A Kinematic Analysis of the Hand Function

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Abstract—**Background: the evaluation of the hand function is an essential element within the clinical practice. The usual assessments are focus on the ability to perform activities of daily life. The inclusion of instruments to measure kinematic variables provides a new approach to the assessment. Inertial sensors adapted to the hand could be used as a complementary instrument to the traditional assessment. Material: clinimetric assessment (Upper Limb Functional Index, Quick Dash), antrophometric variables (eight and weight), dynamometry (palm preasure) was taken. Functional analysis was made with Acceleglove system for the right hand and computer system. The glove has six acceleration sensor, one on each finger and another one on the reverse palm. Method: analytic, transversal approach. Ten healthy subject made six task on evaluation table (tripod pinch, lateral pinch and tip pinch, extension grip, spherical grip and power grip). Each task was made and measure three times, the second one was analyze for the results section. A Matlab script was created for the analysis of each movement and detection phase based on module vector. Results: The module acceleration vector offers useful information of the hand function. The data analysis obtained during the performance of functional gestures allows to identify five different phases within the movement, three static phase and tow dynamic, each module vector was allied to one task. Conclusion: module vector variables could be used for the analysis of the different task made by the hand. Inertial sensor could be use as a complement for the traditional assessment system.**

Keywords—**kinematics, hand, assessment, inertial sensor.**

I. INTRODUCTION

The deterioration of the function of the hand directly affects the development of everyday life [1]. Between the different systems used for the evaluation of the hand, the questionnaires and functional tests are the most used [2].

Self reported questionnaires that are made for the patients offer a subjective vision of the state of health by identifying the own capability to perform various tasks [3]. Similarly the rating scales that are filled in by the therapists depending on the capabilities of the subjects, provide a limited range of responses, referred to the difficulty to perform certain actions [4]. A third element that it not used in the evaluation of the hand is the real performance of the development in the task, this could be the main outcome variable, despite of the time.

The deficiencies identified between the different systems of valuation in the hand, requires a specific job in evaluations to fill those gaps and to obtain a joint vision of all affected items. In this aspect, the use of new technologies such as complementary elements to the conventional evaluations can be of great utility.

One of the technological developments that greater application can have use as a complement to the valuation is the analysis of the kinematics of the movement through the use of inertial sensors [5].

The analysis of the kinematic variables provides information relative to the speed, trajectory, accelerations, and angles, among others. These tools have been used as instruments of measures in different pathologies such as Parkinson's disease [6], cerebral palsy [7], or stroke [8]. In addition have been integrated in virtual environments for functional recovery [9].

The use of the sensors on the hand, has been facilitated by the production of gloves equipped with such technology that offer the possibility of registering the different variables [10-12]. The gloves have already been used in different studies [13,14].

Therefore the purpose of this study is to assess the use of inertial sensors accelerometer type in the hand as a complementary tool to the existing functional assessments. Thus to obtain new variables that provide greater information about the function of the hand.

II. METHOD

A. Design

Quantitative, non-experimental, analytic, transversal approach, aimed at detecting functionality variables of the functional task.

B. Subjects

Ten healthy subjects from the University of Malaga, took part in this study. The inclusion criteria were: age range between 18 and 36 years, no previous health issues, no impairment to upper right limb mobility, no affection skin, right-handed, informed of the study and written consent obtained. The exclusion criteria were: left-handedness, disability locomotive and any other which did not meet with the inclusion criteria.

C. Material

The instruments use for the data collection were classified in four groups: a) anthropometric variables: height and

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weight using the procedure described [15] b) dynamometry; c) clinical variables: the Upper Limb Functional Index (ULFI) [16] and the QuickDASH [17,18]; d) monitorized variable with accelerometer using the Acceleglove device (AnthroTronix,Inc) [10].

The dynamometer used was the Jamar Hydraulic Hand Dynamometer manufactured by Sammons Preston Rolyan [19] activated with palm pressure. The force of palm pressure was measured in kilograms/cm^2.

The AcceleGlove is a nylon/lycra glove equipped with six inertial accelerometer sensors, one on the back of each finger on the middle phalanx and a sixth sensor on the back of the palm. The software used for recording and capturing data was the Acceleglove Visualizer supplied by the manufacturer. The sampling rate of the device was 120 Hz. Each accelerometer (thumb, index, middle, ring, pinky and palm) has three axis positions (X,Y,Z) with a precision range of ±1,5g. The axis correlation of the glove is illustrated in Figure 1.

