Human Tremor: Origins, Detection and Quantification

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1. Introduction

The human tremor is one of the most common movement disorders, which is characterized by repetitive and stereotyped movements. The origins of tremor are still not clear, however tremor can be associated with physiological phenomena, such as ageing, and with neurological disorders, for instance, Parkinson's disease. The first type of tremor is referred to as physiological tremor, whereas the latter as pathological tremor.

The clinical evaluation of tremor can be a valuable tool for the diagnosis of neuromuscular disorders and also for monitoring their progress. However, in a number of circumstances the discrimination between physiological and pathological tremor may not be clinically evident. In this context, the use of sensors for detecting tremor, and the data analysis tools employed in its quantification and classification are of paramount importance.

In this chapter, the origins, detection and quantification of tremor are discussed. The chapter begins with a review concerning the definition and classification of distinct types of tremor. A review of current theories that explain the origins of tremor are presented. The problem of detecting tremor by using electronic devices is addressed, and new advances in the area of tremor detection are introduced. A review and a critical discussion of the most common tools employed for tremor quantification and classification is provided. The chapter finishes by pointing out key unanswered questions in tremor research.

2. Defining the human tremor

Tremor is the most common movement disorder characterized by repetitive and stereotyped movements [1]. The human tremor is a clinical manifestation characterized by an involuntary, rhythmic, oscillatory movement of a body part that can be classified in many ways, depending on its etiology, phenomenology, frequency, location and pharmacological response [2; 3].

The rhythmic characteristic of tremor around a balanced position, as the regular rhythm, amplitude and frequency make easier the identification and also the differential diagnosis of tremor, distinguishing it from other involuntary movements.

The movement caused by tremor can be associated to many factors such as neurological disorders and natural processes. The latter is often referred to as physiological tremor and is present in greater or lesser degree, in all humans [2; 4]. The presence of severe tremor disorders causes many difficulties, and can also indicate the presence of diseases related to the central nervous system (CNS). However, the dividing landmark between physiological tremor and that resultant of dysfunctions is tenuous and has not been precisely established, since the changes in the CNS control that causes it can be associated to many factors. Some examples of pathological tremor, i.e. associated to neurological disorder factors, are the cerebellar, essential and parkinsonian tremor [5], and others, such as in psychogenic, orthostatic and neuropathic tremor, which are considered relatively rare in the medical literature [6].

According to phenomenology, or better, according to the circumstances in which tremor manifests it can be classified in two main types: resting tremor and action tremor [4]. The resting tremor can be observed when the body part in which it appears is not suffering the effects of gravity and the muscles are not contracted [4]. Usually, the resting tremor has the characteristic of adduction-abduction or flexion-extension. The main example of resting tremor is the parkinsonian tremor.

The action tremor appears during a voluntary muscle contraction [4]. The action tremor encompasses postural, kinetic, intentional, task-specific and isometric tremor.

The postural tremor can be observed when maintaining a voluntary position against the effect of gravity [4]. Some examples of postural tremor are the essential, cephalic, axial cerebellar and primary orthostatic tremor. The kinetic tremor can be observed while performing a voluntary movement [4], whereas the intentional tremor occurs during a movement, but specifically when there is the intention to hit a target, like in the test of finger-nose, while writing, speaking and handling objects. The cerebellar, essential and mesencephalic tremor are examples of intentional tremor.

The task-specific tremor is manifested almost exclusively during a specific motor movement, such as the activities of writing, drawing or playing a musical instrument [4]. Finally, the isometric tremor occurs when the affected segment is contracted without the occurrence of the displacement of the body segment [4]. Generally it can be observed in isometric muscle contraction, which occurs when force is exerted against a steady object, like in the act of pushing a wall or flexing the wrist on a surface.

Usually, the essential tremor and the enhanced physiological tremor are classified as postural tremor. The parkinsonian tremor is typically a resting tremor and decreases its amplitude with movement. Instead, the cerebellar tremor appears while performing a movement, therefore, is considered an action tremor, predominantly kinetic. In mesencephalic and Holmes' tremor it can be found a mixture of resting, postural and kinetic tremor with high amplitude and intensity.

Regarding the frequency of tremor, or rather, according to number of oscillations of the affected segment in a unit time, tremor can be classified into three main types: low frequency tremor (less than four cycles per second or Hertz); middle frequency tremor (between 4 and 7 Hz) and high-frequency tremor (more than 7 Hz) [4]. Physiological tremor usually presents high frequency (8-12 Hz) and low amplitude. Essential tremor reaches frequencies between 6-12 Hz while tremor from Parkinson`s disease usually has frequencies between 4 and 6 Hz. The cerebellar tremor is also a low frequency tremor (less than 5 Hz), such as the mesencephalic tremor (2-5 Hz). However, the frequency range for tremor can vary depending on the patient condition and the type of treatment he is receiving.

Regarding to the location, it is possible to observe that tremor can occur in any part of the body; however the limb segments and the head are the most affected. There may be involvement of other body parts, such as the trunk, but this situation is not common [4].

According to drug response, beta-adrenergic blockers are commonly used in physiological tremor treatment. Alcohol, which can be used as therapeutic method, may be employed in patients with essential tremor. Tremor can also be reduced by relaxation, concentration, voluntary suppression and the increase of load on the affected extremity.

About two thirds of patients with essential tremor show considerable reduction of tremor for 45 to 60 minutes after the ingestion of alcohol; however alcohol cannot be used over a long period of time because in the course of time larger quantities will be required to produce similar effects, which can cause chronic alcoholism. Furthermore, when the effect of alcohol is over, tremor gets worse. The treatment of essential tremor is done with primidone or beta-blockers, another alternative is the use of the botulinum toxin direct in the affected muscles. Besides this, alprazolam has effect in the treatment of essential tremor. When this pathology is clinically intractable, a contralateral thalamotomy surgery is indicated.

The parkinsonian tremor can be reduced or controlled by the use of drugs with dopaminergic effects and with anticholinergics; in certain cases, a thalamotomy able to reach the thalamic nucleus, specially the lower ventral medial nucleus, is used in the case of unilateral Parkinson's disease. The constant thalamic high frequency stimulation is related with good results in essential and parkinsonian tremor. The deep thalamic cerebral stimulation is safer and more effective than thalamotomy, which requires the permanent placement of an electrode in the brain. Side effects of deep brain stimulation are reversible with the manipulation of the stimulation parameters.

