shows that the VO_2 (ml · min^{-1}) is higher in men and the mean (Kcal · min^{-1}) is lower in women, but the mean oxygen uptake is almost the same. This study has shown that the mean BMR for men was 1400 kcal/ 24 h (1032- 1775) and for women 1012 (kcal)/24 h (719 - 1293). In our study we did not use a control group, instead we compared to the 1 MET calculation. The 1 MET value is considered the same as the resting expenditure value. 1 Met value for abled -bodied population was calculated with the formula (ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) with the value of 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and then recalculated to get the actual value of the participants in this study. The result from our study is that 1 MET is equivalent to 2,7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ for persons with SCI. This is in contrast to the standard calculation for able-bodied population which suggests a value of 3,5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. The value of 2,7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ as found in this study is similar as found by (Collins et al., 2010).

Table 2. Basal Metabolic Rate presented for all participants and by gender (mean ± SD)

	BMR VO_2 (ml · min^{-1})	Mean Oxygen uptake mL· kg^{-1} ·min^{-1}	BMR Kcal · min^{-1}
All	184 ± 44	2,69 ± 0,55	0,88 ± 0,21
Men	203± 41	2,70 ± 0,57	0,97 ± 018
Women	148 ± 33	2,67 ± 0,59	0,70 ± 0,15

The result for the standardized physical activities show (table 3 and figure 1) that there is a difference between sedentary and physical activities. The value for setting a table is depicted as MET of 2,8 and propelling wheelchair indoors with a MET of 3,2, which is twice as high as watching television with a MET of 1,4 and working with a laptop MET 1,5. The results also show that setting table and propelling indoor have a relative high MET value compared to strength exercise MET 4,3. The highest MET value is propelling the wheel chair outdoors in exercise pace.

Table 3. Output of key variables for analysis of the standardized physical activities (average ± SD)

Activity	VO_2 (ml · min^{-1})	mL· kg^{-1} ·min^{-1}	Kcal · min^{-1}	SCI MET
Watch Tv	250,9 ± 59,1	3,63 ± 0,65	1,21 ± 0,29	1,39 ± 0,30
Deskwork computer	263,5 ± 57,3	3,84 ± 0,71	1,28 ± 0,28	1,46 ± 0,29
Setting table	515,5 ± 134,5	7,39 ± 1,10	2,46 ± 0,64	2,82 ± 0,49
Propelling indoors	598,8 ± 231	8,48 ± 2,36	2,87 ± 1,11	3,20 ± 0,75
Hand bike "Borg, light"*	617,4 ± 149,4	8,93 ± 1,50	3,01 ± 0,73	3,42 ± 0,69
Arm cranking (18W)	657,5 ± 131,6	9,54 ± 1,13	3,22 ± 0,63	3,67 ± 0,75
Propelling outdoors "Borg, light"*	723,6 ± 216,7	10,31 ± 1,92	3,45 ± 1,03	3,95 ± 0,84
Strength training (gym)	789,1 ± 264,6	11,24 ± 2,90	3,98 ± 1,33	4,27 ± 1, 04
Arm cranking (36W)	841,9 ± 180,4	12,16 ± 1,39	4,18 ± 0,88	4,71 ± 1,11
Hand bike exercise	905,5 ± 290,3	13,10 ± 3,55	4,51 ± 1,50	4,96 ± 1,26
Double poling ergometer	1003,5 ± 271,3	13,32 ± 4,53	5,03 ± 1,35	5,13 ± 1,78**
Circuit resistant training (gym)	1060,3 ± 294,9	15,29 ± 3,25	5,34 ± 1,50	5,81 ± 1,19
Propelling outdoors exercise	1143,9 ±384,3	16,27 ± 3,90	5,64 ± 1,94	6,16 ± 1,38

*Borg RPE scale.
**One person did not manage to complete the activity.