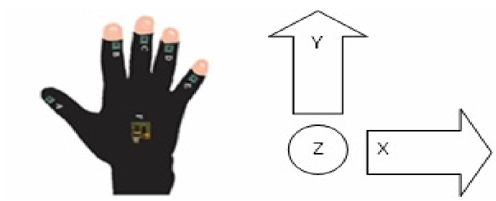

Fig. 1 Acceleglove output signal convention (top view, right hand).

On the basis of acceleration and time data, two new indirect variables were calculated: time; obtained in seconds based on the Unix measurement recorded by the device 1 January 1970 [20]. Module Vector Acceleration; expressed as the following formula: $\sqrt{X^2+Y^2+Z^2}$ $\sqrt{X^2+Y^2+Z^2}$. The operation was performed on the “x”, “y” and “z” axes of each of the accelerometers corresponding to each sensor.

D. Method

The participants performed the functional gesture of the hand (tip pinch, tripod pinch, lateral pinch, force grip, extension grip and spherical grip). Each gesture was repeated three consecutive times and measurements taken. The subjects performed the test while seated on a 50 cm high chair, with a straight back and the arm held close to the body with the elbow bent at 90º. The assessment table was placed opposite the subject on a flat surface 75 cm high. A reference mark was placed on the assessment table on which the middle finger of the right hand was situated prior to commencing the test. Each of the subjects remained in the aforementioned position for a period of 4 seconds, after which a warning sound signalled them to move their hand to the area indicated to carry out the gesture. Four seconds after the first signal, a second warning sound signalled them to return to the initial position. The procedure was performed in a series of three repetitions.

E. Acquisition and Processing of Data

Based on the aforementioned protocol the different gesture of the hand were parametrized and allied with a main module vector. The thumb vector was linked with tip and lateral pinch, index vector with tripod pinch and extension grip; palm vector with the force and spherical grip.

While performing each gesture five sub-phases were identified due to significant variations produced by the acceleration vectors. A Matlab[21] script was been created based on the recognition of numeric patterns, identifying in three different sections the most repeated values on a range data. The stability range was determined around the value that was repeated more times in each static section on one module vector. This range was defined by the production of ten consecutive records with approximate values around the most repeated over a range of ±2 units based on a smooth original signal.

These variations have a direct correlation with the various sub-phases of the gesture (T1-T5), corresponding to the movements and positions adopted by the hand (static or dynamic). In the static phase the main module vector of each movement remained a constant acceleration, in the dynamic phase the module vector did not remain.

The sequencing of the phases was: T1 or repose (static), the hand remains static awaiting the sound signal; T2 or calibration (dynamic), the hand moves to the area indicated to perform the task gesture, T3 or success (static), the hand performs the task in the indicated area; T4 or return (dynamic), the hand moves to the initial position, T5 or repose (static), the hand remains static in the reference mark.

Figure 2 represents the temporal spectrum of a subject while performing the tip pinch gesture based on the resulting module thumb vector of the ACC values throughout the sequence, based on data produced by Sigmaplot [22]. This values have been compressed in order to obtain a more uniform curve.

III. RESULTS

Table 1 provides the analysis of the sample based on: anthropometric variable (age, height and weight), clinical variables (ULFI and QuickDash) and dynamometric values of the ten healthy subjects.

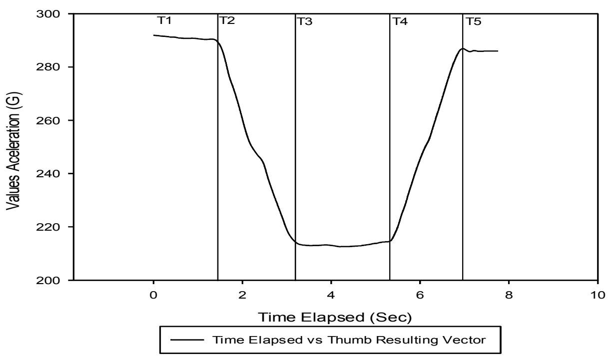

Fig. 2 Tip Pinch by phase based on Thumb module Vector

Table 1 Descriptive of the sample

	N	Mean ± SD
Age	10	26,80 ± 3.67
Height (m)	10	1,68 ± .107
Weight (kg)	10	65,80 ± 16.00
Dinamo Max Ext	10	38,60 ± 13.06
Dinamo Max Flex	10	36,40 ± 11.68
ULFI	10	,85 ± 1.79
QuickDASH	10	4,31 ± 10,30
QuickDash Work	10	2,50 ± 6.06
QuickDash Sport	10	9,37 ± 15.38

The descriptive analysis based on the variation of the module vector values on the static phases of the movement detected, values offered by each module vectors in the terminal pinch, table 2.