The cerebellar tremor does not respond well to treatments. Usually substances that increase the gabaergic activity, like valproic acid, clonazepam and isoniazid, are used. The mesencephalic tremor does not respond well to some drugs either, especially its postural component. However, the resting component can improve with anticholinergics. The stereotactic surgery on the ventral medial nucleus of thalamus can control the postural component.

Thousands of people each year begin to present some type of motor dysfunction, which interferes in their daily activities and reduces significantly the quality of life of these individuals. A number of studies and governmental statistics have shown that the elderly population is the most affected by tremor and its consequences, which are responsible for physical limitations of these individuals [1].

The manifestation of the tremor can cause considerable functional incapacity leading to social isolation by interference in the activities of daily living (ADLs) and instrumental activities of daily living (IADL) such as eating, writing, dressing and maintaining some personal care [7].

Moreover, recent researches from the Brazilian Ministry of Health (available on www.saude.gov.br) suggest that signs like tremor and loss of balance do not always mean the presence of neurological diseases such as Parkinson's disease, which affects mainly the population with age over 50 years old. According to this Ministry about 25% of patients who exhibit signs of Parkinson do not have the disease. The imprecise diagnosis of these diseases and the consequent use of unnecessary or inappropriate drugs also results in waste of public resources.

Generally, current therapies are limited because they relieve symptoms more than cure. The most commonly used drugs are: propranolol, primidone, gabapentin, topiramate and others to be considered comprise in the second row like alprazolam, atenolol, sotalol and clonazepam and, in the third line: clozapine, nadolol, nimodipine, being the botulinum toxin the first line for hands, head and voice tremors, in cases of essential tremor.

Some studies have suggested that moderate tremor, which accompanies the natural aging process can be diagnosed as pathological tremor. It is also possible that the pathological tremor is wrongly diagnosed as physiological tremor [5].

The human tremor is a public health problem faced all over the world. Costs related to medical and social aspects, necessary for diagnosis and treatment of tremor, have grown constantly in past decades and currently reach billions of dollars in many countries. A treatment that seeks to mitigate the symptoms and create the possibility of a person with tremor accomplish everyday tasks constitute an important intervention. In this context, studies that contribute to the understanding of tremor are of paramount importance.

3. Understanding the origins of human tremor

The study of tremor is not new and it can be found in the biblical texts and documents of antiquity coming from India and Egypt [3]. The interest in the study of tremor increased over the past decades and, lately, many researches can be found in this area, especially related to the quantification of human tremor signals. Quantification of tremor allows studying it in an objective way, making it possible to establish relationships between the tremor activity and variables, such as age or the presence of neurological dysfunctions.

Regarding to the study of tremor's origins only relatively recently such ideas have received great interest [8].

The movement caused by tremor can be associated to factors such as neurological disorders and natural processes. [2; 11; 12] The former is called pathological tremor whereas the latter is often referred to as physiological tremor.

There are several hypotheses to explain the appearance of physiological tremor (PT). One explanation for the existence of physiological tremor is the effect of ballistocardiogram, i.e., the passive vibration of the body tissues produced by the mechanical activity of the heart [13], i.e., a result of mechanical reflexes of the heartbeat and also of neural reflexes [14]. Another hypothesis is that physiological tremor is induced by mechanical properties of limbs and motor neurons firings.

It is also believed that the physiological tremor is a peripheral manifestation of neural oscillatory activity in the central nervous system (CNS) and that some types of pathological tremors are resultant of distortions and amplifications of these central oscillations [8].

According to Hallett (1998), the sources of tremor can be summarized into three groups: mechanical, reflex and central oscillations [9].

The first source is the mechanical oscillations, in which joints and muscle movements satisfy the laws of physics and the complex joint-muscle-tendon system can be compared to masses and springs. Therefore, the oscillations can be interpreted as the movements of masses and springs [10].

The second source of tremor is the reflex oscillations that are reported in the central and peripheral circuits. On the peripheral circuit the path occurs from muscles to the spinal cord and from the spinal cord to the muscles. On the central circuit the path occurs from peripheral to the spinal cord and supraspinal segments including the brain, cerebellum, basal ganglia and cerebral cortex [10].

The third and last source of tremor is central oscillations that can be observed since the first recordings of the electroencephalography (EEG). The neural activity follows rhythmic behavior. Therefore, the cerebral cortex, the basal ganglia, the cerebellum and the brainstem nucleus are all involved in the genesis of tremor [10].

Detailed analysis of oscillations in the CNS are imprecise due to the difficulty in performing measurements directly in the human brain [8]. As these neural oscillations can directly influence motor control and indicate the status of the CNS, the interest in the study of various types of tremor, as peripheral manifestations of central oscillations, has grown in recent years.

We still do not have a precise definition of the origin of tremor in humans. It is believed that it is a product of several factors. Thus, the tremor is considered a peripheral oscillation that may also have, in addition to contributions of neural activities, activities originating from the motor units and from the resonances of reflex arcs [8].

Moreover, the pathological tremor can be associated with several factors, such as neurological disorders [2].

4. How to detect and record tremor?

There are several ways for measuring human tremor. However, even today, the most used methods are those that makes the use of severity scales [17; 18]. In these methods, the patients are asked to perform different drawing patterns such as spirals, circles and letters (Figures 1 to 9). These drawings are subsequently classified by neurologists according to a numeric scale, usually ranging from 0 (no visible tremor) to 5 (severe disabling tremor). The drawings made by patients are then compared with examples of previous researches, carried out taking into account others patients previously classified. Therefore, this type of classification consists in a visual comparison and contains the subjectivity of the expert responsible for the analysis. In addition, this analysis prevents the extraction of critical information from tremor activity, such as frequency, amplitude and speed.