Figure 1

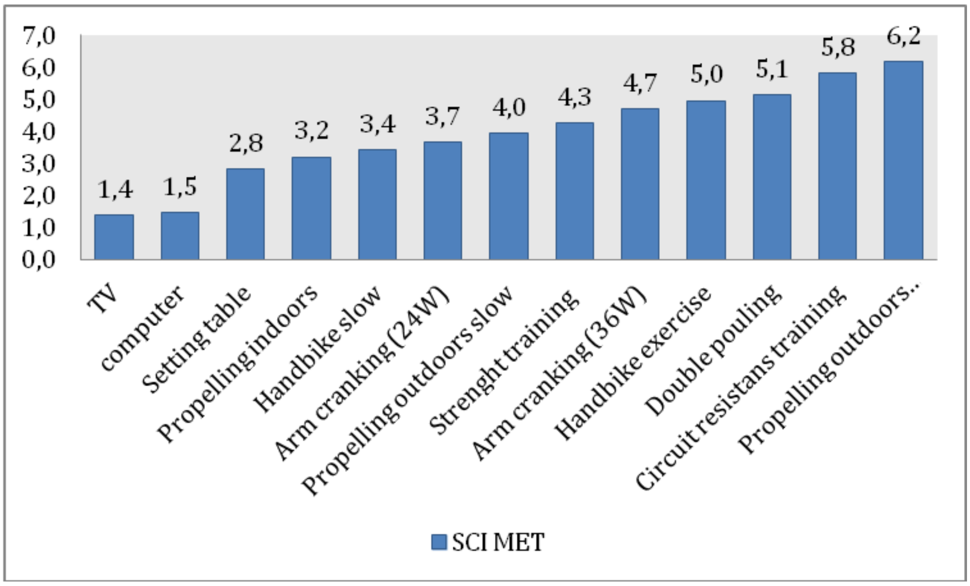
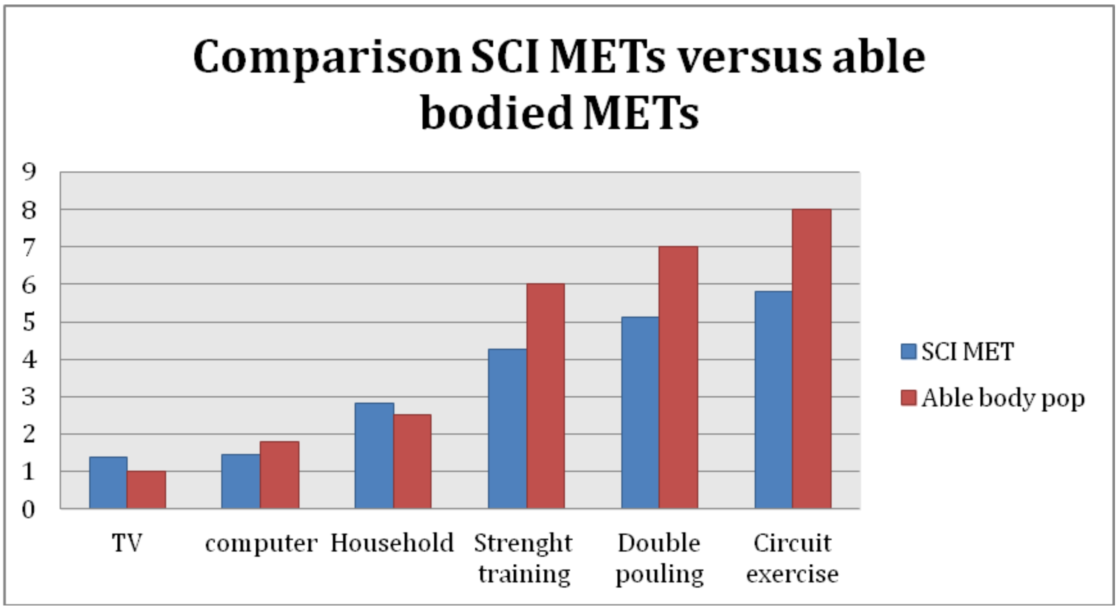


Figure 2. Comparison between the studied SCI –population to the energy expenditure compendium by Ainsworth by (Ainsworth et al., 2000)



Discussion

Results

This study was one of few studies utilizing a specific and homogeneous group of SCI -persons Th 7-12 that explores energy consumption. The main findings of the study suggest that the resting oxygen uptake is almost one fourth lower than that of the general population. Furthermore, the MET -value was lowest for sedentary activities like watching TV and highest for propelling wheelchair outdoors.

