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COMPUTERIZED ASSESSMENT OF HORIZONTAL HAND SKEW FOR NORMAL SUBJECTS COMPARED TO DIABETICS

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Abstract

A computerized setup has been developed and used to quantify deterioration in the hand movement of diabetic subjects, in the form of horizontal hand skew and its associated movement time. The horizontal hand deviation and movement time for diabetics compared to normal subjects were investigated in detail. The test population of this study was a group of females and males of different ages with a total population of 209 controls as well as 50 certified diabetics. The hand movement time was slightly affected by diabetes with a mean value of 5.03 s for diabetic subjects, compared to 4.99 s for controls. The mean values of horizontal deviation (skew) from the vertical track were highly affected by diabetes and were found at 2.72 mm for diabetic subjects, compared to 1.29 mm for controls. The proposed setup can therefore be considered a valuable tool for effective diagnosis of diabetes.

Keywords: Diabetes, Diabetic neuropathy, Horizontal deviation, Interface, Movement time, Skew.

1. Introduction

As the blood glucose level is increased diabetes disease results, which may cause serious health complications such as loss of feeling of hands and feet. Lots of people were affected by diabetes worldwide last year according to International Diabetes Federation (IDF) [1], many of them were susceptible to have diseases like peripheral nerve disorders and peripheral neuropathy which is a form of nerve damage usually impacting the hands which negatively influence daily activities of people [2, 3]. In fact, Diabetic Peripheral Neuropathy (DPN) affects more than 50 percent of people with diabetes disease [4]. It can lead to decreased mobility, lower rates of perceived health and increased mortality rates [5, 6]. The early detection of DPN allows for the implementation of preventive care, awareness and advice interventions that can minimize the risk of DPN complications. Nevertheless, several people are not diagnosed with DPN at an early stage and thus do not receive prompt care [7].

It is also known that diabetes is a costly and burdensome metabolic disorder, if it goes unchecked for an extended period, it can lead to the damage of different body organs and develop life-threatening health complications. Studies showed that the progression of diabetes can be stopped or delayed, provided a person follows a healthy lifestyle and takes proper medication. Prevention of diabetes or the delayed onset of diabetes is crucial, and it can be achieved if there exists a screening process that identifies individuals who are at risk of developing diabetes in the future. Although machine learning techniques have been applied for disease diagnosis, there is little work done on long term prediction of disease [8].

It was found by [9] that neuromuscular fatigue affects workers' productivity and health, which was further deteriorated with chronic conditions such as diabetes, enhanced physiological tremor was a key indicator of neuromuscular fatigue, it showed great potential in detecting the onset of neuromuscular fatigue, their study was intended for determining the feasibility of using a cost-effective wearable accelerometer-based microelectromechanical sensor to convey neuromuscular fatigue-related tremor information in healthy and diabetic patients, equipped with a finger and a wrist accelerometer, performed intermittent submaximal isometric handgrip fatigue exercises using a grip dynamometer.

In this context, the hand movement and its time domain analysis are good measures of severity of diabetes neuropathy, and its progression. In order to differentiate between diabetics and normal controls hand movement behaviours, in terms of space and time, a setup is required to measure both parameters simultaneously, and at the same time be easy to use so that a person can conduct a test without requiring assistance from anyone else, as well as being inexpensive so that a laptop computer suffice for the completion of the measurements needed, on the contrary the setups used by others were difficult to use by an individual people without assistance from medical staff. Resources in this matter were found to be insufficient, and literature focused on horizontal hand deviation and movement time as was proposed in this study were unavailable, which in turn limits the source of information and gives less data for medical staff to base their medical decisions upon, for the treatment and diagnoses of hand difficulties [10]. Built on these facts the aims of our study were to present a suitable setup to measure hand movement dysfunctions and to present a method for diagnosing people suffering from diabetes and compare them to normal subjects.

Movement disorder was studied by Jagota et al. [11] as well as Delrobaei et al. [12] who found that hand functions in people with type 1 and 2 diabetes had negative impact on occupational performance, Jackson [13] found that disability may be diagnosed by movement disorders, Polla et al. [14] used transducers to acquire extremities movements by fixing them to the part needed, Muheilan [15] used a more practical tool for capturing and analysing horizontal hand deviation from a prescribed vertical track using a personal computer, programmed for this purpose using visual basic, and found that deviation was greater with deteriorated state of mental health as well as age, later on Muheilan and Dmour [16], managed to compute the latency and angle of deviation of the hand and produced a comparative study for normal control and subjects suffering from mental illness. The authors of [17] presented a setup which analysed real time quantitative reconstruction of finger movements using a multi-camera system, that was slightly uncomfortable.