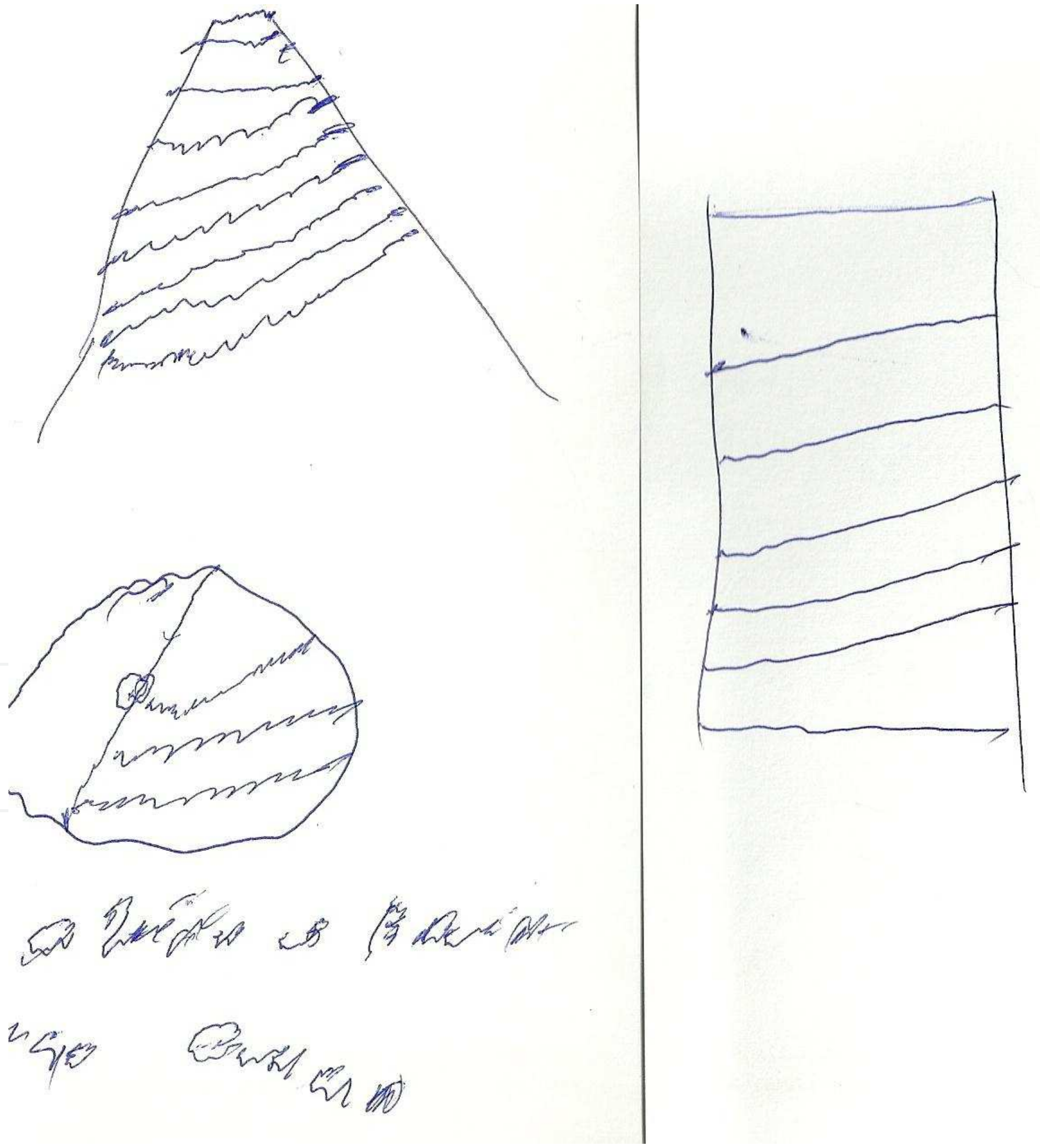

Figure 1. Action tremor. Male patient born in 1934. Date: 09/03/2009.

