

Applications of the PowerGlove

in healthy aging and Parkinson's disease

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Abstract- The hand is important in many daily life activities. During aging, quality of fine motor control of hand and fingers is decreasing. Also motor symptoms of the hand are important to define for instance the neurological state of a Parkinson's disease patient. Although objective and reliable measurement of hand and finger dynamics is of interest, current measurement systems are limited. This paper describes the application of the PowerGlove, a new measurement system based on miniature inertial and magnetic sensors, to study the finger interdependency in healthy elderly and objectively quantify hand motor symptoms in Parkinson's disease. Results of pilot experiments in young healthy subjects are shown to evaluate the feasibility of the applications.

Keywords-component: *healthy aging, Parkinson's disease, hand kinematics, inertial movement sensing, instrumented glove*

1. INTRODUCTION

The hand is important in many daily life activities, such as grasping, lifting, sensing, hand writing, sports, music playing and other fine motor control tasks. Hand motor control is quite complex and measurement of hand dynamics is therefore of high interest in medicine, human movement science, ergonomics, sports, robotics, entertainment and industry [1, 2].

A field of interest of hand motor control is the aging population. Quality of hand motor control decreases with age, due to loss of stability and mobility. The biomechanical function of individual muscles and their neurophysiological characteristics may change with age and influence the level of hand function, including e.g. less independency between the different hand muscle groups [3]. To further increase our understanding of the changing neuromechanics of the hand motor function with age, finger interdependency during various finger tasks in terms of movement, muscle functionality, muscle interactions and force needs to be studied.

In Parkinson's disease (PD), the patient's hand motor symptoms are important to define the neurological state of a patient on- and off-medication and prior and during Deep Brain Stimulation surgery (DBS). Hand motor symptoms are clinically scored using the Unified Parkinson's disease rating scale (UPDRS [4], a 5-point-scale neurological examination). The hand items in the UPDRS include holding hand still (at rest and in a certain hand posture), wrist flexion, finger tapping, hand opening/closing, and hand pro/supination to determine tremor (spontaneous rhythmic repetitive alternating movements), rigidity (resistance to passive movement due to increased muscle tone) and bradykinesia (slowness of voluntary movement). However, the assessment often varies per physician and highly depends on experience. The subjective nature makes it hard to interpret the UPDRS correctly and the currently applied clinical examination seems to be too abbreviated to detect small changes due to medication or DBS [5]. An objective and more accurate and reliable quantification of the hand motor symptoms seems to be necessary to improve the clinical scoring.

Recently, a new method to assess 3D hand and finger kinematics based on miniature inertial and magnetic sensors has been proposed: the PowerGlove [2, 6]. In combination with newly developed miniature force sensors the interaction forces between the fingers and the environment can be assessed as well [6, 7]. The PowerGlove overcomes the common drawbacks of many existing instrumented gloves such as limited accuracy, need for complex calibration, crosstalk due to misalignment of sensors, line of sight problems (optical markers), limited usability during functional tasks or poor robustness [2].

Within the PowerSensor project [2, 6], in which the PowerGlove has been developed, the aim is to evaluate different applications of the PowerGlove. Application of the PowerGlove might enable accurate measure of finger dynamics to study finger interdependency in healthy elderly and objective quantification of the PD motor symptoms. Therefore, the objective is (1) to study finger interdependency in young and aged healthy subjects in terms of individual finger joint movements and muscle activity in various finger movement tasks measured with the PowerGlove and electromyography (EMG) of the extrinsic hand muscles, and (2) to determine the reliability and validity of the PowerGlove to measure PD hand motor symptoms in on- and off-medication state and with respect to the UPDRS. In this paper we show some preliminary results from pilot experiments to evaluate the feasibility of the applications.

2. MATERIAL AND METHODS

Subjects

For the application in healthy elderly, the aim is to include 10 young healthy subjects (age 18-30), and 10 healthy aged subjects (age >65). The measurement protocol is approved by the ethical board of the faculty of Human Movement Science of the VU University in Amsterdam, the Netherlands.

Participants for the application in PD will be recruited from the PD patients who are admitted to the Academic Medical Center in Amsterdam for one day to undergo a preoperative screening for DBS surgery. The aim is to include at least 12 subjects. The measurement protocol will be submitted for approval to the medical ethical committee of the Academic Medical Center in Amsterdam, the Netherlands.

Prior to performance of both application studies, pilot experiments of the measurement protocols were performed in two young healthy subjects (one for each application study) to evaluate the technical feasibility. The medical ethical committee of the Medisch Spectrum Twente in Enschede, the Netherlands, confirmed that for these pilot experiments no further ethical approval concerning the Medical Research Involving Human Subjects Act (WMO) was required.