Sudoscan measures electrochemical skin conductance of hands and feet, to evaluate the efficacy of sudoscan in detecting diabetic neuropathy in comparison with other standardized tests in patients with diabetes. Casellini et al. [18] used sudoscan and hence sudomotor dysfunction as an early detectable abnormality in diabetic small fibre neuropathy, while Grujic and Bonkovic [19] recorded hand movements by a 3D optical motion-tracking system, which used multiple infrared cameras to trace the positions of active infrared-emitting markers. Goyal et al. [20] showed that diabetes mellitus was accompanying a number of hand-influencing musculoskeletal (MSK) symptoms and can dramatically affect the quality of life of a patient. Although much attention was paid to chronic microvascular complications of diabetes, in clinical practice, the complications of MSK were often ignored [20]. Kennedy et al. [21] suggested a method for early detection for tactile weakness in people suspected of experiencing neuropathy using a basic tool named the Bumps to measure the sensitivity of the finger pads. The Bumps test sets the tactile detection threshold by ensuring the subject rub the finger pad over a smooth surface to identify single, coin-shaped bumps of varying heights. Using this system, the authors noticed a discrepancy in the detection thresholds between control subjects and patients diagnosed with neuropathy [21].

Kuo et al. [22] investigated the performance of handwriting of patients with carpal tunnel syndrome and healthy subjects to study the sensory-related deficits in sensorimotor control of the hand related to CTS. The movement trajectories of the thumb-tip and fingertip was monitored using a 3D Qualisys ProReflex- MCU240 [22]. Other researchers explored the influence of diabetes disease on dynamical coordination of hand intrinsic muscles during precision grip. The study highlighted the impact of this disease on hand sensorimotor function [23].

Therefore, to identify the presence of diabetes, and quantify its effect on hand behaviour, the authors of this study postulate that hand movement time and horizontal deviation from vertical track are worsened by this disease and must be fully investigated, further they can be used as a diagnostic technique for categorizing the severity of diabetes. In order to prove their theory, the behaviour of hand movement was studied with respect to other parameters such as: subjects' gender, age, weight, smoking, eyesight, and the state of health (diabetes), using a simple though affective setup comprised of a laptop equipped with a touchpad, the screen of the laptop shows a line that the subject under test was asked to redraw, data collected was analysed as described in this research. This paper, therefore, tackles vertical hand movement in terms of its horizontal deviation and movement time, in a simple and practical way, the set up used was of low cost, just a laptop equipped with a touchpad were needed. The time required to conduct the experiment was very short, that is as soon as the subject moves his or her hand the results become available, unlike other systems which requires lengthy process and a long time to get the results, the setup used and the process described in our research is non-invasive and electrically safe, and hazard free, since all needed is a finger movement on the touchpad. This paper is structured as follows: Section 2 presents the data acquisition system adopted to record the horizontal hand movement for normal and diabetics subjects. In Section 3, the hand skew findings were statistically analysed and thoroughly discussed. Finally, conclusions are drawn in Section 4.

2. Setup and Methods

Study population consisted of 209 controls, 118 of which were normal males aged 13 to 60 years, and 91 were normal females aged 18 to 54 years, with non-diabetic history, other groups consisted of 50 patients of insulin-dependent diabetes, they were inpatients at prince Ali Bin Al Hussein Hospital in Jordan, 24 of which were males aged 23 to 97 years old, compared to 26 females aged 21 to 89 years, all Jordanians, and Arabs.

All subjects took part in the study were selected with no previous hand pathology, or diseases related to traumatic arthritis, rheumatoid arthritis, and thyroid disorders.

The data acquisition system used in this study was a laptop with a touchpad, no light pen was used in this setup as compared to that utilized by [16, 24], the programs operating this system were also modified to commensurate with the hereby presented method, by taking the modulus of the deviations in order to count for any deviation to the right or the left of the reference line. Use of the touch pad eliminated any restriction to hand movement caused by the light pen since previously it was held by the hand, which was then uncomfortable and restrictive, hence it was thought to affect the results of the tests, similar principles were adapted in [25], this can be explained by saying that, holding an object uses more of the hand muscles, and dissipated more energy and weakens the hand especially for diabetics who might already be feeling week, no matter how small was this energy consumed.