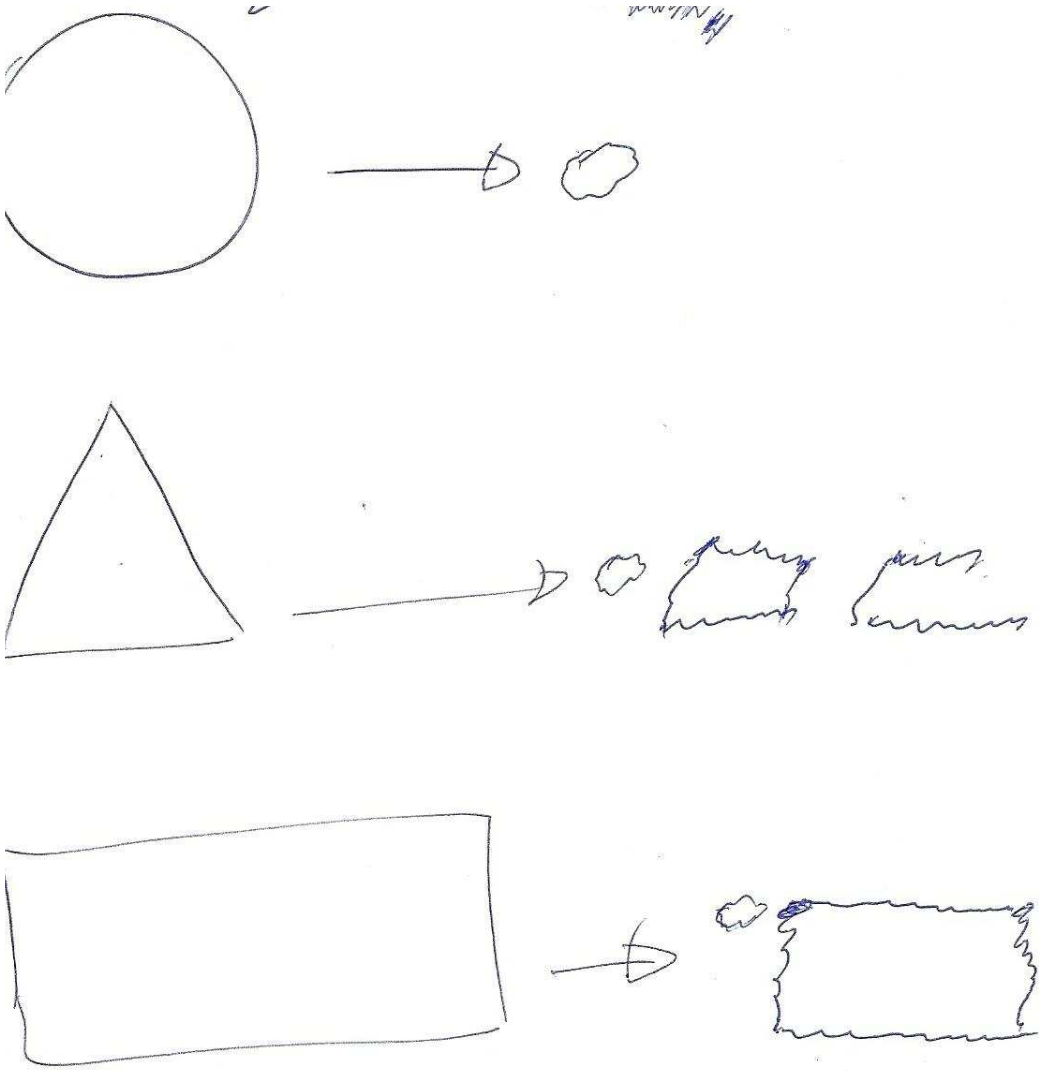

Figure 2. Action tremor. Male patient born in 1934. Date: 09/03/2009.

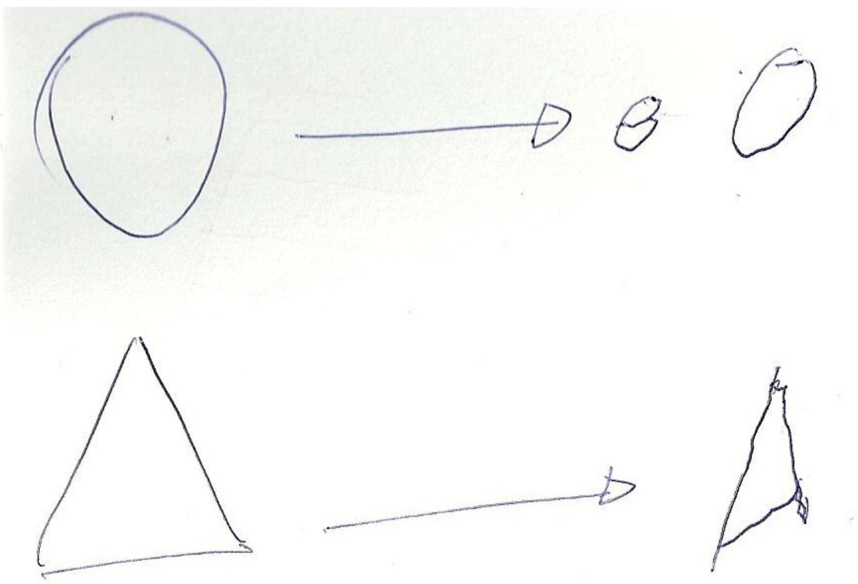

Figure 3. Action tremor. Male patient born in 1934 after treatment with levodopa. Date: 10/05/2010.

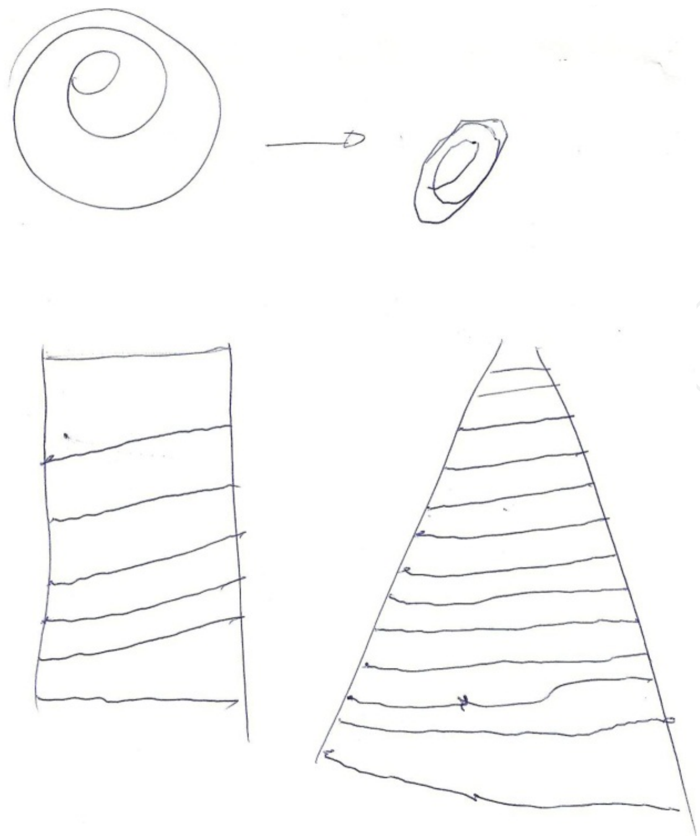

Figure 4. Action tremor. Male patient born in 1934 after treatment with levodopa. Date: 10/05/2010.

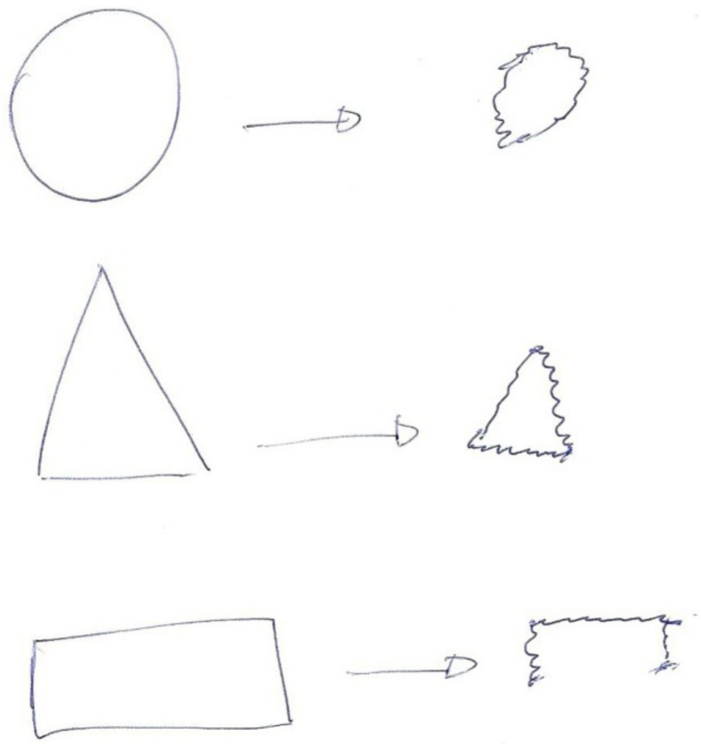

Figure 5. Male patient born in 1937. Vascular tremor: left hand tremor since 1989, dizziness, hypertension, patellar hyperreflexia, leucoaraiose, brain volume reduction, brain gap and microangiopathy. Date: 05/08/2010.

