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Hand tremor Simulator for Preclinical Assessment of Parkinsonism

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Abstract: *Patients visiting hospitals for their treatment are usually in trauma; so, they do not have patience to spare time for research based experiments. For testing the performance, expected output, reproducibility and safety issues of newly developed medical diagnostic and therapeutic devices, many iterative experiments are needed which will be difficult to carry in clinical environment. We designed and developed a hand tremor simulator by which hand is made to shake at tremor frequency. Hand tremors are early symptoms of Parkinson's disease (PD). Before going for real data to assess Parkinsonism from the PD patients, we acquired the data in the laboratory from the tremor simulator. The data consists of Archimedes Spiral drawings drawn from the hand in normal writing speed and shaking the hand at tremor frequency by the simulator. The spirals were drawn on plain white papers by a pen. The data was collected from ten normal adult male persons of mean 24 years age group (+/-2). We validated our results with the standard data published by peer researchers. The protocol for evaluation of spiral drawings at simulated tremor frequency that we established, could help in evaluation of the clinical data obtained from the PD patients.*

KEYWORDS: *Hand Tremor; Parkinsonism; Simulator; Spiral drawing; Parkinson's disease.*

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I. Introduction

A simulator is a device which reproduces or represents under-test conditions phenomena that would likely to occur during actual performance. Briefly, the simulator resembles to the reality under pre-defied conditions that can replicate the realism and unpredictability of actual situations. Simulators and modeling plays important role in biomedical research. They are also being efficiently used for flight simulation, vehicle road driving tests, gaming and medical educational purposes. Newly developed medical diagnostic and therapeutic systems are usually tested for their expected output performance, reproducibility and safety issues in the laboratory before applying on patients under clinical conditions. During the procedure, the patient models are simulated characterizing specific diseases or abnormalities. Hence, the simulated models are more important in the biomedical research for the complex disease systems that is to be conquered, and for preclinical testing of preventive or therapeutic approaches. Model based simulation give scope for exploration, generation and testing of hypotheses [1]. For creating simulated models, engineering and technological skills are required in their construction to target accomplishments.

There are several modes of simulated models being used in biomedical studies. Mathematical models, computer models, animal models, mammalian models and hybrid simulators are few of well-known simulating models used by the medical researchers [2]. Human breast has been modeled from materials to evaluate newly developed imaging systems. For the detection of breast cancer, microwave imaging systems have been developed and tested its performance from simulated breast models. The models were made from materials representing human breast tissues [3]. Several researchers have investigated the effects of mammary gland density for dose calculation on simulated breast models [4][5]. Patient specific kidney was simulated for interventional urology studies [6][7]. Magnetic resonance imaging (MRI) technique is being continuously improving and the protocol has been updating to achieve superior images of body organs. To improve the diagnosis of cardiovascular diseases through MRI, dynamic heart models were developed and validated the technique [8]. From their reported studies, it is understood that any abnormal situation can be simulated to analyze and validate a new diagnostic system, before applying on actual cases. In our study, we developed a human hand tremor simulator to research a probable protocol for the diagnosis of Parkinsonism. The simulator will save the time and effort of accessing Parkinson's disease patients through hospitals.

II. Literature Review

Parkinson's disease is a long term progressive nervous disorder system affecting the movement of the patient. Parkinsonism, which is symptomatic sign of PD, includes trembling of the hands, arms, legs, jaw and face. It also causes stiffness in the arms, legs and trunk resulting in slow movement. The balance of body could be lost while walking and the coordination among limbs may be disturbed. There are no prescribed lab tests are available for PD which makes the physicians difficult to diagnose [9].

It is estimated that about 7 to 10 million people worldwide are suffering from PD and 27 per 100,000 populations have the disease in Saudi Arabia [10]. Signs and symptoms, characterizing PD are varied but the tremor is believed as motor symptom of the disease. A tremor is a rhythmical, involuntary shaking of the body or the parts [11]. The shaking disorder usually begins in the hand or arm, though the limb is resting or relaxed [12]. Tremor is not fatal but it affects the quality of everyday activities. Most of the time, doctors refer the tremor as Parkinsonism which can be a visually noticeable symptom. Tremor can be of two types; either 'rest tremor' or 'action tremor' [13]. Resting tremor, which is at 4-7 Hz frequency, is considered as an important criterion for the diagnosis of PD [14][15]. More than 75% of PD patients experiences difficulties in eating, writing and holding objects [16] due to the tremor. Doctors routinely assess the tremor from writing and spiral drawing samples from the patients. It is then evaluated by a score of 0-9 which is based on visual rating score (VRS). The score is considered as clinical index from which the severity of the tremor is quantified [17]. However, the procedure of visual score assessment is an examiner dependent which is vulnerable to minor changes in the drawing and the measurement protocol. Therefore, the objective of this work is to evaluate the spiral drawings more precisely, considering small changes in tremor induced from the hand. To simulate hand tremor, a technical vibrating platform is designed to shake the hand while drawing spirals on paper at tremor frequency (4-7 Hz) simulating Parkinsonism in the normal hand. The tremor simulator will help to conduct as many experiments in the laboratory as possible. Usually the patients visiting hospitals are in trauma during which they feel discomfort when they are asked for repetition of experiments during assessment. Therefore, the designed simulator can be considered for preclinical trials to standardize the procedure of evaluating tremor.