Measurement protocol and equipment

The different hand motor control tasks defined in the two application protocols are described in Table 1. During each task, kinematics of the hand, fingers and wrist was measured using the PowerGlove (sample frequency 100Hz), including in total 18 3D inertial (accelerometer and gyroscope) and magnetic sensors that are positioned on each hand segment [2]. Prior to measurement, an anatomical calibration procedure based on functional movements was performed to relate each sensor coordinate system to the corresponding body segment coordinate system. This includes a flat hand position, a flexion of the thumb metacarpophalangeal joint (MCP), a flexion of the MCP joints of the fingers and an eight-shaped movement of stretched hand.

During the finger extension and flexion tasks for the aging study, activation of extrinsic hand muscles for finger extension and flexion were measured using a grid of surface EMG electrodes on the forearm (Figure 1) (Refa, Twente Medical Systems International B.V, NL).

Furthermore, during the passive wrist flexion task for the PD patient protocol, a 6D load cell (3D forces and 3D moments, ATI mini45, ATI Industrial Automation USA) was used to measure the forces and moments applied to the hand, to determine wrist rigidity. To measure forearm kinematics, one 3D inertial and magnetic sensor was positioned on the forearm. Four surface EMG electrodes measured the muscle activity of the wrist flexor and extensor in the forearm (Porti, Twente Medical Systems International B.V, NL).

Table 1. Hand motor control tasks in application studies of the PowerGlove

Tasks in measurement protocols	
<i>Healthy young versus elderly^a</i>	<i>Parkinson's disease^b</i>
<ul style="list-style-type: none"> • Extension of the metacarpophalangeal joint (MCP) • Flexion of the MCP joint • Flexion of the proximal and distal interphalangeal joint (PIP/DIP) • Finger tapping 	<ul style="list-style-type: none"> • Holding hand still at rest (for tremor) • Holding hand still in certain hand posture (for tremor) • Passive wrist flexion (for rigidity) • Finger tapping thumb/indexfinger (for bradykinesia) • Hand opening/closing (fist) (for bradykinesia) • Hand pro/supination (for bradykinesia)

a. Index, middle, ring and little finger separately and in combination for all tasks

b. Hand items 20-25 of the Unified Parkinson's disease rating scale [4]

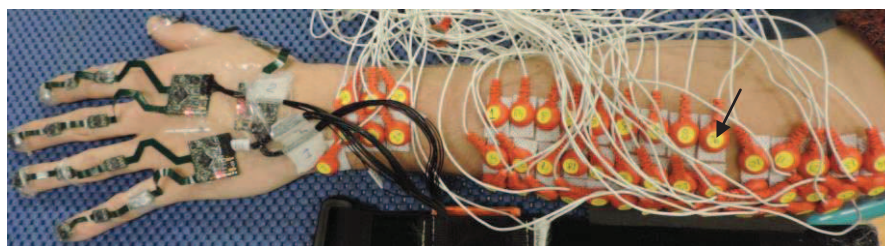


Figure 1. Experimental setup to determine finger interdependency in various finger movement tasks in young and aged healthy subjects: use of the PowerGlove and surface EMG. A grid on the finger extensor muscles is shown. The main extensor muscle is the human extensor digitorum muscle (ED), a muscle group in the posterior forearm with tendons to the index, middle, ring and little finger. The ED consist of anatomically segregated compartments for each finger, which can be assessed individually by surface EMG [8]. The arrow is pointed at the anatomic location for the index finger compartment of the ED.

3. RESULTS

Figure 2 shows an example of active PIP flexion of the index and middle finger in a young healthy subject. Also the MCP and DIP joints of the index and middle finger show some flexion. Furthermore, the ring and little finger show passive or involuntary active movements, illustrating the dependency between the adjacent fingers. For MCP flexion/extension tasks and fingertapping tasks in aged subjects and PD patients, the PowerGlove will be used to measure these MCP/PIP/DIP joint angles.

EMG activity of one channel positioned on the extensor digitorum muscle (ED, for index finger extension, see Figure 1) and MCP joint angle of the index finger during MCP extension measured synchronously with the PowerGlove in a young healthy subject is shown in Figure 3. It illustrates the relation between muscle activity and movement.

An example of the wrist joint moment versus wrist angle during passive wrist flexion in a young healthy subject is shown in Figure 4. The wrist rigidity is the derivative of the moment-angle curve. It is illustrated that active resistance by the subject to the applied movement results in higher wrist joint moments, resulting in higher rigidity. In PD patients in off-medication or off-DBS state, rigidity might be caused by increased muscle tone [4].