More specifically relating to the first objective, the resting oxygen uptake or BMR in this study was 24% (women 25%, men 23%) lower than that reported for able-bodied persons (Ainsworth et al., 2000). The BMR for SCI persons has been reported in other studies (Collins et al., 2010). The latter study included 34 participants, all men with level of injury at Th1 –L4, and the results of the BMR was 23% lower, compared to the reported abled-bodied persons. Also, Monroe et al found that the BMR was 26% lower in ten men, nine with paraplegia and one with tetraplegia all with complete lesions, compared to age matched controls (Monroe et al., 1998). In a study with males and females with paraplegia the BMR was 14% less when compared to abled-bodied persons (Buchholz, McGillivray, & Pencharz, 2003). The result from our study is that 1 MET is equivalent to 2,7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ for persons with SCI. This is in contrast to the standard calculation for able-bodied population which suggests a value of 3,5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. The value of 2,7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ as found in this study is similar as found by (Collins et al., 2010). This finding clearly shows the important difference between the SCI subpopulation and the able-bodied population with regard to the resting energy expenditure or 1 MET value. This study did not attempt to determine the factors associated with the reduction in BMR, but other studies have found such reductions appear mainly due to loss of fat-free body mass (muscle tissue). This loss can be attribute to the loss of motor control in the muscles below the level of injury, which could lead to degeneration of fat-free body mass (Buchholz et al., 2003; Lavis, Scelza, & Bockenek, 2007).

The outcome of the standardized physical activity assessment shows that persons within this subpopulation of SCI start to increase their energy consumption from engaging in daily activities such as “setting table” and “propelling indoors”. It is evident that MET values differ between activities. For example, if a person in this subpopulation watches television the energy consumption is equal to 1,21 kcal/min. Now comparing the previous example to setting at table or propelling a wheelchair indoors, the energy expenditure increases more than 100% to 2,46 kcal/min for “setting table” and 2,87 kcal/min for “propelling wheelchair indoors”. This shows the importance of engaging in daily activities and that persons with SCI, like the abled-bodied population, can increase their daily energy expenditure by starting to become physically active on a daily basis. Considering the energy expenditure during exercise, our study shows that all exercises performed at Borg 10-11 fairly light/light intensity demonstrated a variation between 3,4 – 4,0 MET or 3,01 – 3,45 kcal/min. For the activities that were performed at Borg RPE 13-14, indicating somewhat hard, showed a variation between 5 – 6,2 MET or 4,51 – 5,64 kcal/min. In this study we chose to use Borg RPE scale 10-14 because it has been found that exercise intensity at anaerobic thresholds or lactate thresholds levels have been associated with Borg RPE 11-13, independent of training state (Ceci & Hassmen, 1991; Hetzler et al., 1991; Purvis, 1981; Seip, Snead, Pierce, Stein, & Weltman, 1991). The strength training activities that was performed in the gym showed a variation 4,3 MET or 3,98 kcal/min for regular gym training to 5,8 MET or 5,34 kcal/min for circuit resistance training. These results show that propelling outdoors both in Borg 10-11 fairly light/light intensity and in Borg RPE 13-14 somewhat hard is an excellent example of exercising when it comes to energy expenditure, as compared to gym exercise, that have a higher MET value, but is harder to perform for a longer periods of time. Also known from the abled-bodied population, the easiest way of achieving higher energy expenditure is to initiate a physically active life style instead of a sedentary lifestyle. The change from a sedentary lifestyle to a more active daily life could also have positive effects on CVD risks for the SCI population. It is also shown in the current study that when one compares the data to the abled –bodied population as described by the energy expenditure compendium by (Ainsworth et al., 2000) figure 2. The difference in energy expenditure is larger in activities with higher levels of energy expenditure than activities with lower energy expenditure. It is hypothesized that the difference in results could be due to the absence of big muscle groups, as found in the lower extremities.