III. Methodology

Design and development of tremor simulator

A small hand shaking table has been fabricated in order to simulate hand tremors that could be analogous to symptomatic Parkinsonism. The simulator has a horizontal sheet (100x60x4 mm) for keeping the hand and the plywood sheet is supported by four vertical stands, each carrying a linear spring to produce dynamics on the sheet during compression action. The hand resting sheet is fitted such that it can make translational motion from a d. c. motor attached below the sheet. The motor powered by 12 V battery source, has a gear attachment so that the geared motor can rotate at 100 RPM speed. A cam shaped disc is firmly fixed at the motor shaft end. When the motor rotates, the disc pushes a metal pin which is fixed to the bottom surface of the sheet. The sheet was drilled four holes for the supporting screws which carries four springs. The holes are of 10 mm long to allow the sheet to make back and forth movement.

The motor with 100 RPM speed can produce 1.67 Hz frequency by shaking the sheet. But, the cam disc has four edges so that the frequency of our simulator is 6.67 Hz., which is same as tremor frequency. The four holes in the sheet are 10 mm long by which the tremor intensity can be envisaged. Figure 1 shows schematic of the designed simulator. When the forearm is placed on the sheet of the simulator, it allows the hand to shake at tremor frequency.

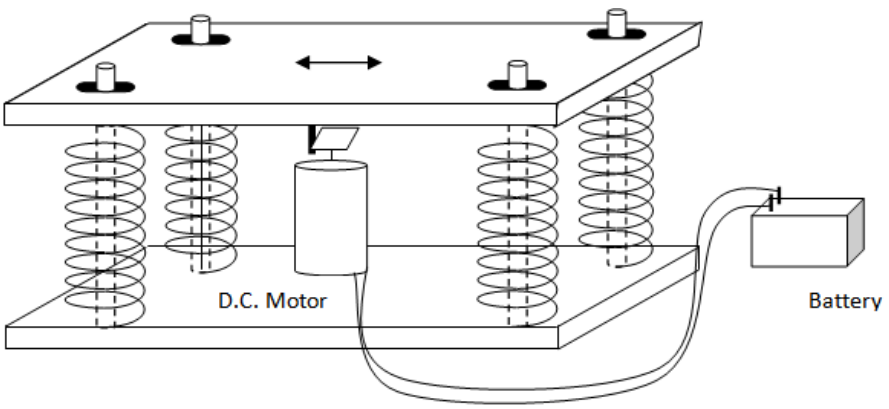


Fig. 1. Schematic diagram of tremor simulator.

The simulator has been designed and fabricated by the authors. This is a novel design and this type of tremor simulator did not find elsewhere. The frequency of the simulator was calibrated with a standard linear actuator.

Spiral drawing

Investigators have been using simple tests like writing and drawing in the preliminary assessment of upper limb movement disorders. Spiral drawing approach has become significant and is considered as standard for clinical evaluation purposes and it has been recommended by the Movement Disorder Society [18]. Mathematical definition of a spiral in words is a curve that emanates from a point, moving farther away as it revolves around the point. There are three types of spiral based on mathematical equations; Archimedean spiral, logarithmic spiral and hyperbolic spiral. Archimedes spiral drawing to detect tremor has become a standard method because the drawing captures frequency, amplitude and direction of hand tremor. They are simple to draw and appear symmetrical to observer. Distortions in the spirals drawn from the tremor hand can be quantifiable and the resulting values could be index of tremor severity. While drawing a spiral, there is continuous movement until an end point of the spiral. Such a continuous recording of the movement cannot be achieved during writing process. Therefore, Archimedean spiral drawing has become a gold standard in detecting tremor.