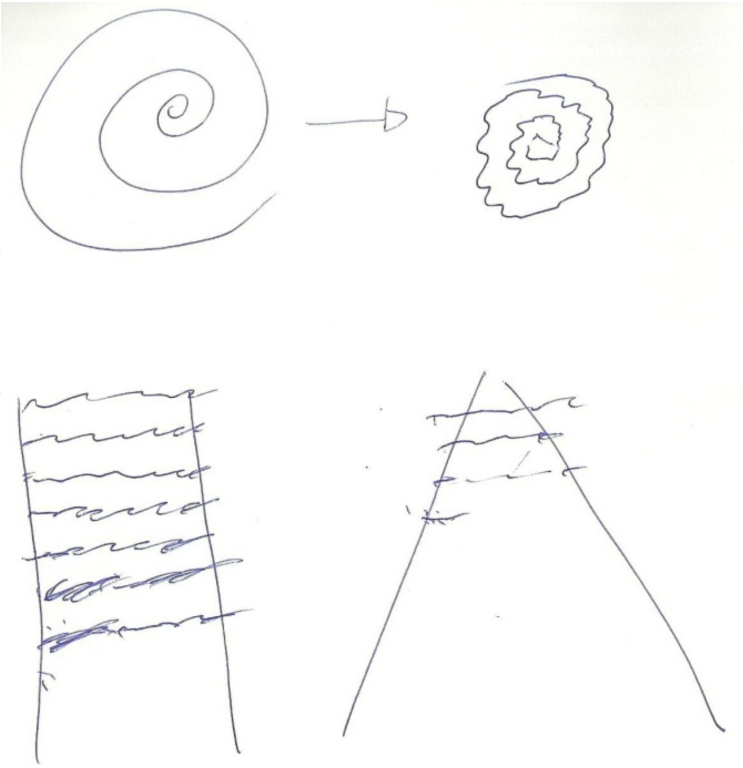

Figure 6. Male patient born in 1937. Vascular tremor: left hand tremor since 1989, dizziness, hypertension, patellar hyperreflexia, leucoaraiose, brain volume reduction, brain gap and microangiopathy. Date: 05/08/2010.

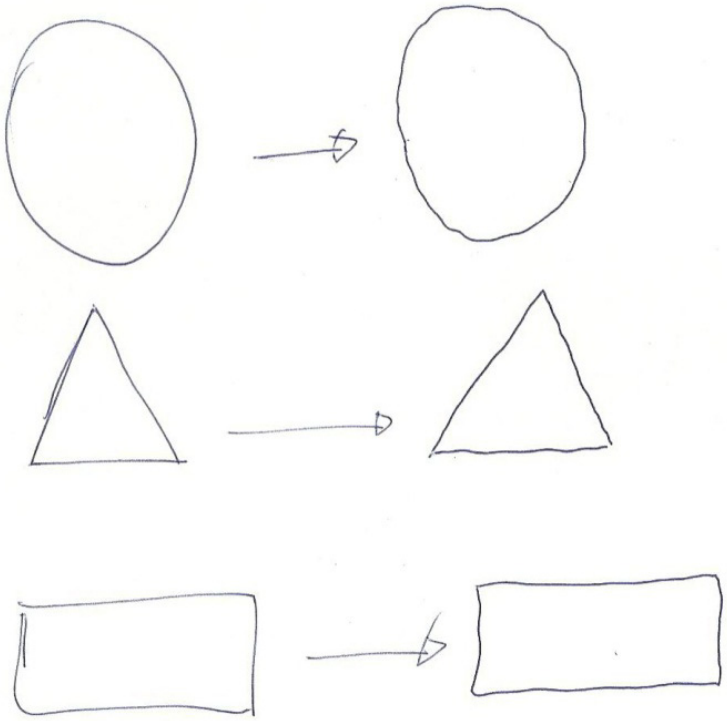

Figure 7. Female patient born in 1983. Hand tremor for four years that gets worse with anxiety and while handling objects. Absence of neurological signs. Normal dosage of calcium and parathyroid hormone. Absence of familiar cases.

