Feartures of Physiological Tremor in Diabetic Patients

Lilia Aljihmani
Department of Electrical & Computer Engineering
Texas A&M University at Qatar
Doha, Qatar
lilia.aljihmani@qatar.tamu.edu

Hasan Abbas
Electronic & Nanoscale Engineering
University of Glasgow
Glasgow, Scotland

Yibo Zhu
Department of Environmental & Occupational Safety
Texas A&M University
College Station, USA

Ranjana K. Mehta
Department of Industrial & Systems Engineering
Texas A&M University
College Station, US

Farzan Sasangohar
Department of Industrial & Systems Engineering
Texas A&M University
College Station, USA

Madhav Erraguntla
Department of Industrial & Systems Engineering
Texas A&M University
College Station, US

Mark Lawley
Department of Industrial & Systems Engineering
Texas A&M University
College Station, USA

Qammer H. Abbasi
Electronic & Nanoscale Engineering
University of Glasgow
Glasgow, Scotland

Khalid Qaraqe
Department of Electrical & Computer Engineering
Texas A&M University at Qatar
Doha, Qatar

***Abstract*— In this paper, we estimate the effect of fatigue on physiological tremors in adults suffering from diabetes. We used a simple, wearable accelerometer to collect the acceleration data from 5 diabetic subjects with varying physical activity levels. Fatigue was induced via an intermittent submaximal isometric handgrip protocol, normalized for individual grip strength, until voluntary exhaustion. The overall results presented here show that the physiologic tremors in the range of 10-14 Hz are most noticeable under fatigue.**

***Keywords*— Physiologic tremor, wearable non-invasive sensor, fatigue**

I. INTRODUCTION

An estimated 425 million people have diabetes worldwide according to the International Diabetes Federation [1]. There is a growing concern that this number may surge to 629 million by 2045, an increase of 48% [1]. In 2017 alone, diabetes was the direct cause of deaths of over 4.8 million people [2].

Hundreds of millions of people suffer from hypoglycemic events (low blood sugar level) daily. Adverse effects of hypoglycemic events may lead to reduced quality of life, lost productivity, massive hospitalization costs, and premature death [3] [4] [5]. Hypoglycemia is associated with the development of muscle tremors that become apparent in the form of shaking of the hands. Smart detection of such tremors may prove a significant step forward in the proactive management of hypoglycemic events. With the help of a non-invasive approach to record tremors using wearable accelerometers, blood glucose level may be continuously tracked, and any drops in the levels that point to impending hypoglycemic events can be inferred from the tremors. To achieve this, we investigated hand tremors using a previously developed detecting system [6] for healthy [7] and diabetic adults.

The purpose of this study was to estimate the effect of fatigue on physiologic tremors in adults suffering from diabetes. We used compact high-precision accelerometers to measure the tremor amplitude and frequency contents due to fatigue manifestation. Furthermore, we aimed to investigate the tremor data to further understand tremor onset during hypoglycemic events.

II. METHODS

A. Subjects

Five type 1 and type 2 diabetic patients, including 2 males and 3 females participated in the study. The study was approved by the Institutional Review Board (IRB) of Texas A&M University. The participants' characteristics such as age, gender, height, weight and duration of hand grip endurance observed are summarized in Table I. The participants declared no cardiovascular diseases or autonomic neuropathy history.

TABLE I. PARTICIPANTS' CHARACTERISTICS

	Type of diabetic	**Gender**	**Age**	**Height, cm**	**Weight, kg**	**BMI, kg/m^2**	**Record, min**
P1	T2	Female	40	160	80	31	90.38
P2	T2	Female	62	165	104	38	70.23
P3	T1	Male	22	175	64	21	36.79
P4	T2	Female	50	178	104	33	38.17
P5	T1	Male	29	170	61	21	83.70

B. Data collections

Data was collected from the wrist of the dominant hand using compact high-precision 3-axis accelerometer, ADXL 335 (Analog Devices, Inc., Massachusetts, United States. Data was wire transferred to an Arduino UNO R3 (Adafruit) microcontroller fixed on the wristband and then to a computer at a sampling rate of 45 Hz and digitized using a 14-bit analog to digital converter. Signal analysis was performed using MATLAB (release 2018b; The MathWorks, Natick, MA). Acceleration data was split into episodes according to EMG event markers and then was high-pass filtered to remove any static content. For the acceleration data, fast Fourier transforms (FFTs) and power spectral densities (PSDs) were computed.