IV. Results

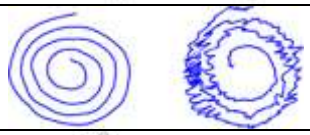
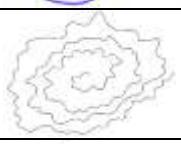
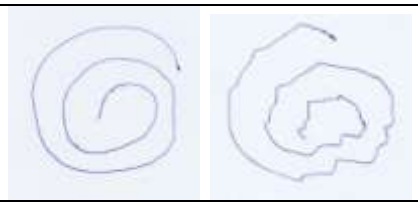
Figure 2 shows arrangement of the simulator to acquire data from tremor hand. The subjects under investigation were asked to sit in relaxed position. Forearm of the right hand was placed on the horizontal sheet of the simulator. The center of mass of the writing forearm was made to rest on the simulator. This will overcome any artifacts in drawings occurred from imbalanced body segmental weights. For analyzing hand tremors, the spiral drawings were considered as our data. In the first stage, the data was acquired from the simulator, without running the motor which is considered as without tremor. During the second stage of data acquisition, the spiral drawings were obtained by switching on the motor. This data was considered as the drawings with hand tremor. The drawings, with and without tremor, were then analyzed to assess the tremor.

Fig. 2. Spiral drawing data acquisition from the tremor simulator.

Archimedes Spirals were drawn on white papers by pen. All the drawing papers were scanned and saved in jpg file format. From image processing technique, the drawings were analyzed. Spiral drawings (with and without tremor) were validated by comparing with standard data which were published in peer journals.

Few examples of spiral drawings from normal and PD patients are shown in the Table. Names of researchers and publication details are also given in the Table. In the last row of the Table, the spirals drawn from the normal and tremor simulator, designed in this work are shown. Visually our results appear similar to the peer works. However, further analysis of this data will quantitatively differentiate and evaluate the tremor. This method is only for evaluation of data analysis and standardization method before taking the real data and clinical evaluation of tremor severity.

Table: Examples of spiral drawings from normal and PD patients appeared in the peer journals.

Reference	Normal and with Tremor
Ideal Archimedes Spiral	
Authors: Dietriches E and Vebjornkvikstad Journal: Tidsskr Nor Legeforen nr. 19, 128: 2210–3, 2008. [19].	
Authors: Chung,Sun Ju Journal: Jl. of the Korean Medical Assoc. ,55(10):987, 2012. [20].	
Authors: Solé-Casals Jordi, Anchustegui-Echearte Iker, et al. Journal: Front. Physiol., 17 January 2019. [21].	
Authors: Manto, Mario and Giuliana, et al. Journal: Current Bioinformatics. 4. 154-172, 2009. [22].	
Authors: Andreas Wille et al. Journal: Biomed Tech 2013; 58 (Suppl. 1), 2013. [23].	
Normal and tremor spiral drawings obtained from our Tremor Simulator	

V. Conclusion

We have designed and developed a tremor simulator for assessment of hand tremors. The simulator is useful for repeated experiments in the laboratory and standardizing a protocol for evaluation of tremor. This will help to generate Archimedes Spiral drawings from the normal persons simulating tremor in their hands during data collection. We have collected the data in our laboratory from normal control group of ten young adults. The subjects were in the age group of 24 years (+/-2) years. We compared the spiral drawings taken from our experiments with standard database. Our data were found in good agreement with the standard data. The designed tremor simulator is intended to use in the laboratory, before going for real tests on PD patients in the clinical environment.

References

[1]. J.Nancy, Nersessian, Topics in Cognitive Science 1 (2009) 730–757.
[2]. Biomedical Models and Resources: Current needs and future opportunities, ISBN: 0-309-56996-6, 84 pages, National Research Council, National Academy Press, Washington, D.C. 1998.
[3]. S.M. Salvador, and G. Vecchi, Experimental Tests of Microwave Breast Cancer Detection on Phantoms, IEEE Transactions on Antennas and Propagation, vol. 57 (6), 2009, 1705-1712.
[4]. N.Noriko, Yuka Okafuji, Saori Adachi, Kana Takahashi, Takashi Nakakuma, and Sohichirou Ueno. Effect of Different Breast Densities and Average Glandular Dose on Contrast to Noise Ratios in Full-Field Digital Mammography: Simulation and Phantom Study. Radiology Research and Practice Vol. 2018, Article ID 6192594, 1-9.
[5]. V.L. Green, Mammographic breast density and breast cancer risk: Implications of the breast density legislation for health care practitioners, Clinical Obstetrics and Gynecology, vol. 59 (2), 2016, 419–438.
[6]. A. Ristolainen, Ross P, Gavšin J, Semjonov E, Kruusmaa M. Economically affordable anatomical kidney phantom with calyxes for puncture and drainage training in interventional urology and radiology. Acta Radiol Short Rep. 3(5), 2014.
[7]. Johannes Tran-Gia, Susanne Schlögl, and Michael Lassmann. Design and Fabrication of Kidney Phantoms for Internal Radiation Dosimetry Using 3D Printing Technology. The Journal of Nuclear Medicine, Vol. 57 (12), December 2016, 1998-2005.