Therefore, this system considers hand movement detection, tracking, measures deviation and at the same time records real time motion. Hand detection was based entirely on touch pad tracking mechanism, through which the subject was comfortably seated in front of the laptop, taking into consideration whether he or she was left or right-handed, then given sometimes to get used to the experiment by trying it beforehand. The laptop was programmed using Visual Basic [26], to show a 15 cm long straight line on its screen, starting from the top side of the screen downward which serves as reference line to the user, who was asked to move the index finger and hence the hand on the touch pad to redraw this line as if his finger is moved on the screen itself. Measurements were made while hand was resting on a horizontal datum, this was necessary to eliminate three-dimensional motion complexity which was outside the scope of this study, the reflection of the finger movement on the screen was a non-straight line, and was made up of many discrete points each has a pair of X and Y coordinates and was saved in the computer memory as an array, the time of each point drawn was also recorded and the total time of motion elapsed while drawing was measured and referred to as the movement time as shown in Fig. 1.

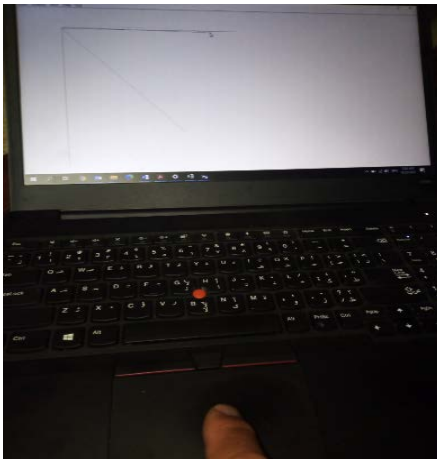

Fig. 1. A photograph of the finger movement on the touch pad as reflected on the screen of the laptop after performing the test.

The line drawn by the user started at a discrete point of certain height this was the height of the first point of the reference line, as the hand moved it reproduced the line, but not as straight as the reference line as is shown in Fig. 2.

Fig. 2. Straight line represents the reference line while dotted line represents the trace made by the hand performing the test.

The downward hand movement unintentionally made deviations to the left or to the right of the reference line, even though it was meant to produce a straight line it could not do so, it was actually producing a non-straight line, if we assume that the *X* coordinate of the first point of the reference line is given as X_r the difference between any point made by the hand and the coordinate of the reference line was termed skew, or horizontal deviation.

For the first point drawn by hand with respect to the first point of the reference line, the skew or deviation can be represented by:

$$D_1 = X_1 - X_r \quad (1)$$

where D_1 is the horizontal deviation in mm of point1, X_1 is the coordinate of discrete point1 made by the hand and X_r is the coordinate of the reference line (X_r is constant for all points of the reference line).

The total skew (horizontal deviation) of the hand D_h, calculated away from the reference line is the sum of these deviations and is given as:

$$D_h = \sum_{i=1}^{n} (X_i - X_r) \tag{2}$$

where i=1 is the initial point and n is the last point drawn.

As the hand performs a vertical movement, the deviation to the right of the line was considered positive, while deviation to the left of the line was considered negative, it is mathematically clear that summing the deviations implies adding positive and negative values, which will cancel each other, so to eliminate such false results (as any deviation to the left or the right is needed to be considered) the absolute values of deviations are considered, therefore Eq. (2) is rewritten as:

$$D_h = \sum_{i=1}^{n} |X_i - X_r| \tag{3}$$

This way of dealing with deviations will give the amount of error in the form of skew as any movement away from the reference line is an erratic hand movement regardless of its sign, and measuring this deviation is one of the aims of this study.

To calculate the hand movement time, the authors of [27] used a measurement system composed of a computer and a data glove. The data glove used fifteen magnetic sensor units to measure joint angles of a hand by sticking one sensor unit on the middle of each phalanx of a finger, and each sensor unit consisted of an acceleration sensor, a gyro sensor, and a magnetic sensor. The computer was responsible for capturing; processing and displaying the measured data transmitted from the data glove and communicates with the data glove through RS232. But our method is far easier and a lot more practical than that, it in fact records the laptop real time clock while the hand is moving, from the onset of the hand movement and for every point in sequence up to the last point travelled, which was termed hand movement time, and was kept in computer memory for further processing. To measure this movement time or hand movement duration, the time difference between last point made by the hand and the initial point was computed, as given in the following equation:

$$T = t_{last} - t_{first} \tag{4}$$

where T is the movement time in s, t_{last} and t_{first} are the times of the last and first points in s.