C. *Experimental protocol*

The participants were seated comfortably in a quiet laboratory at Texas A&M University, College Station. The rest, posture and action tremors were estimated during the different tasks in three stages.

During the first stage, pre-fatigue test, the subjects repeated 3 times a cycle that consisted of posture (PC), rest (RC) and loaded posture condition (LPC) tasks each with a duration of 15 s and rest interval of 30 s between them. During the rest task, the participant's arm was fully relaxed and was placed on the armrest of the chair. In posture condition test, the participants held the dominant arm horizontally at shoulder's height, with the arm in elbow and fingers stretched out. In the next task, loaded posture condition task, they retained the previous position but held a 300g weight (Jamar Hydraulic Hand Dynamometer).

The second stage, maximum voluntary contraction (MVC) test, included 3 times repetition of pre-MVC task in which the objects pressed the dynamometer with maximal force. After the first and second MVC they rested for a period of 60 s, whereas after the third one, they started the main part of the fatigue test (30 % MVC tasks) without any rest. The 30 % MVC test consists of the repetition of 15 s squeezing the dynamometer with 30% of the maximal force measured in the MVC test followed by 15 s rest. The subjects estimated the fatigue level every 4 min using the Rating of Perceived Exertion scale ranging from 1 to 10. When they declared that they were fatigued, the second stage stopped, and they started the final part of the experiment, post-fatigue, which included 4 times repetition of post-MVC, posture, rest and loaded posture condition tasks each with duration 15 s and without rest between them. The rest period after each cycle of the tasks was 0, 2 and 4 min.

III. Results and Discussion

A. *Tremor frequency*

The fatigue study started with posture, rest and loaded posture condition tasks. Even when the participants were at rest before starting the test, the frequency peak in posture condition for each person was very different (3-11 Hz) due to their physical activity level. On the other hand, the peak frequency values 10 min after the fatigue test was in 3 to 4 Hz range for rest and loaded posture condition (Fig. 1b,c). During the rest condition task in pre-fatigue stage, the frequency peak interval was between 3.5 and 6.5 Hz (Fig. 1b), while for loaded posture condition it was (3-4 Hz) (Fig. 1c). Although varying physical activity level of the subjects, the performance of the posture, rest and loaded posture condition tasks the frequency peaks become approximately the same in loaded posture condition, i.e. the interval of the frequency peaks of all patients narrows.

Unlike the case of posture, rest and loaded posture condition, the frequency peaks' changes during the MVC tasks were insignificant for all subjects (Fig. 1d-f). During the fatigue test, the frequency of tremor was in the 10-14 Hz range and it was almost the same for all participants except Person 2 (3-4 Hz range) (Fig. 1d-f). Through the experiment, the frequency peaks of this patient were in the 3-6 Hz range even during the tasks involving maximum voluntary contraction except the frequency value measured 10 min after the exhaustion. We conclude that this is due to the influence of age, body mass index (BMI) and duration of the fatigue test (Table 1). Throughout the fatigue tests, the participants' frequency peak changed with no more than 20 %. The frequency peak intervals varied from 12-14 Hz (PC) to 10-14 Hz (RC and LPC) for the other four participants. The repetition of exercises with weak loading (30 % MVC) and rest are the possible reasons for the slightly frequency peak's changes.

