Measurement 80 (2016) 207–216

Contents lists available at ScienceDirect

Measurement

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

A clinically feasible kinematic assessment method of upper extremity motor function impairment after stroke

Ali Ozturk [a,*], Ahmet Tartar [b], Burcu Ersoz Huseyinsinoglu [c], Ahmet H. Ertas [d]

[a] *Engineering Faculty, Department of Mechatronics Engineering, Karabuk University, Turkey*
[b] *Engineering Faculty, Department of Biomedical Engineering, Inonu University, Turkey*
[c] *Faculty of Health Sciences, Division of Physiotherapy and Rehabilitation, Istanbul University, Turkey*
[d] *Engineering Faculty, Department of Biomedical Engineering, Karabuk University, Turkey*

ARTICLE INFO

Article history:
Received 12 October 2015
Accepted 3 November 2015
Available online 2 December 2015

Keywords:
Stroke
Rehabilitation
Reaching
Kinematic
Inter-joint coordination
Kinect

ABSTRACT

The development of feasible kinematic assessment methods of upper extremity motor function impairment after stroke is clinically extremely important in physiotherapy and rehabilitation engineering. Microsoft Kinect has a potential of a low-cost and compact solution for clinical based assessment of the upper limb motor function after stroke. However, the reliability of Microsoft Kinect in the upper limb motor function assessment has not been well established. Therefore, there is a hesitation in usage of Microsoft Kinect for clinical applications. It is expected that any measurement procedure has the capability to differentiate between pathological and normal performance. On the other hand, the identification of the kinematic metrics that best evaluate impairment of upper-extremity motor function is a key problem of any measurement protocol. Primary objective of our study is, by differentiating pathological performance from the healthy performance and identifying the kinematic metrics that best evaluate the impairment, to demonstrate the robustness/usability of Microsoft Kinect in kinematic analysis of motor performance of stroke patients. We compared the kinematic metrics of the forward reaching movement obtained data recorded from Microsoft Kinect between three stroke patients and two healthy subjects based on the Principal Component Analysis (PCA). In the study, we have defined a new inter-joint coordination index (IJCI) based on PCA to capture inter-joint coordination dynamic of reaching movement in addition to other metrics those have been previously defined and used in literature to quantify upper limb impairment. We observed that the IJCI has significant importance to detect impairment of upper-extremity motor function during a forward reaching task and to discriminate stroke patients from healthy controls.

We hope that this paper will promote the acceptance of objective kinematic analysis into routine rehabilitation practices.

1. Introduction

The most commonly used clinical measurements about motor function of hemiparetic upper extremity such as Wolf Motor Function Test (WMFT) can be considered subjective, as they depend on the evaluation of the data extracted by physician observations. They are not sensitive

* Corresponding author. Tel.: +90 5315413346; fax: +90 3704333290.
E-mail addresses: aliozturk@karabuk.edu.tr (A. Ozturk), atartar34@gmail.com (A. Tartar), burcu.ersoz@istanbul.edu.tr (B. Ersoz Huseyinsinoglu), ahertas@karabuk.edu.tr (A.H. Ertas).

http://dx.doi.org/10.1016/j.measurement.2015.11.026
0263-2241/

enough to detect the slow improvement signs on the complex upper extremity motor function. Also they cannot explain the underlying biomechanical characteristic of the motor function deficits [1]. Moreover, they mainly focus on the realization of the given functional task and have not the capability to detect improvement in how the task is performed [2].

The kinematic analysis, which is realized by using the motion tracking technologies and thereby minimize the observation errors of the physicians, make possible an objective, specific and evidence-based assessment of the motor functions of the upper extremity by providing objective and quantitative parameters. Kinematic analysis is an effort to reach an objective assessment based on the 3D (three-dimensional) positional data of some segment of subjects captured by a motion capture system during execution of a given task. Kinematic analysis of upper extremity motor function depends on four major factors: Motion capture systems with the 3D positional data of some segments of the subjects collected, Movement Category that subjects are asked to realize, Kinematic Metrics extracted from 3D positional data, and Interpretation of the kinematic metrics.