In the preceding calculations, two arrays were used to store the values of the two parameters, D_h and T, the first is the deviation array which keeps the values of the differences between the reference line and the instantaneous coordinates of the finger position while moving on the touch pad in the form of horizontal hand skew, the other array is associated with movement time which keeps values of the computer timer in real time from the start of the finger motion to the end. Calculations were performed on the elements of each array and results were presented in the form of Eqs. (3) and (4). A valuable property of visual basic, which is its capability of offering the actual position of the cursor any were on the laptop screen, made this study possible and practical, in the sense that as the finger moves on the touch pad it is correspondingly reflected as a curse movement on the screen and calculations are then based on the coordinates of the curser as given by Eq. (3) above.

Results were statistically analysed using Minitab 19 [28], means, standard deviations and other statistical functions were considered for comparison purposes, correlation was used as appropriate at certain stages.

3. Results and Discussion

3.1. Movement time

Mean values of movement time elapsed while drawing the reference line by the whole population, diabetics, and controls, are presented in Fig. 3, from which it can be seen that they were not affected by state of health, since a mean value of 4.99 s (S.D. 2.75 s) was calculated for controls compared to 5.03 s (S.D. 2.54 s) that was calculated for diabetics, respectively.

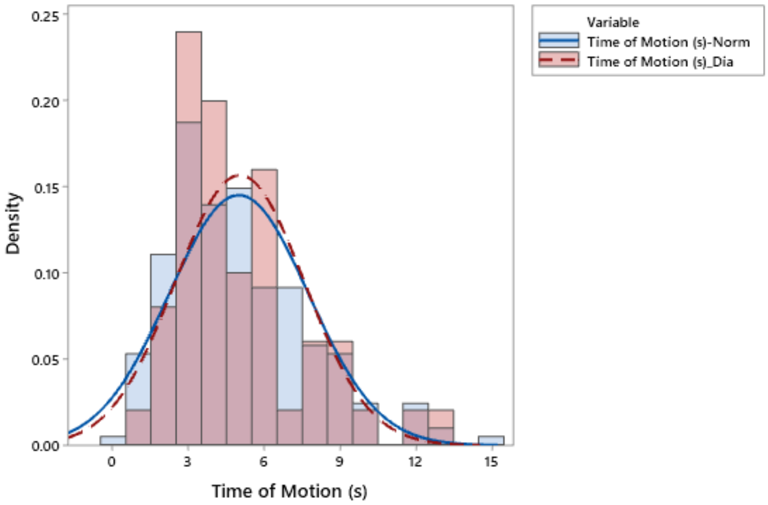

Fig. 3. Mean values of movement time for diabetic and control subjects.

This small ratio is due to the fact that movement time is a matter of attentiveness to move rather than ability and strength, therefore; normal subjects and diabetics behaved similarly and diabetes is not a determining factor of the quality of hand movement time, this was ascertained by [29] and also when reinvestigated with other parameters such as gender, age, weight, smoking and vision for whole population, as is presented in the half normal probability plot of Fig. 4, which shows the absolute values of the standardized effects from the largest effect to the smallest effect. The standardized effects are t-statistics that test the null hypothesis that the effect is 0. The points are shown relative to a reference line for the case when all the effects are 0. Effects further from 0 on the *x*-axis have greater magnitude. Effects further from 0 are more statistically significant [28], here again it was found that diabetes had less effect on hand movement time than gender and age as it came third in sequence.

The regression equation for the movement time for all subjects is given as:

$$T\ (s) = 3.494 + 1.241\,A + 0.0459\,B - 0.0044\,C - 0.818\,D - 0.495\,E - 1.480\,F \qquad (5)$$

The signs of coefficients of the different parameters given in this equation are useful for demonstrating whether a direct or inverse proportionality linked a parameter with movement time.