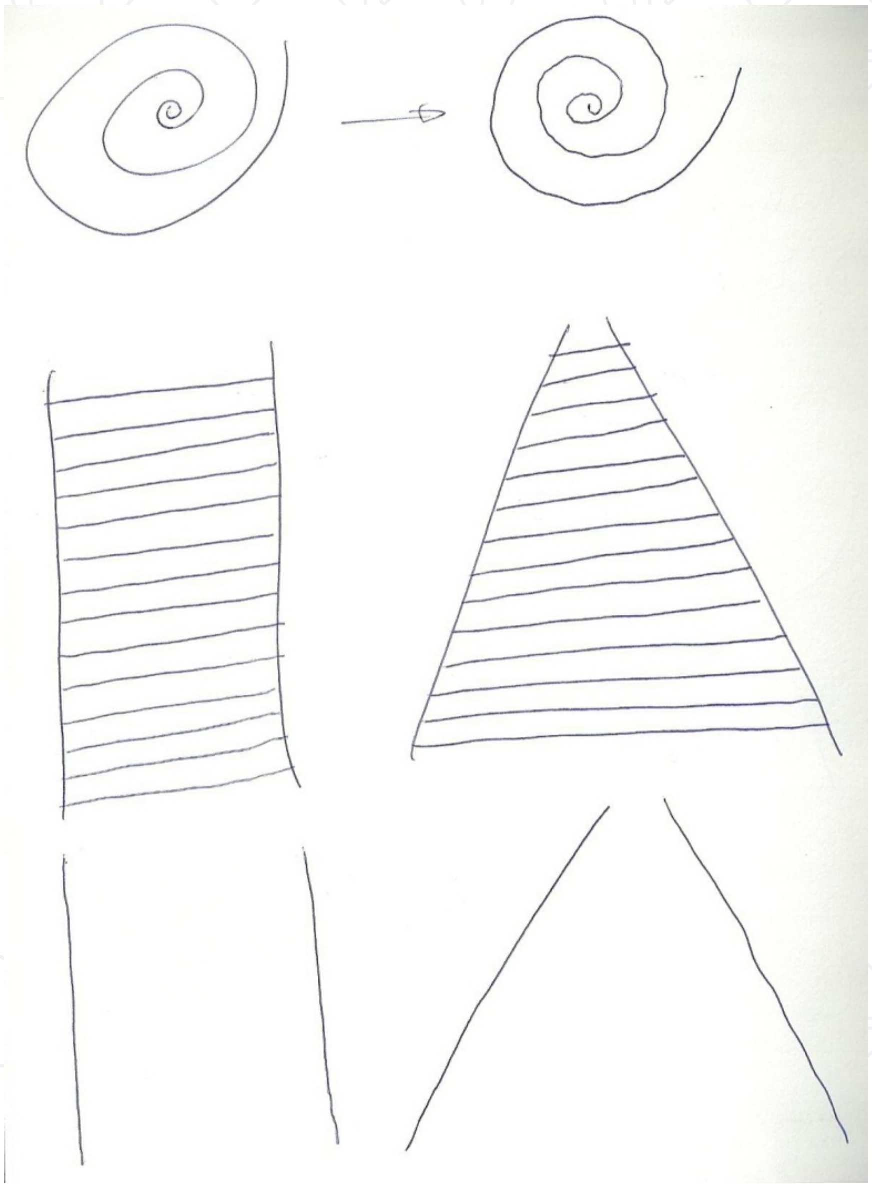

Figure 8. Female patient born in 1983. Hand tremor for four years that gets worse with anxiety and while handling objects. Absence of neurological signs. Normal dosage of calcium and parathyroid hormone. Absence of familiar cases.

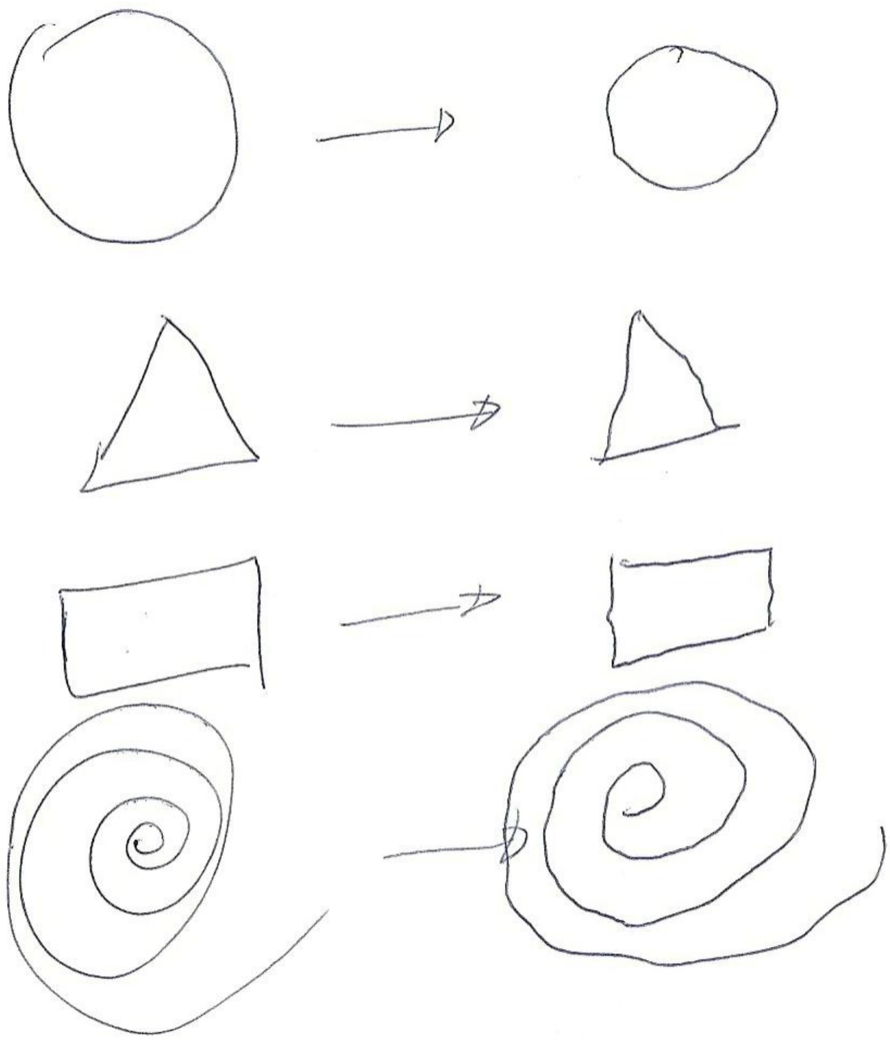

Figure 9. Female patient born in 1929. Left hand tremor, oblivion, normal neurological examination. Nuclear magnetic resonance of the brain: ischemic lacunar lesions, acute semioval center ischemia, slight brain reduction.

For the clinical diagnosis of tremor, it is necessary a complete and detailed medical history relative to factors, such as age of onset of tremor, family history, circumstances that modifies the tremor, use of drugs that can trigger the movement, existence of comorbidities, use of alcohol, smoking, anxiety, stress and depression. Besides this, it is important to do a clinical neurological exam analyzing the semiological aspects, with special focus on the type of tremor and how it presents, examining the patient standing, sitting, walking or performing movements of limbs (evidence of coordination of upper and lower limbs), supination and pronation movements, presence or absence of cog.

Regarding to physiological and essential tremor, there is no need for further investigation. Laboratory tests are important to rule out endocrine (thyroid) or other extrapyramidal diseases that manifest tremor, e.g. dosage of ceruloplasmin and copper, as well as eye examination (in Wilson's disease). Imaging and functional neuroimagins – PET and SPECT-CT positron and photon emission tomography may be useful in differentiation between essential and parkinsonian tremors, using markers for dopamine transporter or striatal dopaminergic terminals.

