Gait & Posture 39 (2014) 303–307

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Sensitivity of sensor-based sit-to-stand peak power to the effects of training leg strength, leg power and balance in older adults

G. Ruben H. Regterschot [a,*], Marjanne Folkersma [a], Wei Zhang [b], Heribert Baldus [b], Martin Stevens [c], Wiebren Zijlstra [a,d]

[a] University of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, Groningen, The Netherlands
[b] Philips Research Europe, Eindhoven, The Netherlands
[c] University of Groningen, University Medical Center Groningen, Department of Orthopaedics, Groningen, The Netherlands
[d] Institute of Movement and Sport Gerontology, German Sport University Cologne, Cologne, Germany

ARTICLE INFO

Article history:
Received 18 October 2012
Received in revised form 18 July 2013
Accepted 26 July 2013

Keywords:
Accelerometry
Kinematics
Falls
Clinical assessment
Aged

ABSTRACT

Increasing leg strength, leg power and overall balance can improve mobility and reduce fall risk. Sensor-based assessment of peak power during the sit-to-stand (STS) transfer may be useful for detecting changes in mobility and fall risk. Therefore, this study investigated whether sensor-based STS peak power and related measures are sensitive to the effects of increasing leg strength, leg power and overall balance in older adults. A further aim was to compare sensitivity between sensor-based STS measures and standard clinical measures of leg strength, leg power, balance, mobility and fall risk, following an exercise-based intervention. To achieve these aims, 26 older adults (age: 70–84 years) participated in an eight-week exercise program aimed at improving leg strength, leg power and balance. Before and after the intervention, performance on normal and fast STS transfers was evaluated with a hybrid motion sensor worn on the hip. In addition, standard clinical tests (isometric quadriceps strength, Timed Up and Go test, Berg Balance Scale) were performed. Standard clinical tests as well as sensor-based measures of peak power, maximal velocity and duration of normal and fast STS showed significant improvements. Sensor-based measurement of peak power, maximal velocity and duration of normal STS demonstrated a higher sensitivity (absolute standardized response mean (SRM): $\geq$0.69) to the effects of training leg strength, leg power and balance than standard clinical measures (absolute SRM: $\leq$0.61). Therefore, the presented sensor-based method appears to be useful for detecting changes in mobility and fall risk.

1. Introduction

Muscle strength and muscle power decline during aging [1,2]. Muscle power can be defined as the speed with which muscular forces produce movement of body segments [3]. The decline in leg strength and leg power in older adults is related to difficulties with mobility related activities, i.e. activities that require moving the center of mass (CoM) from one place to another. For example, lower leg strength and leg power are related to a reduced sit-to-stand (STS) performance [2,4]. Lower leg strength and leg power are also associated with a higher fall risk [5]. Falls often result in major injuries, leading to reduced quality of life and increased health care usage and costs [6]. However, studies show that training of leg strength, leg power and balance can improve mobility and reduce fall risk in older adults [7,8].

Evaluation of leg strength and leg power is important to identify older persons with a low functional status and an increased risk of falling, and to monitor changes in functional status and fall risk over time. Usually leg strength and leg power are assessed using laboratory methods, such as computerized dynamometers. These methods are expensive and require skilled lab personnel. Mobility is often evaluated by using simple field tests, such as the Timed Up and Go (TUG) test and the Five Times Sit To Stand Test [9–12]. However, these field tests only provide duration as an outcome measure. Therefore, accessible and practical methods are needed to measure leg strength and leg power during mobility related activities.

Zijlstra et al. (2010) introduced a new method for assessing the power required to lift the body's CoM during the STS transfer [3]. Assuming that trunk kinematics are indicative of CoM kinematics,

* Corresponding author at: University of Groningen, University Medical Center Groningen (UMCG), Center for Human Movement Sciences, P.O. Box 196, 9700 AD Groningen, The Netherlands. Tel.: +31 50 363 8846; fax: +31 50 363 3150.
E-mail addresses: g.r.h.regterschot@umcg.nl (G. Ruben H. Regterschot), marjanne@folkersma.org (M. Folkersma), wei.zhang01@philips.com (W. Zhang), heribert.baldus@philips.com (H. Baldus), m.stevens@umcg.nl (M. Stevens), zijlstra@dshs-koeln.de (W. Zijlstra).

0966-6362/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gaitpost.2013.07.122

this study estimated the vertical power required to elevate the body's CoM during STS transfers based on the vertical acceleration signals of small hybrid motion sensors worn on the trunk in young and older adults. Results demonstrated that a sensor worn on the right side of the hip provided the most accurate single sensor-based estimation of vertical CoM acceleration during STS. Furthermore, the results by Zijlstra et al. (2010) showed fair to excellent correlations between sensor-based STS peak power and STS peak power as measured with force plates. Thus, this study showed that vertical peak power during the STS transfer can be estimated with hybrid motion sensors in young and older adults.