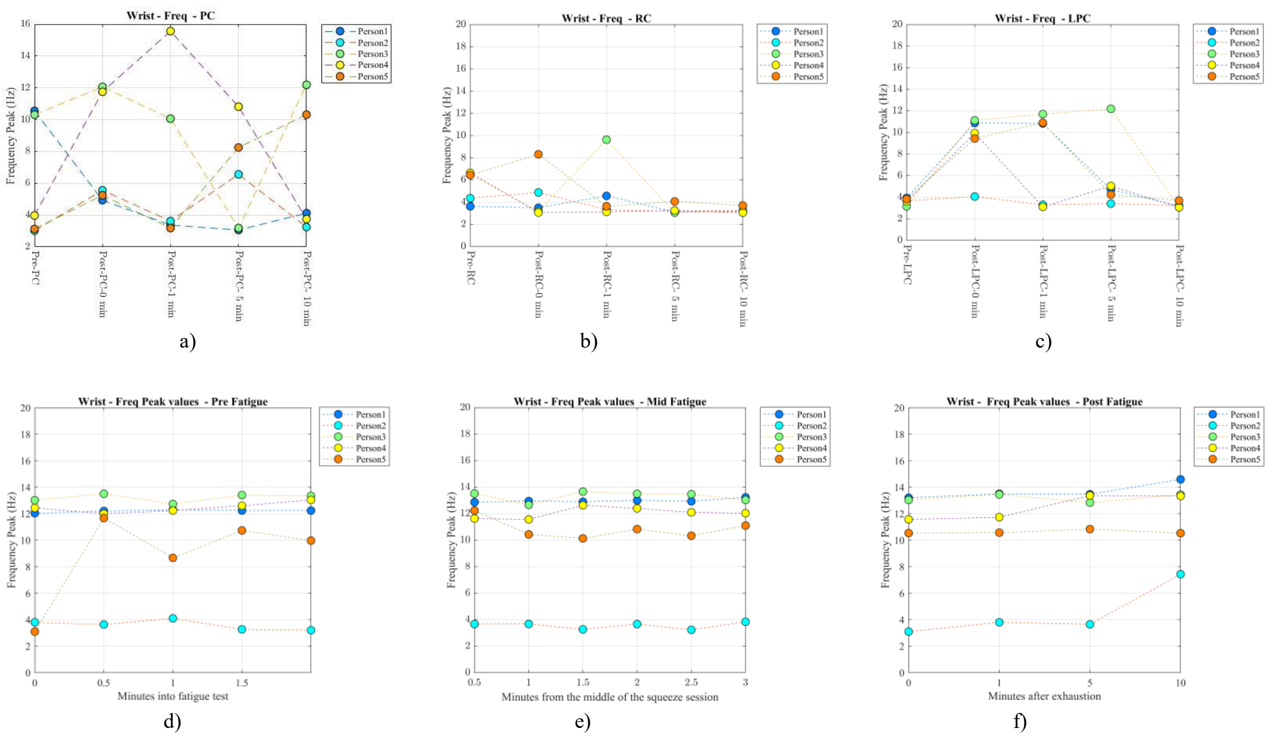

Fig. 1. Frequency peaks in posture (a), rest (b), loaded (c) posture condition, pre- (d), middle- (e) and post- (f) fatigue.

