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A comparison of energy consumption between the use of a walking frame, crutches and a Stride-on rehabilitation scooter

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HIGHLIGHTS

- The energy consumption ambulating with a Stride-on knee walker has not been investigated previously.
- The use of a Stride-on knee walker requires less energy compared to ambulation with crutches or a frame.
- This can be used in post-operative patients to aid rehabilitation in patients with reduced upper body strength or poor cardiovascular reserve.

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ABSTRACT

Background: Following foot and ankle surgery, patients may be required to mobilise non-weight bearing, requiring a walking aid such as crutches, walking frame or a Stride-on rehabilitation scooter, which aims to reduce the amount of work required. The energy consumption of mobilising using a Stride-on scooter has not previously been investigated, and we aim to establish this.
Methods: Ten healthy volunteers (5 males:5 females) aged 20–40 years mobilised independently, then with each mobility device for 3 min at 1 km/h on a treadmill, with rest periods, whilst undergoing Cardio-Pulmonary Exercise Testing (CPET). Oxygen consumption (VO_2), carbon dioxide excretion (VCO_2), minute ventilation (MV), respiratory rate (RR) and pulse (HR) were measured at baseline, and after 3 min of walking, without and with all 3 devices. Wilcoxon signed rank test was carried out to calculate significance with non-parametric values with Bonferroni correction.
Results: Three-point crutch mobilisation demonstrated significant increases in VO_2 (0.7 L), VCO_2 (0.7 L), MV (16.7 L/min), pulse (24.8 bpm) and RR (11.4 breaths/min) compared to walking ($p < 0.05$). Mobilisation with a frame produced significant ($p < 0.05$) increases compared to walking; VO_2 (0.7 L), VCO_2 (0.7 L), MV (18.3 L/min), pulse (35.9 bpm), and RR (11.7 breaths/min). Tests using the Stride-on demonstrated no significant increase compared to walking with regards to VO_2 (0.1 L; $p = 0.959$), VCO_2 (0.2 L; $p = 0.332$), pulse (10.1 bpm; $p = 0.575$), and RR (4.7 breaths/min; $p = 0.633$). The MV was significantly higher compared to walking (4.3 L/min; $p < 0.05$).
Discussion: Energy required for unit distance ambulation with a Stride-on device is similar to walking, and significantly lower than with a walking frame in single legged stance and three-point crutch mobilisation. This justifies its use as part of routine practice aiding early mobilisation of patients requiring restricted weight bearing or single legged weight bearing, especially in those with reduced cardio-pulmonary reserve as it is less physiologically demanding and does not rely on upper body strength.

1. Introduction

Medical rehabilitation requires active participation and work on the part of the patient seeking to regain the capability of ambulating. Effective rehabilitation programmes must attempt to increase the patient's ability to perform work and concurrently decrease the amount of work required. The former goal is achieved through exer-

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cise and rehabilitation training, and the latter by use of adaptive devices or environmental manipulation [1].

Following foot-and-ankle surgery, many patients will need to mobilise without bearing weight through their operated limb. This requires the use of a mobility aid. There are a number of devices available to patients to aid rehabilitation following foot-and-ankle orthopaedic surgery or lower limb surgery. These include crutches, walking frames and more recently innovative devices such as the 'Stride-on' knee walker. The 'Stride-on' knee walker is a five wheeled, patient-propelled, mobility scooter designed specifically for patients who have undergone foot-and-ankle surgery. Its key design features include four stabilising wheels, a fifth wheel for steering, which is attached to a steering column, a knee support for the patient to rest the affected knee and shin on, and a shopping basket [2].

Three-point ambulation with crutches has previously been shown to double the energy expended by patients compared with normal walking [3,4]. It has also been demonstrated that patients with spinal cord injuries have a higher energy consumption and oxygen cost, with a lower walking velocity compared with able-bodied control subjects, and within this group, mobilising with three point crutch ambulation is more energy efficient compared to a walker [5].

To date, there is no record in the literature as to the energy consumption of a patient using a 'Stride-on' device. It has been shown however that a two-wheeled mobility scooter, designed for African amputees, which is significantly different in design to the 'Stride-on', reduced energy consumption by 60% compared with three-point crutch ambulation [6].

We therefore seek to investigate the difference in energy consumption between a walking frame and three-point ambulation with crutches compared to the Stride-on rehabilitation scooter.

1.1. Aim

To investigate the difference in energy consumption with the use of a Stride-on rehabilitation scooter compared with the use of crutches (three point ambulation) or a walking frame in physically healthy individuals to identify the suitability of its use.

1.2. Null hyopthesis

There is no difference in the amount of energy consumed when mobilising with a Stride-on scooter compared to a walking frame or crutches.

2. Materials and methods

We recruited ten healthy and able-bodied volunteers aged between 20–40 years. They were all able to give valid consent, and none had any history of lower limb injury in the past or any difficulty mobilising. They took no long-term medication and were all non-smokers.

All patients underwent baseline measurements of height, weight, heart rate (HR), resting oxygen saturations (SATS) and resting blood pressure (BP).

We measured energy consumption using Cardio-Pulmonary Exercise Testing (CPET) whilst the subjects were asked to mobilise on a standard treadmill (Fig. 1).

A pilot trial was carried out to calculate ideal walking speed and time that could be transferred to all 3 mobility aids safely, without tiring significantly and all subjects were required to mobilise at a speed of 1 km/h for a time of 3 min a zero inclination, whilst being on the CPET monitor.

CPET is a functional assessment of cardiopulmonary reserve, and has been used to assess elite athletes as well as assessing fitness for surgery. The ability to perform exercise is related to the cardiopulmonary systems ability to supply oxygen and remove carbon dioxide. This requires adequate pulmonary ventilation, gas exchange, gas and substrate transport in the blood and uptake and utilisation at a cellular level. CPET is a measure to reflect this whole process [7].

Fig. 1. Cardio Pulmonary Exercise Testing Machine.

The variables measured include oxygen consumption (VO_2), carbon dioxide excretion (VCO_2), minute ventilation (MV) and respiratory rate (RR). The VO_2 is the product of the cardiac output and arterio-venous oxygen difference and therefore also reflects cellular aerobic oxidation of glycogen and fatty acids in the mitochondria as adenosine triphosphate is sourced. The VCO_2 should then reflect the VO_2 changes as long as the exercise is within the anaerobic threshold, and there is no cardiopulmonary disease. This is therefore a good and sensitive marker of energy consumption and reflects all aspects of cardiopulmonary function [8,9].

The setup involves walking on the treadmill whilst being connected to a pulse-oximeter at the set speed. Inspired and expired gases are sampled by a metabolic cart via a mouthpiece whilst a nose clip is worn, allowing oxygen consumption and carbon dioxide excretion to be measured by the calibrated machine. Subjects all initially performed the walk test and then sequentially