However, so far it is unknown whether STS peak power as estimated with hybrid motion sensors can detect changes in mobility and fall risk. If sensor-based STS peak power is sensitive to the effects of training leg strength, leg power and balance, then this method could be useful for detecting changes in mobility and fall risk over time. Therefore, the aim of this study was to determine the sensitivity of sensor-based STS peak power and related measures to the effects of training leg strength, leg power and balance in older adults. A further aim was to compare sensitivity between sensor-based STS measures and standard clinical measures of leg strength, leg power, balance, mobility and fall risk, following an exercise-based intervention.

2. Methods

2.1. Participants

In total 26 older adults (16 females, 10 males) voluntarily participated in this study. Inclusion criteria were: age ≥70 years, being able to walk ≥10 meters without or with a wheeled walker or cane, being able to stand up from a chair without using the armrests, living independently or in sheltered accommodation. Exclusion criteria were: Cardiovascular/respiratory disorders, neurological disorders, severe comorbidity that influences mobility or participation in the exercise program, acute orthopedic conditions, cognitive disorders that affect comprehension or execution of the exercises, simultaneous participation in another intervention or exercise program. Age of the participants ranged from 70 to 84 years (mean ± SD: 77.7 ± 3.7 years), height ranged from 1.48 to 1.87 m (1.67 ± 0.1 m) and body mass ranged from 43.0 to 113.9 kg (80.0 ± 15.8 kg). Eleven participants reported they fell at least once during the year before the start of the intervention. A fall was defined as 'unintentionally coming to rest on the ground, floor or other lower level' [13]. Number of falls in the previous year ranged from 0 to 3. All participants received detailed information about the study and signed an informed consent. The study was approved by the Medical Ethical Committee of the University Medical Center Groningen (UMCG), Groningen, the Netherlands.

2.2. Exercise intervention

The exercise program was based on best-evidence protocols for improving leg strength, leg power and balance in older persons [7]. The duration of the exercise program was eight weeks. Subjects participated in two group training sessions per week (one hour per session) under supervision of a physical therapist. Subjects also received instructions for daily exercises at home (about 30 min/day). The group and home exercises consisted of: Knee extension movements while sitting on a chair, STS movements, hip abduction movements while standing next to a chair, hip abduction movements while sitting on a chair, knee flexion movements while standing behind a chair, hip extension movements with straight leg while standing behind a chair, heel raise exercises while standing, knee lifting exercises while sitting on a chair, standing still with eyes closed, stair walking, large forward step movements, moving body weight from one leg to the other. Participants were instructed to perform concentric contractions with high velocity and eccentric contractions with low velocity. Progression in the training program was achieved by a weekly increase of training intensity or training volume. Intensity was elevated by using therabands and ankle weights.

2.3. Procedures

Assessments were performed before and after the exercise program. During the pre-intervention and post-intervention assessments participants performed three STS transfers at normal rising speed and three STS transfers at as fast as possible rising speed. Prior to standing, participants sat against the back of the chair. All STS transfers were performed without using the armrests. After rising up, participants stood still for five seconds before sitting down again. After sitting down, participants sat still for five seconds before standing up again. A chair of standard height was used (0.47 m).

After the STS transfers, participants performed several standard clinical tests. First, the Berg Balance Scale (BBS) was performed [14]. This test consists of 14 balance-challenging tasks. Performance of each task was rated on a 5-point ordinal scale of 0 (low performance) to 4 (high performance). The final score (range: 0–56) was calculated by summing all 14 scores. Next three trials of the TUG were performed [9], preceded by one practice trial. Participants also performed three trials of an "as fast as possible" version of the TUG (without running). The use of walking aids (wheeled walker or cane) was allowed during the TUG. For the normal and the fast TUG, time needed to complete the test was measured and the final score was the average time of the three trials. Also maximal isometric quadriceps strength of the left and right leg was measured three times at two different knee angles (90° and 40° knee flexion) with a quadriceps force measuring device consisting of a chair and measurement equipment [15]. The final score per knee angle was the average of the three trials performed with the right and left leg. The same evaluator conducted all standard clinical tests.

2.4. Data acquisition

Participants wore a small hybrid motion sensor (π-Node, Philips) on the right side of the hip (just above the trochanter major femoris) during the normal and fast STS transfers (Figs. 1 and 2). The sensor contained a 3D accelerometer to measure accelerations (±2 g), a 3D gyroscope to measure angular velocities (±300 deg/s) and a 3D magnetometer (±2 Gauss) to measure orientation in the Earth's magnetic field [16]. Sampling frequency was 50 Hz and data

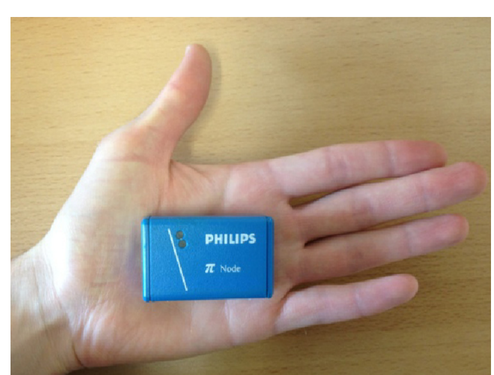

Fig. 1. The hybrid motion sensor.