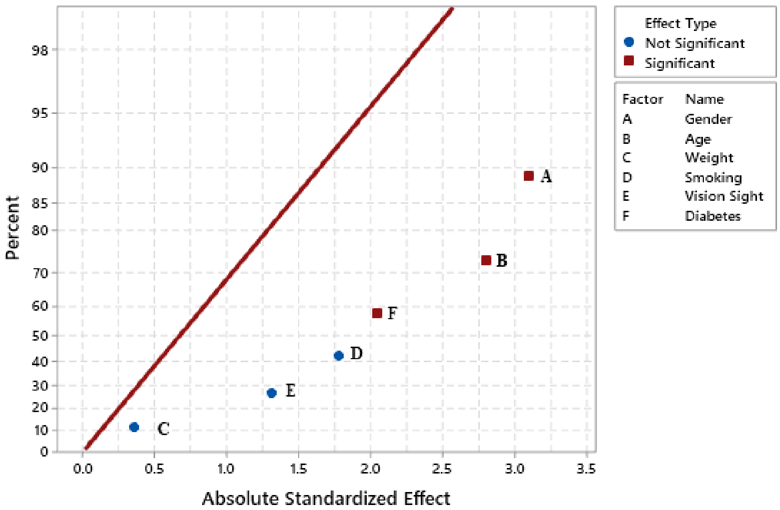

Fig. 4. Half normal probability plot of movement time for diabetic and control subjects.

From regression Eq. (5) above it can be seen that gender (*A*) has a positive coefficient and as males were given a value of one and females were given a value of zero, this indicates that males have longer mean movement time than females, age (*B*) also had a positive coefficient this means that elderly subjects wither normal or diabetics had a long mean movement time, this is justified as older people tend to be less responsive in terms of motion. Weight (*C*) had the smallest coefficient of all parameters in this regression equation with a value of (0.0044) which indicates that it had small effect on movement time, and its negative coefficient indicates that as weight gets larger mean movement time gets smaller which is an indication of quick withdrawal of hand movement, this may be because the subject feels uncomfortable and tries to end the test rapidly. Smoking (*D*) had a very small coefficient too and its slope is negative which means a shorter mean movement time this may be explained by the lower amount of oxygen in the blood which leads to less effort expended by muscles and the subjects tend to end the test quickly. Vision (*E*) had a negative coefficient which means small movement time with long sighted people, i.e., since the screen is far from the user and sighting is good for them for far objects than for closer objects this means better tracking and hence less time (as short sighted were assigned a value of -1, normal sighted a value of zero and long sighted a value of 1). Finally, diabetes (*F*) coefficient was negative which indicates that it inversely proportional to mean movement time, this indicates that diabetic subjects moved their hand fast regardless of the quality of the hand motion, as if they intended to conduct the test as swift as possible and not being keen on how perfect their hand is tracing the line this is due to poor health. The comparative means of movement time for females and males, diabetics to controls are presented in Fig. 5.

This figure shows that diabetic females movement time mean value is equal to 4.65 s compared to 4.41 s for normal females, while diabetic males mean value is equal to 5.43 s compared to that of 5.39 s for normal males, this confirms the fact that hand movement time is not sensitive enough to diabetes, the reason behind which is that hand movement time is based on personal attitude and willingness to move, rather than state of health.

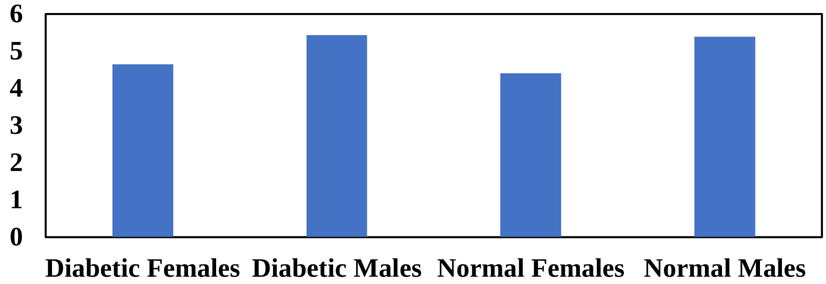

Fig. 5. Mean values of movement time (s) for diabetic and control subjects.

Inspection of the results of hand movement time as described by Figs. 3 to 5 which first considered the whole population, and then the results of male and female separately for comparison purposes, all results were consistent with each other and it can be deduced that movement times were very lightly affected by diabetes.

This way of measuring movement time can be used in other types of research fields, such as measurements of certain movements of the hand in certain sport activities and measuring extremities resilience and fatigue withstanding.

3.2. Horizontal deviations

The horizontal deviations from the vertical line measured for the whole population (diabetics and controls) is presented in Fig. 6, from which it is largely affected by diabetes, with a mean value of 1.29 mm (S.D. 1.02 mm) for controls compared to 2.72 mm (S.D. 2.89 mm) for diabetics.

