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The energy expenditure of non-weight bearing crutch walking on the level and ascending stairs

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ABSTRACT

Crutches are commonly prescribed to patients with lower limb dysfunction during rehabilitation to assist with mobility. The aim of this study was to determine the energy expenditure for non-weight bearing crutch walking on level ground and ascending stairs at a self selected speed in a healthy adult population. Thirty-one healthy male and female adults (mean ± SD: age 21.6 ± 1.2 years; height 170.8 ± 10.8 cm; weight 70.8 ± 11.4 kg) mobilised non-weight bearing with elbow crutches along a 30 m corridor and (with one crutch) up a flight of 13 stairs.

Energy expenditure for each activity was measured by indirect calorimetry using the COSMED K4b^2 portable ergospirometry system. The established VO_2 values were 16.4 ml/kg/min for crutch walking on level ground and 17.85 ml/kg/min for stair climbing. Non-weight bearing crutch walking at a self selected speed on the level ground and up a flight of stairs resulted in a MET value of 4.57 and 5.06 respectively. The mean heart rate (HR) for crutch walking along the flat was 117.06 ± 20.54 beats per minute (bpm), while the mean HR for ambulating upstairs with crutches was 113.91 ± 19.32 bpm.

The increased energy demands of non-weight bearing crutch walking should be considered by physical therapists when instructing patients on crutch use. Further investigation to determine the implications of these results in populations with chronic disease is warranted.

1. Introduction

Collectively, adults aged <20 and 20–29 experience the highest incidence of lower extremity fractures due to motor vehicle collisions in the USA [16]. A total of 119,815 reports of lower extremity injuries due to a variety of reasons occurred in the USA between January 1st and December 31st 2009 [14]. Strains and sprains resulted in 36% of all lower limb injuries followed by contusions and abrasions. Fractures of the toe (38%), lower leg (29%) and upper leg (31%) were the most common injuries. In the Republic of Ireland 175.7 per 100,000 people with diabetes underwent lower limb amputation in 2009 [4]. The rate of non-diabetes related amputation in 2009 was 9.2 per 100,000 people. A non-weight bearing gait pattern may be prescribed following lower limb fractures, severe sprains or amputations to facilitate independent mobility and to promote healing. While crutches allow greater mobility for patients with lower limb conditions [11], the energy required to non-weight bear using crutches upon discharge, in the home environment has not been widely considered.

Whilst many studies to date have found that crutch walking requires more energy than normal walking [1,3,8,22–24] data regarding energy expenditure while non-weight bearing stair climbing is weaker. Previous work has reported that the energy cost of ascending stairs with crutches is greater than crutch walking on the level ground at predetermined speeds [8].

The energy expenditure of crutch walking ascending stairs at a self-selected speed has not been quantified. Patient selected speed is an important factor in energy expenditure as it requires the least amount of energy expenditure during both assisted and unassisted mobilisation [10,12,21]. Only one previous study, has measured crutch mobilisation at self-selected speeds [1]. The results report that estimated energy expenditure of crutch stairs ascent is higher than crutch mobilising on the level ground, however energy expenditure was measured indirectly using rate pressure product,

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which is calculated as a function of heart rate (HR) and blood pressure.

The energy expenditure of mobilising with crutches at a self-selected speed in terms of VO_2 must be established. The large number of lower extremity fractures among <20 and 20–29 age groups present the need to analyse the energy cost of a non-weight bearing gait pattern among a similar participant cohort. Improved understanding of the energy expenditure required to mobilise with crutches could help inform therapists prescribing crutches.

2. Aims and objectives

The aim of this study was to determine the energy expenditure for non-weight bearing elbow crutch walking on level ground and ascending a flight of stairs at a self-selected speed in a healthy adult population.

The objectives were:

- To determine the energy expenditure, in terms of VO_2, required to ascend stairs with a non-weight bearing crutch pattern at a self-selected speed.
- To quantify the energy expenditure in METS, needed to ascend stairs with a non-weight bearing crutch pattern at a self-selected speed.
- To compare the energy expenditure of non-weight bearing crutch walking at a self selected speed on the level ground and ascending stairs.

3. Methodology

3.1. Participants

Healthy adults from the university were recruited to participate in this study. Male and female subjects were included if they were aged between 18 and 25. Subjects with a history of a neurological condition, a cardiovascular disorder, confirmed or suspected pregnancy, a systemic condition that would affect basal metabolic rate or a musculoskeletal disorder that would affect walking were excluded from the study. Ethical approval was granted from The Faculty of Health Sciences, Ethics Committee, Trinity College Dublin and written informed consent was obtained from all individuals.