Table 2 Terminal pinch in static phase

	T1	T3	T5
Thumb	8,65±5,11	10,39±4,512	11,94±6.46
Index	7,78±6,25	16,19±9,05	11,02±7.37
Middle	9,14±14,20	18,20±23,86	10,53±5.32
Ring	10,03±15,49	15,23±13,43	11,04±9.88
Pinky	8,83±10,72	11,93±7,82	10,43±6.44
Palm	8,62±6,99	6,93±2,48	18,98±35.05

Variation of the vector values in terminal pinch (mean± SD).

Table 3 shows the descriptive results of the variation of the acceleration (mean ± SD) in relation with the task done and the director vector of the same, refereed to static phase of the movement. Variation values offered by module vector were static when it´s lower than 15 unit (g).

Figure three shows the range values of the module vector in the terminal pinch, calculated on basis to the maximum values, minimum and means of all values based on the results obtained by the participants. These values are obtained by extraction from each one of them in each unit of time measurement, for the tip pinch. In the graph the dotted line reflects the maximum possible values, the line continues the average value obtained and the striped line the minimum values.

Table 3 Static phase of the movement, task and director vector

	T1	T3	T5
Tip Pinch (Thumb)	8.65±5.11	10.39±4.51	11.94±6.46
Lateral (Thumb)	10.57±9.87	11.56±3.53	11.21±8.24
Tripod (Index)	6.32±5.33	7.35±1.31	6.94±1.40
Extension (Index)	5.33±1.37	8.72±1.52	10.11±4.65
Grip (Palm)	6.81±4.49	8.66±4.23	12.53±5.68
Spherical (Palm)	6.77±3.70	7.02±1.41	9.80±5.48

The variation of the acceleration has been obtained between the difference of maximum and minimum values of each periods. SD (65%). Unit (g).

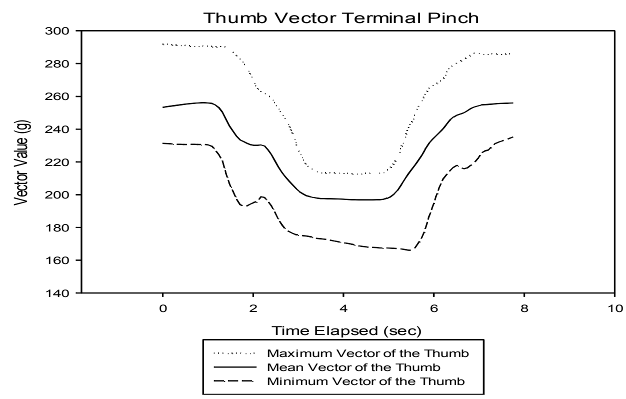

Fig. 3 range values of Thumb Vector in terminal punch

IV. DISCUSSION

The designed protocol is valid for describing the different functional task of the hand, based on descriptive variables obtained using inertial sensors.

The use of peripheral devices (Acceleglove) for the parameterization in real-time of the task movement, enabled it to be fragmented into various phases. The fragmentation of the results obtained from the resulting vector was a key element in describing and predicting the movement.

Phases T2 and T4 (Figure 2) did not follow a standard pattern in their graphic and numerical representations due to the different combinations possible at the approximation phase (T2) and return phase (T4). In other words, depending on the subject who performed the approximation movement, this took place either by first flexing the elbow, placing the shoulder on a flat surface, or flexing the wrist, amongst others.

There are various studies in which analyzes the function of the hand from different perspectives. Lui X et al.[23] analyzed the different areas of existing contact and the direction vector produced in the hand relation to their involvement in the different hand tasks.

The motion capture systems have been used to reproduce different movement of the human body, based in ergonomics applications [24] or for obtained new numerical variables of the movement based of reflective marker system [25]. Periods of reach, grip and return equivalent to T2, T3 and T4 in this study, have been valued by electromyography and kinematic variables by other authors at arm and shoulder complex [26], getting an important new variables for the analysis of them such as tangential velocity of the wrist relative to the time of completion of the task.

The inertial sensors also have been used in the analysis of the effects produced by the pathologies that affect the upper limb of the human body as it is Parkinson's disease [27] or stroke survive [28].

The module vectors obtained on the basis of the results of the inertial sensors are valid for the fragmentation of the movement in temporal phases, based on the variation of the data.

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