The effects of multiple parameters such as gender, age, weight, smoking, vision and diabetes on the horizontal hand deviation of the whole population, are presented in Fig. 7, it was found that diabetes had the highest effects on deviation (i.e. statistically the most significant factor) as it's the furthest away relative to the reference line, effects further from reference line are more statistically significant, in other words this means that a diabetic person had the highest deviation, i.e. erratic hand movement, and this is ascertained by the positive sign of its coefficient as given by the regression Eq. (6), which also indicates a direct proportionality between diabetes with deviation with a positive coefficient of 1.97, which is higher than all other parameters, which means a diabetic person had larger deviation compared to a healthy subject, while the rest of the parameters have minor effect on deviations since all of them are close to the reference line; diabetes therefore; will be the factor that justifies further investigation, other factors will be briefly investigated hereafter.

From the half normal probability plot Fig. 7, and the horizontal deviation regression Eq. (6) it can be said that when a parameters coefficient has a positive sign the response (deviation) increases with that parameter, therefore smoking (*D*), vision (*E*) and diabetes (*F*) fulfil this requirement, therefore; horizontal deviation is increased with smoking, long-sighted subjects, and diabetics. On the other hand, gender (*A*), age (*B*) and weight (*C*) all have negative standardized effects that is, an increase in any of them leads to a decreases in deviation, this might sound a little irregular, but when we think of the values of these parameter as indicated in Eq. (6), we can see that they are all of very small values which indicated a very small effect on divination on contrast to the pre-mentioned parameters which had large values.

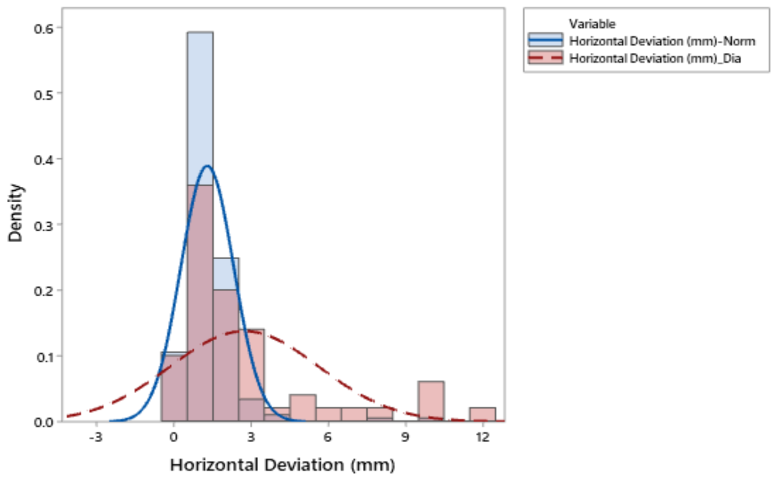

Fig. 6. Horizontal deviations for diabetic and control subjects.

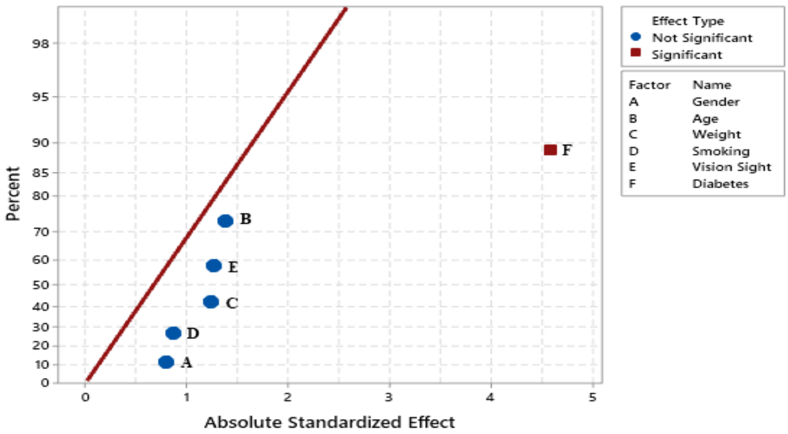

Fig. 7. Half normal probability plot of horizontal deviations for diabetic and control subjects.