When comparing the result from this study to the result from the Collins study, there is a difference in SCI MET values because they operationalised SCI MET values of 1 MET to be equivalent to 2,7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. While in our study we used the actual MET values from each participant, which could be one explanation of why MET values differ. They also chose to present their data in males and females because some of the activities only consisted of male participants. A big difference between our study and the Collins study was the selected injury categories for inclusion. The reviewed study divided the thoracic levels in Th1-8 and Th9-L4. In our study we chose only to include injury levels between Th7-12 because we wanted to avoid influence from the sympathetic nervous system (Price, 2010) and that the participants did not have motor function in their lower extremities.

Comparing to able- bodied population

This study report data for basal metabolic rate and energy expenditure for thirteen activities, divided in activities of daily living and fitness activities. The results from this study show that this subpopulation of persons with SCI has lower basal energy expenditure that leads to a lower output of kcal per day. If comparing to the recommendations to burn 150 kcal/day or 1000 kcal/week extra for a healthy lifestyle (Leon A, 1987; Paffenbarger RS Jr, 1993; Slattery M, 1989). To achieve weight loss an individual needs to burn an additional kcal of at least 2000 kcal/week or 1000 kcal in addition to 1000 kcal for a healthy lifestyle (Donnelly et al., 2009). In order for persons in this subpopulation to burn 150 kcal/day, that individual needs to propel outdoors at Borg RPE 10-11 "Light/ fairly light -intensity" for at least 1 hour, which will be equivalent to 154 kcal. If propelling a wheelchair is not possible, the person could default to strength training in the gym for 50 min to burn 155 kcal. The subpopulation in this study had an average energy expenditure of 4 SCI MET propelling outdoors in Borg 10-11 fairly light/light. When comparing to the abled –bodied population (Ainsworth compendium), it almost corresponds to MET value (3,8) for walking at a speed of 3,5 mph on at brisk on a firm surface. However, the energy expenditure in Kcals used for the same activity is at least 24% lower in the SCI population.

Study design

The purpose of descriptive studies is to document aspects of a situation after observing and describing, but not to explain underlying causes. The disadvantage of the design is that the selection process was not random and there was no control group. In our study the selection process was to find persons that was homogeneous in level of injury and completeness characteristics, but varies in age, gender and weight. Since the selection process was not random in nature, an exploratory design was used. In this study we selected 15 participants (10men and 5 women) who met the inclusions criteria. The sample size can be considered as a small group but this is only one subpopulation of approximately 24 groups. Further, this particular subpopulation Th7-12 is approximately 40 persons, and the sample size represents almost 40 % of the described population. The inclusion criteria was set to exclude persons with autonomic dysreflexia (AD), which is a condition that can occur in SCI persons at a level of injury over TH5-6 (Holtz A, 2006) or as little as possible influence from the sympathetic nervous system (Price, 2010). Persons with injury levels lower than Th12 was also excluded because that the motor innervation for the leg muscles start at L2. Taking the level of motor innervation into consideration, the lowest level of injury was set to be at th12 to ensure that none of the participants had activity from their hip flexors and adductors. Spasticity was assessed with Penn, which is a self reported muscle spasm frequency scale that clinically measures spasticity (Penn, 1988). At the end of the study it was debated whether a clinical measure, such as the Modified Ashworth scale, should have been used. Due to the subjective and changing nature of spasticity in persons with SCI, the Penn scale was found to be appropriate. However, future studies of this nature should include both self-report and a clinical measure of spasticity, since it is speculated that increased levels of spasticity could influence energy consumption.