[8]. Gullansl Ed, Erica Ollinickl, Scott Reinl, Christopher Saffosl, Jay Shilling, Karen Chang Yan, James,. Pilla, Chun Xu. Design of a dynamic heart phantom for magnetic resonance imaging, IEEE 35th Annual Northeast Bioengineering Conference, Boston, MA, 2009, 1-2.
[9]. William C. Koller, Eldad Melamed. Parkinson's Disease and Related Disorder Part II, Handbook of Clinical Neurology. Vol. 84, pp. 2-572, 2007.
[10]. S.Alrajeh, Bademosi O, Ismail H, Awada A, Dawodu A, al-Freihi H, et al. A community survey of neurological disorders in Saudi Arabia: The Thorough study. Neuroepidemiology 12, 1993,:164-78.
[11]. G. Deuschl, Bain P, Brin M. Ad Hoc Scientific Committee. Consensus statement of the Movement Disorder Society on Tremor. Mov Disord., 13 (3), 1998, 2-23.
[12]. G.K. Wenning Kiechl S, Seppi K, Muller J, Hogl B, Saletu M, et al. Prevalence of movement disorders in men and women aged 50-89 years (Bruneck Study cohort): a population-based study. Lancet Neurol., 4,2005, 815-20.
[13]. Onanong Jitkritsadakul, Priya Jagota, Roongroj Bhidayasiri. Pathophysiology of parkinsonian tremor: a focused narrative review. Asian Biomedicine, Vol. 10 (1) 2016; S15 -S22.
[14]. H. Teravainen H. and D. B. Calne, Action tremor in Parkinson's disease, Journal of Neurology, Neurosurgery and Psychiatry, 43 (3), 1980, 257–263.
[15]. Alexandre Gironell , Berta Pascual-Sedano, Ignacio Aracil, Juan Mar´ın-Lahoz, Javier Pagonabarraga, and Jaime Kulisevsky, Tremor Types in Parkinson Disease: A Descriptive Study Using a New Classification, Parkinson's Disease, 2018, Article ID 4327597, 1-5.
[16]. G. Grimaldi G, Manto M. Neurological tremor: sensors, signal processing & emerging applications. Sensors.10(2), 2010, 1399–422.
[17]. D. Haubenberger, Kalowitz D, Nahab FB, Toro C, Ippolito D, Luckenbaugh DA, Wittevrongel L, Hallett M. Validation of digital spiral analysis as outcome parameter for clinical trials in essential tremor. Mov Disord.,26(11), 2011, 2073–80.
[18]. G. Deuschl G, Bain PG, Brin M,Ad hoc Scientific Committee. Consensus statement of the Movement Disorders Society on tremor. Mov Disord, 13(Suppl. 3), 1998, 2–23.
[19]. . E. Dietrichs, Kvikstad V. Essential tremor. Tidsskr Nor Laegeforen.,128(19), 2008 Oct 9, 2210-3.
[20]. S.J. Chung, Diagnosis and treatment of hand tremor. J Korean Med Assoc., 55(10), 2012, 987-995.
[21]. Solé-Casals Jordi, Anchustegui-Echearte Iker, Marti-Puig Pere, Calvo Pilar M., Bergareche Alberto, Sánchez-Méndez José Ignacio, Lopez-de-Ipina Karmele. Discrete Cosine Transform for the Analysis of Essential Tremor. Frontiers in Physiology, 9, 2019, pp 1-11.
[22]. Mario Manto*, Giuliana Grimaldi, Thomas Lorivel, Dario Farina, Lana Popovic, Silvia Conforto, Tommaso D'Alessio, Juan Manuel Belda-Lois, Jose L Pons, Eduardo Rocon. Bioinformatic approaches used in modelling human tremor. Current Bioinformatics, 4, (20), 2009, 154-172.
[23]. Andreas Wille1, Mohamed Sangaré1and Susanne Winter. Analysis of Patterns in Tremor Diagnosis Spiral Drawings for Automated Classification. Biomed Tech, 58 (Suppl. 1), 2013.

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