The regression equation for the hand deviation for all subjects is given as:

$$D_h(mm) = 2.379 - 0.189A - 0.01343B - 0.00924C + 0.237D + 0.284 \quad (6)$$

If each parameter is considered separately for its effect on deviation staring from Gender, this had a negative sign, which means females have less deviation than males for normal subjects; this can be explained by the tendency of females toward being patient and hence produce a more accurate and near perfect movement compared to male subjects. Age had a negative and small coefficient when compared to other factors, which indicates a small effect on deviation and its minus sign indicates an inverse proportionality with deviation i.e., as age gets larger deviation gets smaller which can be explained by the care and patience by which subjects were moving their hands. Weight had the smallest coefficient of all parameters (1% or less compared to other factors) at a value of 0.00924 which indicates its small effect on deviation. Smoking had a positive coefficient with a high value which means direct proportionality with deviation, since smoking implies less oxygen contents in the body as a whole, and as motion normally requires more oxygenated blood to strengthen muscles performance consequently smokers' subjects have these higher deviations. Vision was classified in this test as follows: short sight was given a value of -1, normal sight was given a value of 0, long sight was given a value of 1, from the results it had a positive coefficient which means large deviation with long sighted people, i.e. since hand movement is based on what a person is watching, and since this is accompanied by eye movement which is based on a distal position (up screen) to a proximal position down screen therefore; eye sight is changing slowly from far to near position and as sight for longsighted people is better for farther position than nearer position the closer is the subject the less clear it becomes and hence worse pursuit of hand and hence worse deviation. So far it is clear that horizontal deviation was largely affected by diabetes therefore, further investigation will be made henceforth on diabetics and controls. The comparative means of horizontal deviations for females and males, diabetics to controls are presented in Fig. 8.

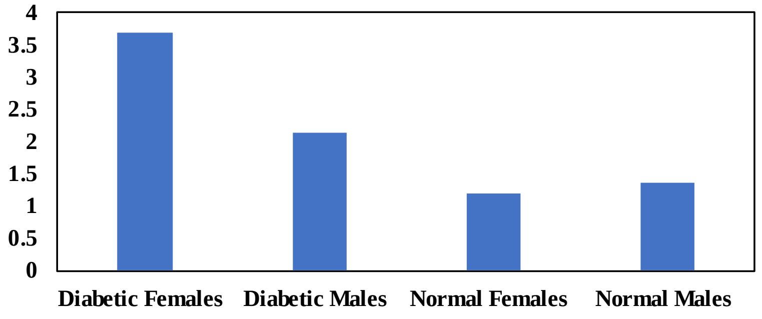

Fig. 8. Horizontal deviation mean value in (mm) for diabetic and normal subjects.

This detailed figure shows that diabetic females have mean horizontal deviation value equal to 3.69 mm compared to a mean value of 1.19 mm of normal females, and that diabetic males have a mean value of 2.13 mm compared to 1.36 mm for normal males, both results agree with what was found earlier of high deviation for diabetic compared to controls.

If the movement time mean values as given by Fig. 5 are compared to horizontal deviation mean values as given by Fig. 8 it can be found out that diabetic females had large movement time at 4.65 s and a large deviation at 3.69 mm and if these same parameters are compared for diabetic males they were equal to 5.43 s and 2.13 mm, that is longer time and smaller deviation i.e., an inverse proportionality which proves the fact that movement time is alternating and is not a determining factor for diabetes. But if these parameters are compared for normal female, they were equal to 4.41 s and 1.19 mm i.e., small time and small deviation, and for normal males they were given as 5.39 s and 1.36 mm i.e., large time and small deviation which again support the earlier assumption of independency of movement time and deviation.

Correlation of horizontal deviation and movement time for males and females with respect to state of health (diabetes) was also performed as is shown in Fig. 9, the positive value of 0.017 for normal males indicates that correlation between movement time and deviation is negligible, while the value of that for normal females was at approximately 0.098 indicate that a very small consistency exists between movement time and deviation, on the contrary negative value of correlation as for diabetic females and males designates inverse proportionality between deviation and movement time, i.e. even though a diabetic person moves the hand fast with small movement time it produces large deviation so that movement time is decreased while deviation was increased which proves that diabetes is a disease which deteriorates horizontal hand movement in the form of a horizontal skew.

In general, as none of the correlation coefficients were close to 1, this signify that deviation is independent of movement time for vertical hand movement, and as for diabetics having an inverse proportionality between the two parameters implying that the shorter the movement time the higher is the hand deviation which again indicates that diabetics move their hand in an uncoordinated way with time, i.e. some people moves their hand fast while others slow but their hand deviation is always poor.

Inspection of the results of horizontal deviation as described by Figs. 6 to 8 which considered first the whole population, and then the results of male and female separately for comparison purposes, the results were consistent with each other and it can be deduced that hand deviation is largely affected by diabetes.