Data collection

The data collection procedure for studies exploring energy expenditure and BMR measuring should ideally be measured after at least 5 hours of fasting and abstaining from physical activity, caffeine, nicotine or other stimulants (Haugen et al., 2007). In our study the participants were overnight fasting (8h) and asked to abstain from physical activity, caffeine, nicotine or other stimulants. The method used to assess BMR and MET -values in activities was with indirect calorimetry and this method is considered the golden standard for assessing energy expenditure in clinical setting/experimental designs (Haugen et al., 2007). While direct calorimetry is more accurate, the procedure to measure the total energy expenditure in a thermally sealed chamber is not well tolerated and hard when assessing fitness activities. For that reason indirect calorimetry is more often used when measuring the energy expenditure during physical activities. The data collection for the standardized physical activities was chosen from an activity that is commonly performed and that are commonly used in clinical settings for rehabilitation of persons with SCI. That, in turn, can be used to prevent CVD and be the foundation for recommendations for physical activity for persons with SCI. The sedentary activities were chosen for reference values, since the sedentary life style is common in the SCI population (Bauman, Adkins, Spungen, Herbert, & Schechter, 1999; Noreau et al., 1993). The sequence in which the activities were performed was carefully planned so that the preceding activities do not influence the next activities within the sequence, due to fatigue. All data collection for one participant was carried out during two different sessions, one for the BMR and one for the activity assessment. There are also different ways of preforming strength training activities; for example in this study we decided to instruct the participants to find a resistance where they were able to perform 10 repetitions. The reason for allowing the participant to decide on the ideal weight was that we did not want to spend time during the assessment to determine the resistance, which could have influenced the results due to fatigue. In the only other study done on SCI persons they decided to allow the participant to choose the resistance during the assessment.

Data analysis

The BMR analysis in this study is almost the same as (Collins et al., 2010) used and it is a standardized way of conducting this type of research. Data was then transferred to SPSS and EXCEL for analysis, which is the most common way.

Activity testing, the Collins et al., 2010 study used breath-by-breath values over intervals of 30 sec instead of 15 sec periods; our method might be more accurate because of the shorter time intervals. All data collected for the standardized physical activity had a big variation in between subjects in each activity, which need to be taken into consideration. On the other hand, the variation in between subjects was expected since a large variety of persons with SCI were included. This variation in participant characteristics is essential when conducting exploratory studies with the prime focus on establishing important factors that could alter results. These findings could then be used to better control such confounders during experimental or randomised controlled trials in the future. In order to provide a basis for recommending exercises and health lifestyle habits, it is considered important to have a widespread of participant with SCI to cater for individual or group recommendations.

Strengths and Limitations

The limitations in this study were the small sample size and the absence of a control group or age and weight matched persons without SCI may perhaps have strengthen the comparison between this SCI-subpopulation and normal population. Other limitations are that there were only five women included in the cohort. Because of the preexisting heterogeneity between groups among persons with SCI the internal validity could have been altered. The internal validity was enhanced by the fixed inclusion criteria the experienced assessor. The task team for this study ensured this aspect by adhering to the protocol of data collection and by conducting the collection of data at similar point in time of day. Considering the external validity, the preexisting difference among SCI–groups makes it hard to generalize findings to both between SCI groups and to other neurological diagnoses.

Conclusion

This study has shown that the basal metabolic rate for this subpopulation of SCI person is 24% lower than in the general population. Further the result for the physical activity assessment resulted in three different levels of energy expenditure. These findings show that there are positive effects (regarding energy consumption) for living a more active compared to a sedentary lifestyle. This study also shows that the calculation of 1 MET value for the abled-bodied population (3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) by Ainsworth may not be the same for persons with SCI. An adjustment of the calculation value to (2.7 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$) is more precise. These results emphasize the importance that the energy expenditure compendium by Ainsworth is not applicable for this SCI sub-population. Further more, the results of this study give a close to reality account of the energy expenditure for this cohort during the exploratory phase, however, future research should also include other sub-groups of SCI.

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Supplement 2

Borg's RPE Scale	
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (Heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Borg RPE scale