3.2. Materials

The COSMED K4b^2, a lightweight portable ergospirometry system was used to measure the energy demands of non-weight bearing crutch walking on the level ground and stairs ascent. The COSMED system analyses cardiopulmonary gas exchange on a breath-by-breath basis. The COSMED was worn in a comfortable harness on the shoulders. Heart rate was measured using a POLAR (T31) heart rate monitor. Data from each subject was telemetrically transferred to a laptop where it was analysed using the COSMED software. The COSMED has been shown to have good repeatability against the metabolic cart (ICC = 0.7–0.9, $p < 0.05$) [6] and good validity against the COSMED Quark b2 [7]. The modified Borg Rating of Perceived Exertion (RPE) Scale was used as a subjective measure of physical exertion. Chen et al. [5] reported moderate weighted validity coefficients between RPE scores and VO_{2max} (0.63), % VO_{2max} (0.64), HR (0.62) and respiration rate (0.72).

3.3. Procedure

All subjects were requested to fast for at least 2 h prior to testing so as to reduce the influence of the thermal effects of food on energy expenditure values. Written consent was obtained on arrival to the research laboratory and participants were assigned an individual study identification number. Testing procedures were standardised and completed by the same member of the research group for each test. Subject's height was measured using a stadiometer in triplicate and averaged for data entry. Weight was measured barefoot, using a digital scale on the Tanita MC-180MA multi-frequency body composition analyser, Tanita UK Ltd. Body mass index was calculated using the following formula: weight (kg)/height (m^2).

Subjects received an education session of up to 10 min which included demonstration and instructions on a non-weight bearing, swing through crutch pattern and explanation of the Modified Borg Rating of Perceived Exertion (RPE) Scale. Non-weight bearing gait was achieved using elbow crutches. The energy cost of using elbow crutches has been shown to be comparable to that of using axillary crutches [1]. Standard elbow crutches (Sunrise Coopers, UK) were fitted for all subjects according to Mulley's guidelines (1988) [17] and subjective feedback from subjects within ±2.5 cm [18]. Subjects were allocated 10 min practice time if needed and were supervised both on the flat and on the stairs by two members of the research team. Subjects were randomly required to weight bear on either the right or left limb following blind selection. Subjects were then fitted with the COSMED equipment. The face mask was inspected for air leakage. Prior to each test the COSMED and turbine was calibrated against gas cylinders of known concentration as per the manufacturer's instructions. Ultrasound gel was placed on the polar heart rate monitor which was positioned left of each subject's xiphisternum.

Before testing, resting HR was obtained each minute for 5 min with the subject seated and an average was calculated. Subjects were then instructed to walk at a non-weight bearing self-selected speed down the corridor. Once completed, HR and time taken were recorded and subjects were asked to give a score on the Borg RPE Scale.

Before ascending the stairs (13 steps, step height 16.5 cm) subjects were required to rest in a seated position until their HR returned to within five beats of their resting HR [18]. Subjects ascended the stairs using one hand-rail and carrying the other crutch in the opposite hand as per Lane and LeBlanc [15]. On ascending the stairs, HR and time taken were recorded. Subjects were asked again to give a score on the Borg RPE Scale and testing was completed. The percentage of maximal HR was calculated using the age-predicted maximal HR formula (220-age) [9].

3.4. Data analysis

Data was described using descriptive analysis. Mean and standard deviations for baseline subject characteristics and for each test variable were calculated. The percentage of VO_{2max} at which each participant worked, for each activity, was calculated using age allocated normative VO_{2max} values from tables published by Wilmore and Costill [25].

4. Results

Thirty six healthy male and female adults between the ages of 18 and 25 were recruited for this study. Due to technical difficulties, five subjects' data was not recorded and so data is presented for 31 subjects only (see Table 1). The mean and standard deviation was calculated for each of the test variables (see Table 2). Data for crutch walking on level ground and stair climbing was analysed separately.

4.1. Energy expenditure during crutch walking on level ground and stair climbing

The average VO_2 for crutch walking on level ground was 16.39 ± 5.65 ml/kg/min. The average VO_2 for stair climbing was 17.85 ± 5.04 ml/kg/min. Gender differences in VO_{2max} are well documented with females generally have lower average VO_{2max} values than males [25] In the current study, when VO_{2max} were analysed by gender, females tended have a higher percentage VO_2 while mobilising on level ground and stairs ascent, compared to males (Fig. 1), however this was not deemed to be statistically significant ($p \geq 0.05$).