Measurements of hand deviations in this way can be used in other types of research fields, such as evaluating the quality of hand movement for certain tasks and for certain people, such as evaluating the quality of body deviations for people suffering from diseases such as multiple scleroses, which causes tremor to the whole body, and affect the stability of peoples extremities, particularly those conducting jobs that requires high accuracy with very tight movements, that do not allow for any tolerance or deviation, this test can also be used for measuring deviations under fatigue. The adaptation of the above given process in other fields of research is thought to be useful and practical, useful because this technique is already tested and proved applicable as the results showed, and practical because any measurements regarding movement time or deviations of other parts of the body such as the leg or the head may just require certain adjustment to the software used, and since it was done using visual basic then a person with little knowledge in programming can do the necessary modification.

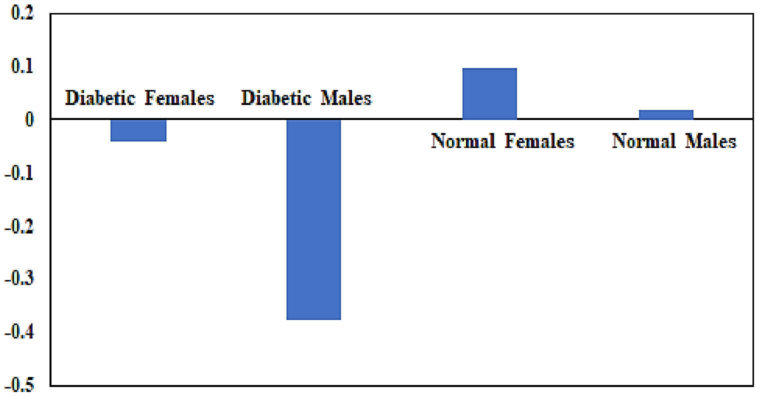

Fig. 9. Correlating horizontal deviation and movement time for males and females with respect to state of health.

The findings above are consistent with those reported by others such as Pandey et al. [30] who observed that the severity of hand deviation tends to increase with diabetes, which also established by the research performed on hand parameters by Mota et al. [31] who noted that hand disorders in diabetic patients with prevalence of 40.5 percent compared to controls with prevalence of 19 percent, i.e., a ratio of approximately 2 to 1. Other research, such as [32], reported that diabetes restricted joint mobility shows an elevated risk of microvascular disease. Seibold [33] also reported that sclerosis is a possibility for children with insulin-dependent diabetes mellitus. Furthermore, the time needed to carry out the test is extremely short (i.e., in the range of seconds relative to other methods such as those suggested by Grujic and Bonkovic [19]. In addition, the proposed solution is cost-effective because no hardware interface is required to perform the test as well as being non-invasive as reported by Lekha and Suchetha [34].

4. Conclusions

The study was meant to establish a quantitative criterion for the evaluation of hand movement time and hand horizontal deviation from a prescribed vertical track, as a function of diabetes, gender, age, weight, smoking and vision. Some concluding observations from the investigation are given below.

- Movement time was not clearly influenced by diabetes, since when the whole population was tested its mean value was found at 5.03 s for diabetic subjects, compared with 4.99 s for controls. While mean values were found at 4.65 s for diabetic females compared to 4.41 s for control females, and they were at 5.43 s for diabetic males compared with 5.39 s for control males.
- Mean values of horizontal deviation for the whole population were equal 2.72 mm for diabetic participants, contrasted with 1.29 mm for controls, deviation is worsened to a large degree by diabetes. It was also found that diabetic females mean values were equal to 3.69 mm compared to a value of 1.19 mm of control females, and that diabetic males have a mean value of 2.13 mm compared to that of 1.36 mm for control males.
- Main advantages of this system over other systems used for these purposes were ease of use, under-priced (just a laptop), fully computerized (can be reprogrammed to perform other tests at different inclination not necessarily vertical deviation) and no interface was needed. Therefore, it can be said that the set up was successful for analysing hand movement time and deviation as a function of diabetes and many other parameters. In future, tests may be performed at another angle and not necessarily vertical.

Nomenclatures

A	Gender
B	Age, Year
C	Weight, Kg
D	Smoking state
D_h	The total skew (horizontal deviation) of the hand mm

E	Vision state
F	Diabetes
T	The hand movement time, s

Abbreviations

CTS	Carpal Tunnel Syndrome
IDF	International Diabetes Federation
MSK	Musculoskeletal
S.D.	Standard Deviation

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