

Assessment of Sit-to-Stand Movements Using a Single Kinect Sensor: A Preliminary Study in Healthy Subjects

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ABSTRACT

The aim of this article is to show that the absolute measurement difference between the Kinect-based system and the marker-based system for the sit-to-stand exercise is less important provided that the difference is caused by systematic errors in the Kinect measurement. Three healthy individuals participated in this study. Marker trajectories and Kinect skeletal joint data were collected while each subject performed the sit-to-stand exercise. Three key parameters, the initial, minimum, and maximum hip angles obtained from the two systems are compared. This preliminary study shows that the Kinect-based system has good agreement with the marker-based system, and it has comparable between-trial reliability and variability to those of the marker-based system. This study shows that Kinect can be used to reliably assess the quality of the sit-to-stand exercise provided that the systematic measurement errors are compensated. This study establishes the foundation to implement a Kinect-based system to automatically monitor, assess, and provide realtime feedback to a patient who carries out the sit-to-stand exercise with or without the supervision of a clinician.

KEYWORDS

Between-Trial Reliability, Between-Trial Variability, Functional Assessment, Hip Angles, Microsoft Kinect, Sit-To-Stand Movements

INTRODUCTION

In preventive and rehabilitative health care, physical exercise is a powerful intervention. However, many people do not adhere to the prescribed program (Bassett, 2003) that may require in the range of thousands of practice repetitions (Kleim & Jones, 2008). Also, exercises may be performed incorrectly, making the exercise ineffective, or even dangerous (Escamilla et al., 2009). The current state-of-the-art for exercise instruction and monitoring is usually limited to written instructions, exercise recording logs, and simple repetition counting devices. Unfortunately, these do not provide any feedback to the patient on the quality or correctness of the exercise performance, and they do not provide the clinician with a reliable record of whether the patient carried out the prescribed exercises adequately in quantity or quality.

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The release of the Microsoft Kinect sensor, which is equipped with a depth camera capable of measuring 3 dimensional positions of the objects in its view, has triggered tremendous interest in its use to monitor in-home physical therapy exercises (Clark et al., 2012; Clark et al., 2013; Gibson et al., 2013; Guerrero & Uribe-Quevedo, 2012; Schmitz et al., 2015; Lun & Zhao, 2015). Several clinical trials with Kinect-based systems have aimed to characterize the accuracy of the Kinect sensor. However, these validation studies have focused on direct comparison of absolute differences between the Kinect-based system and a much more expensive, marker-based system for a subset of joints or segments (Bonnechere et al., 2014; Clark et al., 2012; Clark et al., 2013; Galna et al., 2014; Gibson et al., 2013; Guerrero & Uribe-Quevedo, 2012; Mobini et al., 2014; Obdržálek et al., 2012; Pfister et al., 2014; Schmitz et al., 2015; Zannatha et al., 2013).

This study takes a different approach by focusing on the validity of using a Kinect-based system to assess the correctness rules (Zhao et al., 2014a; Zhao et al., 2014b; Zhao et al., 2014c) for the sit-to-stand exercise. The sit-to-stand exercise is often used as a strengthening exercise for the large muscle groups of the legs or it can be a motor re-learning activity, or both. A patient who has multiple sclerosis, for example, may practice sit- to-stand to improve strength and coordinated movement of the gluteal and quadriceps muscles as well as practicing the postural control needed throughout this task. Specifically, for an individual client, the determined task requirements might entail having both feet placed evenly on the floor at all times, and the hip angle, left/right knee angles, and left/right ankle angles all at about 90 degrees of flexion at the beginning of the exercise. The person would then lean forward with his or her trunk, moving into more hip flexion, and then stand in a typical manner from that point. The exercise is useful to the client only if the task requirements are met, i.e., if it is performed correctly.

We propose that the Kinect-based system can be used to assess the sit-to-stand exercise performance adequately to assure the task requirements of the exercise are met. This preliminary study shows that as long as the key parameters for the correctness rules are adjusted to compensate for systematic errors, the Kinect-based system has good agreement with the marker-based system with comparable between-trial reliability and variability.

We should note that this study is focused on the validity of the Kinect-based system with respect to its measurement accuracy and reliability for the sit-to-stand rehabilitation exercise. As such, this study does not include a usability study and does not address the concern of its use for large amount of repetitions of rehabilitation exercises. Furthermore, this study does not investigate the applicability of using the Kinect-based system to make diagnosis and predication of orthopedic, muscular or neural abnormalities.

METHODS

Experimental design

The human subject trials for this study were approved by the institutional review board (IRB #29358-ESP-HS) at Cleveland State University. Three healthy people participated in this study (2 males and 1 female, height 1.65 ± 0.1 m, mass 66 ± 15 kg, age 25 ± 5 yrs). A marker-based motion capture system was used to establish the ground truth of the movement of the subjects, using a full Helen Hayes marker set and Cortex (version 2.5) and Orthotrack software (version 6.2) (Motion Analysis Corp, Santa Rosa, CA). The Orthotrack software was used to derive the joint center from the marker positions for lower extremity joints.

More specifically, the Helen Hayes marker set contains 25 1-in (in diameter) markers that are placed in the following locations: top of the head, front of the head, back of the head, L/R (left/right) shoulders, shoulder offset, L/R elbows, L/R wrists, L/R anterior pelvis, sacrum, L/R thighs, L/R lateral knees, L/R shanks, L/R lateral malleoli, L/R foot, and L/R heel.

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