The different forms of assessment of tremor can be divided into clinical and biomechanical evaluation that takes into account qualitative and quantitative analysis. Clinical evaluation is based on clinical studies dedicated to the understanding of the characteristics, evolution and treatment of diseases, which has tremor as one of its manifestations. Thus, these evaluations are basically composed of scales. Currently, rating scales such as Washington Heights-Inwood Genetic Study of Essential Tremor – WHIGET tremor rating scale – wTRS [19; 20], Fahn-Tolosa-Marin Tremor Rating Scale [21], and the Essential Tremor Rating Assessment Scale – TETRAS [22] are used to evaluate essential tremor during the clinical examination. Each tremor rating scale subjectively scale the intensity of tremor from 0 to 4, generally corresponding (0) normal (1) slightly abnormal, (2) mildly abnormal (3), moderately abnormal, and (4) severely abnormal. Other scales are also used for evaluation of Parkinson's disease, such as UPDRS and Hoehn and Yahr. The UPDRS is a clinical tool for evaluating patients with this disorder. Recently, the Movement Disorder Society – MDS recommended a review, published in 2008, named MDS-UPDRS [16]. The MDS-UPDRS scale consists of a list of questions divided into four parts, in which the values 0-4 should be assigned depending on the severity of tremor: 0 - normal or smooth, 1 - minimum problems, 2 - mild impairment, 3 - moderate problems and 4 - serious problems. Another scale used to assess the level of Parkinson's diseases in patients is the Hoehn and Yahr. The scale is a simple staging that evaluates the overall severity of Parkinsonism based on bilateral motor dysfunction, involvement and the compromise of gait and balance. The original 5-point scale (Stage 1-5) was subsequently modified to a 7-point scale stages that included 1.5 and 2.5 in the 1990s [23].

The clinical evaluation of patients with pathological tremor is usually based on patterns that are obtained by observing groups of analysis. For each disease there is a standard for evaluation of patients. Some of these patterns are briefly described below.

MDS-sponsored UPDRS Revision (MDS-UPDRS) – Result of changes in the original pattern known as the Unified Parkinson's Disease Rating Scale (UPDRS), is the most used method for analyzing the development of Parkinson's disease. This tool is used for quantitative assessment and treatment of patients and consists in a list of questions divided into four parts, to which must be assigned values between 0 and 4, depending on the severity of the problem: 0 - normal, 1 - light, 2-soft, 3 - moderate, and 4 - severe. The MDS-UPDRS maintains the structure of the UPDRS, i.e contains four parts. However, these component parts have been modified in order to promote integration with elements of non-motor Parkinson's disease: part I - non-motor experiences of daily living; Part II - motor daily experiences, part III - motor examination, part IV - motor complications. Parts I and II are evaluated according to the patient's own responses to a questionnaire. The tool analyzes the symptoms of Parkinson's disease through clinical evaluation and patient self-report [24].

Hoehn and Yahr Scale – This tool is used in the evaluation of patients with Parkinson's disease, classifying them into six stages, ranging between 0 and 5 [3]. In its original version, this scale comprises five stages of evaluating the severity of Parkinson's disease and covers comprehensive measures of signs and symptoms, including postural instability, rigidity, tremor and bradiscinesia [24]. Patients classified between stages I and III have light to moderate stage of the disease, as those who fall between stages IV and V have severe disabilities, and the stage V indicates an inability to move alone. A modified version of Hoehn and Yahr Scale also features two intermediate stages for evaluation of disease [24]. The protocol of this tool includes tests that evaluate the severity of resting, postural and kinetic tremors. Besides this, the test includes tasks such as extension of the arms, ingestion of liquids using spoons and cups, drawings of the spiral of Archimedes and exercises like touch the own nose with the finger. The protocol also includes specific instructions for scoring and that the expert can classify each task performed by the patient.

Washington Heights-Inwood Genetic Study of Essential Tremor (WHIGET) – It is the most used tool in clinical assessment of essential tremor. This tool has emerged from a study started in 1955, which aimed to investigate genetic aspects of essential tremor by using methods not yet implemented [3].

Bain – Clinical examination of Bain consists in performing a series of tests that analyze the various components of tremor (resting tremor, postural tremor, kinetic tremor, intention tremor) [25]. The various components of the tremor are analyzed as follows: 1 - the resting component of the tremor of the head is measured with the patient lying on a couch with his head resting on cushions and postural component is collected with the patient sitting unsupported on the head and looking forward; 2 - component of the postural tremor of lower limbs is analyzed with the patient seated and with the extended leg, while the rest tremor is analyzed with the feet of the patient placed on the floor, the upper limbs are evaluated with the patient seated, three component of the tremor at rest is analyzed while the arms are relaxed and flat on the neck of the patient, while the postural component is analyzed with arms outstretched, hands pronated and fingers separated; 4 - the kinetic component is measured during the transitional phase of the test finger-nose and intentional component is measured while the finger of the subject gets closer to a target placed at reach. Vocal tremor is analyzed from the speech of each patient (patients should speak his own name, address and birthday) and, moreover, from the sound of singing from the patient, holding a musical note with the voice. All the tasks are scored from 0 to 10, as follows: 0-3 - light, 4-6 - moderate, 7-9 - severe and 10 - very severe [25].

We can observe that clinical evaluation is not able to provide many answers regarding the evolution of the disease, since it does not consider the peculiarities of each patient and uses the subjectivity of experts during the evaluation and classification of the individuals.

Aiming to eliminate the subjectivity and limitations of the analysis methods based on scales some techniques to measure and analyse the tremor electronically have been developed. Thus, besides the methods employed in the clinical evaluation, many others are applied to evaluate the tremor in the laboratory. The most common methods are accelerometry, electromyography (EMG) and spirography [5]. The biomechanical analysis of the tremor involves qualitative and quantitative aspects, and its main methods of measuring are electromyography (EMG), magnetic tracker system, active optical markers, accelerometers, gyroscopes and spirography.

The most common method for eletronic evaluation of tremor is the accelerometry, which makes use of sensors to measure the acceleration of a body part [12; 26; 27; 28]. Accelerometers are the main tool for the identification of tremor, easily observed by the large number of recent studies addressing the assessment of tremor [29; 30; 31; 32; 33; 34; 35]. The accelerometers measure linear acceleration forces in three orthogonal directions, being able to capture the movement of members produced by the action of gravity and muscle action, including tremors.