Visual marker based sensors (opto-electronic system based on active or passive markers) [3], robotic devices [4], electromagnetic sensors, and initial sensors [5] have been used as a motion capture system on kinematic analysis of neurological disorders related to movement impairment. Each motion tracking technology comes with its own positive and negative characteristics [6]. Accuracy, reliability, compactness and cost of the sensors are very important in terms of the acceptance of the kinematic analysis into routine rehabilitation treatment and flexibility of implementation in clinic and home environments. Indeed, there is an increased need for the home based rehabilitation schemes and clinically feasible methods for assessing the upper limb motor function to lift burden on health care services and expense in the national health service [7]. Visual marker based sensors are the most widely used technologies as a golden standard in the kinematic analysis because of their high accuracy and reliability. However, because of the difficulty in transportation, calibration and marker-placement, required large set-up volume and high cost of the visual marker based sensors make implementation of the kinematics analysis limited to research laboratories. Because of its cheap cost, compactness and marker-free skeleton tracking capability; Kinect has been increasingly drawing attention of the rehabilitation community since it first released in 2010 by Microsoft. Kinect has been used in elderly care and rehabilitation of neurological disorders. In literature, several researchers have investigated the neurological disorders related diagnostic potential of the data obtained from the comparison between Kinect and the visual marker based sensors [8,9]. Chang et al. only showed that profiles of elbow and shoulder angles obtained from Kinect and OptiTrack are closed enough when Kinect is placed in front of the subjects [10]. Clark et al. showed that the Microsoft Kinect provides anatomical landmark displacement and trunk angle data which possesses excellent concurrent validity when compared to data obtained from a visual marker based motion tracking system (VICON). Also it was suggested that the Microsoft Kinect can be used in clinical applications for a wide range of patient population [11]. Olesh et al. showed that joint angles of the upper limb obtained by both Kinect and a visual marker based sensors were correlated [12]. The results of the previous studies are promising that the Kinect can provide reliable tools to assess objectively upper limb motor function after stroke. Therefore, we don't need to compare data obtained by Microsoft Kinect with data obtained by a visual marker based motion tracking system.

One important problem that should be resolved is the identification of the kinematic metrics that best evaluate impairment of upper-extremity motor function and interpretation of the metrics in terms of the treatment efficacy in person with stroke [13]. Currently there is a paucity of kinematic metrics with regard to upper extremity [14]. However, information on how to interpret the complex data is still missing [15]. Each of the metrics evaluate a specific characteristic of upper extremity movements. Therefore, selection of metrics depends on what kind of movement category that subjects are asked to realize. Movement categories in kinematic analysis are reaching movements (point to point reaching), path drawing and activities of daily living (ADL). However, most stroke survivors are far from to realize any ADL such as handling a glass due to impairment in prehensile function in their hand [16]. Upper-extremity point to point reaching movement related kinematic metrics can be classified into two categories; end-point (hand) kinematic metrics and joint kinematic metrics [17]. End-point kinematic metrics is widely calculated by 3D Cartesian coordinates of only one marker on the wrist. While peak velocity, movement smoothness, movement straightness of the wrist displacement belongs to end-point kinematics, inter-joint coordination and joint range of motion belongs to joint kinematics. Trunk displacement has also been used to quantify compensatory strategies may also be considered within joint kinematics. End-point kinematics can be considered as a motor performance and joint kinematics and trunk movements can be considered as a movement quality [18]. Subramanian et al. [18] stated that trunk displacement was the only variable that distinguish between different level of impairment in stroke patients for reach-to-grasp task and suggested that movement quality variables are more sensitive in identifying upper limb deficits. van Dokkum et al. [19] argued that motor performance kinematics (movement time, trajectory length, directness, smoothness, mean and maximum velocity of the hand) were sensitive to change over time and distinguish movements of paretic, nonparetic and healthy limbs for reach-to-grasp movement task. Murphy et al. [13] claimed that the number of movement units (movement smoothness), total movement time, velocity, and peak angular velocity of elbow discriminated best between healthy subjects and those with stroke as well as between those with moderate versus mild arm impairment during reaching and drinking from a glass. Hence, it is well understood that response of the metrics vary between trials and it may depend on demographic properties of the stroke population and functional task that subjects are asked to realize during measurement. It is also worth emphasizing that