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Lecture

The effects of body weight unloading on kinetics and muscle activity of overweight males during Overground walking

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ABSTRACT

Background: Excess body weight has become a major worldwide health and social epidemic. Training with body weight unloading, is a common method for gait corrections for various neuromuscular impairments. In the present study we assessed the effects of body weight unloading on knee and ankle kinetics and muscle activation of overweight subjects walking overground under various levels of body weight unloading.

Methods: Ten overweight subjects ($25 \leq \text{BMI} < 29.9\,\text{kg/m}^2$) walked overground under a control and three (0%, 15%, 30%) body weight unloading experimental conditions. Gait parameters assessed under these conditions included knee and ankle flexion moments and the Electromygraphic activity of the Tibialis Anterior, Lateral Gastrocnemius and Vastus Lateralis.

Findings: Increasing body weight unloading levels from 0% to 30% was found to significantly reduce the peak knee flexion and ankle plantarflexion moments. Also observed was a significant reduction in muscle activity of the Tibialis Anterior, Lateral Gastrocnemius and Vastus Lateralis under the three body-weight unloading conditions.

Interpretation: Our results demonstrate that a reduction of up to 30% overweight subjects' body weight during gait is conducive to a reduction in the knee and ankle flexion moments and in the balancing net quadriceps moment and ankle flexors moment. The newly devised body weight unloading device is therefore an effective method for reducing joint loads allowing overweight people who require controlled weight bearing scenarios to retrain their gait while engaging in sustained walking exercise.

1. Introduction

Excess body weight is a major worldwide health and social problem. This problem has been characterized as "pandemic" since it has progressively increased over the past several decades. In 2014 > 1.9 billion adults (39% of adults over 18 years of age) worldwide were categorized as overweight (OW), $25 \leq \text{BMI} < 29.9\,\text{kg/m}^2$ and body fat percentage (BF%) > 24, based on the WHO criteria (World Health organization-WHO, 2015). Regular physical activity such as walking and running is usually recommended for its health benefits, one of which is weight reduction (Browning and Kram, 2007). To reduce the BMI and improve health outcomes of OW individuals, the American College of Sports Medicine (ACSM) (Medicine, 2013) recommends exercising at a low to moderate intensity (40% to 65% VO_2max) for a relatively long duration, that is at least 30 min. Engaging in such activities is often not only a challenge but also a burden for OW people due to the excess of weight on their lower extremity joints and consequent risk of injury. Accordingly, a variety of non-weight bearing low-impact exercise devices such as aquatic treadmill exercise protocols (Greene et al., 2009) have emerged on the market to optimize the ability of OW people to engage in physical exercises with minimum risk of injury.

Aquatic treadmill training aims at reducing the vertical component of the ground reaction forces (GRF) commonly seen during overground exercise. It was observed to reduce the load on lower joints of OW subjects and thereby decrease the risk of injuries while improving their aerobic capability (Nakazawa et al., 1994). Nevertheless, aquatic treadmill training suffered from several limitations some of which included drag forces that modified the gait speed and gait event timing. The comparison of gait biomechanical parameters of OW subjects during overground aquatic treadmill walking showed significant differences in joint kinematics, kinetics and muscle activity in these two walking modalities (Barela et al., 2006; Chevutschi et al., 2009).

The significant limitations imposed on gait parameters of OW subjects during gait with aquatic body weight unloading (BWU) resulted in the need to find alternative BWU devices to reduce lower limb joints loads and potential risks of injuries while replicating daily walking

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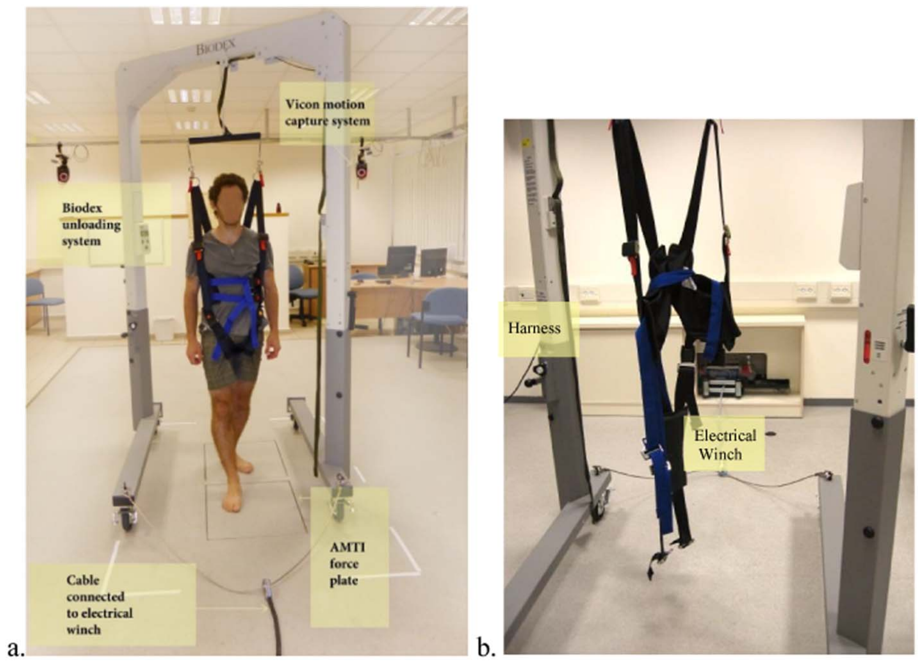

Fig. 1. a. The BWU Biodex system attached to a healthy normal weight subject, b. The BWU system connected to the electrical winch.