In accelerometry, data acquisition is performed by a sensor known as accelerometer that based on the Newton's second law, is capable of measuring the acceleration of a body. The accelerometer consists of an electromechanical device, usually based on the piezoelectric effect or the variation of capacitance which, when attached to any part of the body is capable of measuring acceleration forces or the movement caused by the tremor. This device generates a sequence of values (time-series) representing the instantaneous value of the acceleration as a function of time on the body part in which the sensor has been set. This series is stored and it can later be analyzed computationally.

Following this same logic (electronic evaluation, storage and computational analysis), other methods have been proposed, such as gyroscopes (evaluation of angular displacement) and speed / position transducers of many types [11; 29].

Gyroscopes are devices used to measure angular velocity. It is a simple device to detect the rate of change in the orientation of each segment and are insensitive to gravitational force [36].

Another tool to detect tremor consists in the use of electromyography. The electromyographic signal (EMG) can be considered as the superposition of individual activity of several active motor units during muscle contraction and may be used to diagnose many types of neuromuscular disorders. The EMG signal may be picked up by electrodes placed on the skin surface or by means of needle / wire electrodes which are introduced into the muscle tissue [26; 27; 28; 37].

Electromyography is an experimental technique concerned with the development, recording and analysis of myoelectric signals. The frequency (Hz), mean amplitude (mV) and pattern (synchronous or alternating) are used to evaluate the tremor [38].

In the acquisition of electromyographic signals for tremor analysis is common to use a specific task with the use of weights to reduce the influence of the heartbeat on the acquired electromyographic signal. For example, Elble (2003) compared the tremor in two groups of healthy individuals, a group of young (20-42 years old) and another group of elderly (70-92 years old). Elble analyzed the signals obtained in a state without load and with the addition of a weight of 300g. In this study, subjects were seated with the forearm supported and hands at rest or under load (palm and fingers extended in a straight line with the forearm).

Currently, there are devices for movement capture with wireless technology, that are capable to integrate accelerometers and gyroscopes. These devices are light and easy to use, being commonly used for the study of tremor [39].

Furthermore, there are still new devices for tremor evaluation through videos [30] and tools that use accelerometers and transmit information through internet and Bluetooth technology [41]. The magnetic tracker system provides the movement displacement (x, y and z) and orientation (pitch, roll and yaw) of each body segment relative to a fixed transmitter [42]. From the active optical markers can be extracted the acceleration and the application of trigonometry makes possible the description of the vector orientation and the estimation of limb posture [43].

Tremor quantification can be used to control the administration of therapeutic drugs [39] and the optimization of deep brain stimulation [40].

The signal processing and analysis of tremor often involves the spectral analysis, based on Fast Fourier Transform – FFT [35; 39; 41], but this technique as modified weighted Fourier Linear Combiner –WFLC [44] is suitable for periodic or quasi-periodic estimation of motion with single dominant frequency, whereas Band-Limited Multiple Fourier Linear Combiner – BMFLC [34] is suitable for estimation of band limited signals consisting of multiple frequency components. Other methods can also be found as Detrended Fluctuation Analysis (DFA) to analyze hand essential tremor time-series extracted from regions around the first three main frequency components of the tremor power spectra – PWS [45]. To increase the accuracy other modifications or algorithms are used [46; 47]. However, it is not possible to determine the best way to perform these analyses, since this depends on the objectives of the study. Therefore, it is not possible to reach any conclusion on the most appropriate methodologies for the detection and diagnosis of tremor [3].

Hand-drawing patterns are commonly assessed by means of visual rating scales.[48; 49] However, such scales provide only crude subjective estimates of tremor amplitude. In order to reduce the subjectivity and limitation of some methods based on visual scales, there have been developed a few strategies for electronically measuring tremor, such as accelerometry and digitizing tablets. The use of digitizing tablets is common and provides the possibility of tremor activity detection under kinetic conditions.

The usual function of a digitizing tablet is to enable the analysis of drawings directly on the computer. The measurement of tremor by using digitizing tablets is a non-invasive alternative for tremor detection that combines simplicity with the precision and versatility of computational methods. The digitizing tablet is able to inform the position of the tip of the pen on its surface. By using this property this device can detect the movement of a subject following standard drawing patterns placed on it [27; 49; 50; 51; 52; 53; 54; 55; 56]

Subjectively interpreted in previous decades, nowadays the digital spirography can provide quantitative data of the movement control [57]. The spirography has been considered valid and reliable to diagnose early Parkinson's disease [58], essential tremor [59] and to distinguish tremulous parkinsonian patients with normal presynaptic dopaminergic imaging from tremulous patients with Parkinson's disease [60]. In general, the signals are recorded and stored for posterior analysis. The analysis involves methods such as the radius-angle transformations of the two-dimensional spiral pictures that are captured from the original clinical information (shape, kinematics and dynamics) [57; 58]. In addition, more sophisticated tools and modern statistical algorithms can be used for data evaluation [59; 60].

Digitizing tablet was used by Almeida (2010) [5] with a technique known as spirography. This technique consists in the reproduction by the patient of the Archimedes' spiral according to an ideal model. Thus, a model of this spiral is displayed on the table surface and the patient should try to cover the route of the model as accurately as possible.

Several attributes of the spiral of Archimedes make its use attractive in tests for the detection of human tremor. First, it has a simple design and it is easily understood by subjects who can follow its trajectory. Secondly, the shape of the spiral is smooth with an increasing radius, reducing the occurrence of false-positive tremor caused by abrupt changes in the direction of motion

There are a number of research studies concerning the employment of digitizing tablets for both the quantification of pathological tremor and the detection of movement disorders [49; 50; 51; 52; 53; 54; 55; 56; 61]. However, even with the advances in the technology of digitizing tablets, which allowed for more precision and accuracy in the measurement of movements, no study focusing upon the use of these devices, as a tool for investigating the relation between physiological tremor and ageing in kinetic conditions, was found in our literature survey. Although some authors, e.g., Wenzelburger *et al.*,[62] support the hypothesis that kinetic tremor is related to an enhancement of physiological tremor this assumption is not consensual [26; 27; 63] and therefore additional studies in this area are required.

The different ways of evaluating the tremor, clinical and biomechanics, can be viewed as complementary and in general are used simultaneously, with the aim of compare the qualitative and quantitative data. Thus, it is expected that future improvement of existing tools, as well as the introduction of new tools better clarify this point.

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