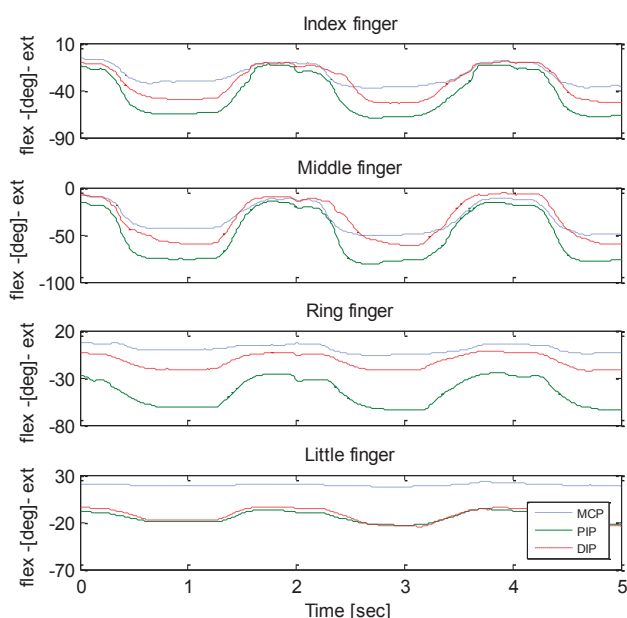


Figure 2. MCP, PIP and DIP joint angles during active PIP flexion of the index and middle finger, measured with the PowerGlove in a young healthy subject.

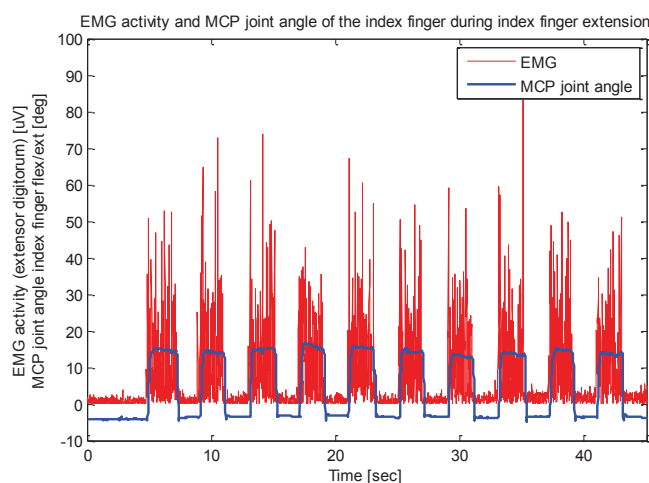


Figure 3. Example of EMG activity of the extensor digitorum muscle (rectified and high pass filtered at 20 Hz) and MCP joint angle during index finger extension in the MCP joint of a young healthy subject, measured synchronously with a surface EMG grid and the PowerGlove to explore application in aged subjects.

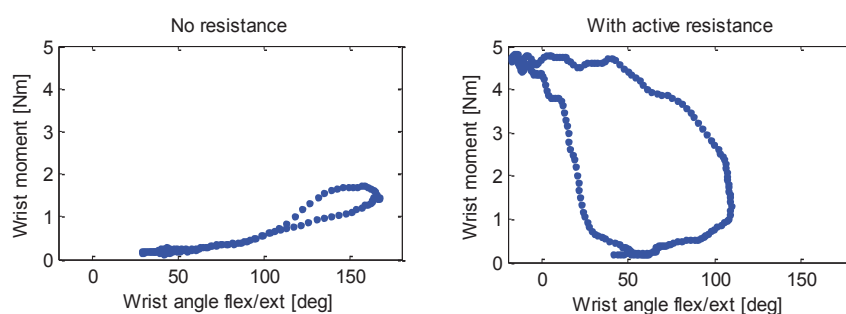


Figure 4. Wrist moment-angle curve during passive wrist flexion in a young healthy subject with and without active resistance of the subject to the movement, measured with the PowerGlove and a force/moment sensor to explore the application in Parkinson's disease patients.

4. DISCUSSION

In this paper examples of applications of the PowerGlove are shown (finger joint flexion, finger joint extension and wrist flexion) that are important in hand motor function assessment in healthy elderly and Parkinson's disease patients. These preliminary results from the pilot experiments in young healthy subjects show the feasibility of different applications of the PowerGlove. Future research will focus on the specific outcome parameters of the PowerGlove that are of interest in relation to the two applications, such as 3D individual finger joint kinematics and fingertip positions for flexion/extension and tapping tasks, frequency analysis of hand kinematics for hand tremor tasks, reliability and validity measures for kinematic outcome of the PowerGlove in comparison to the UPDRS, and relation of individual finger movement to EMG activity for both finger extensor and flexor muscles. For the analysis of the EMG profiles, principal component analysis and RMS will be used for amplitude estimation in each EMG channel. Subsequently cluster analysis will be used to reveal distinct activation patterns for the different finger tasks [9]. On the long term, the aim is to apply the PowerGlove in PD patients during DBS-surgery, to optimize assessment of the clinical neurological state of the patient while a new DBS-stimulation protocols are being tested.

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