(Goldberg and Stanhope, 2013; Lewek, 2011; Sousa et al., 2011). Treadmill and overground training with partial body weight support have become common methods of gait corrections for patients with neurological and orthopedic impairments (Barbeau et al., 2004; Hesse et al., 1994; Patiño et al., 2007; Threlkeld et al., 2003). Gait rehabilitation with BWU could be started early after injury or post-surgery to induce sensory stimulation (Threlkeld et al., 2003), improve gait speed, balance and locomotion (Dickstein, 2008; Perry and Davids, 1992; Schmid et al., 2007; Sousa et al., 2009; Van Hedel et al., 2006).

Gait research and rehabilitation on treadmills with BWU has assumed that treadmill and overground gait patterns are similar enough to allow for the gait corrections observed on treadmills to transfer to daily overground walking. Research comparing treadmill and overground gait of healthy subjects has refuted this assumption by showing significant modifications in knee moments (Lee and Hidler, 2008; Riley et al., 2008) and muscle activation patterns that resulted in a significant decrease in forward propulsion during treadmill walking (Murray et al., 1985; Riley et al., 2008; Sousa et al., 2011; Strathy et al., 1983). Since treadmill gait does not replicate overground gait, treadmill walking with BWU may confound the benefits of BWU on gait parameters. Researchers therefore recommended to conduct research and training on the effects of BWU during overground walking (Carollo and Matthews, 2002; Fischer and Wolf, 2015, 2016; Harris and Smith, 1996; Hesse et al., 1997; Ivanenko et al., 2006, 2004; Murray et al., 1985). The major challenge to be faced when conducting overground gait research with BWU was related to the subjects' inability to maintain a comfortable walking speed when having to pull the BWU system to which they were attached. To meet this challenge, the Technion gait lab created a mechanical device that pulled the BWU suspension system at a constant speed, thus enabling subjects to maintain a comfortable speed during overground walking with BWU (Fischer et al., 2015; Fischer and Wolf, 2015). By controlling the potentially confounding effects of speed variability during overground walking, we could assess the effects of BWU on OW subjects' overground gait kinetics and muscle activity.

The objectives of the present study were to evaluate the effects of BWU on the knee and ankle sagittal plane moments and the balancing contraction of weight bearing muscles of OW subjects walking overground at comfortable speed under several levels of BWU. We hypothesized that overground walking with BWU will decrease knee and ankle flexion moments of OW subjects. We furthermore hypothesized that increased levels of BWU during overground walking will decrease the activation of muscles associated with weight bearing of OW subjects.

The importance of the present study is to be emphasized since no study known to the authors has investigated the effects of BWU on the kinetics and Electromyographic (EMG) activity of OW individuals. OW subjects gait kinetic and EMG parameters may thereafter be compared to those of normal weight subjects in order to develop a custom training program with BWU to improve OW individuals biomechanical gait parameters.

2. Methods

2.1. Subjects

Ten OW ($25 \leq \text{BMI} < 29.9\,\text{kg/m}^2$) male subjects were recruited for the present study. Selection criteria were being healthy with no previous orthopedic, musculoskeletal, or neurological pathology and $25 \leq \text{BMI} < 29.9\,\text{kg/m}^2$ with appropriate body composition measurements, including BF% > 24. The average and standard deviation (SD) age of the subjects was 25.3 (3) years, their height was 1.75 (0.07) m, and weight 84.5 (6.4) kg with an average BMI of 27.7 (1.7) kg/m^2 and an average BF% of 26.5%. The present study was approved by the Israel Institute of Technology Institutional Review Board (IRB), and informed consent was obtained from all subjects before data collection.

2.2. Instrumentation

The Biodex Unweighing System (Biodex Co., Shirley, NY, USA) (Fig. 1a) was used to reduce the subjects' body weight and accommodate for the vertical displacement of the center of gravity during overground gait under various levels of BWU. The system is composed of a suspension vest with shoulder straps, a pelvic belt, and a groin piece attached to the belt. Once subjects are suspended in an upright position, a pulley system lifts them until a predetermined BWU level is reached, as a function of their body weight (in kg). The effectuated reduction of 0%, 15% or 30% body weight is indicated on the screen of the Biodex system and maintained constant throughout the trials of the experimental conditions.

To neutralize the confounding effects of subjects' overground speed