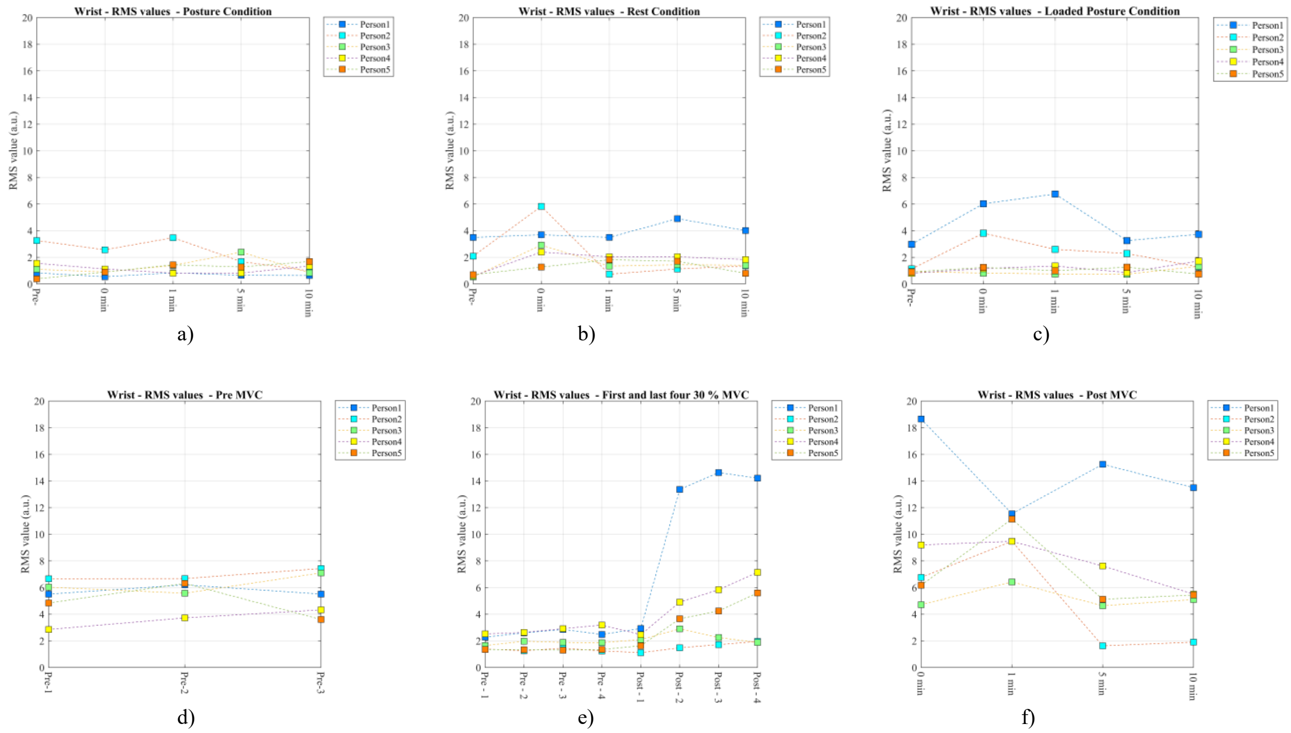

Fig. 2. RMS values during the posture (a), rest (b), loaded (c) posture condition, pre- and post-MVC (d and f) and 30 % MVC (e) tasks.

B. *Tremor amplitude*

In the pre- and post-fatigue stage, the tremor amplitude in posture, rest and loaded posture condition changed weakly and most of the values were found to be in the range of 0.5 to 4 with the units being arbitrary. As can be seen from the figures, during posture and rest tasks the amplitude of the tremor (Fig. 2a-c), alter slightly and the trend of dependencies do not differ much for all persons, while for the frequency peaks (Fig. 1a-c) cannot be noted any trend. In these condition tasks, the amplitudes of the Persons 1 and 2 differ slightly from the amplitude trend of the other participants. It could be noted that for the Person 2, the frequency peaks values distinguished significant from the values of the other participants during the performance of the MVC tasks (Fig. 1d-f), while for the amplitude values the difference was not so big and was during the posture and rest tasks (Fig. 2a-c). We assume the reason for the higher amplitude values is the complex influence of the participant's age, the continuance of the test and the levels of physical fitness and activity.

The RMS values during the pre-MVC and first four 30 % MVC tasks lie in 2.5 to 7.5 and 1 to 3 ranges, respectively (Figs. 2d, e). Although each 15 s 30 % MVC was followed by 15 s rest, the weariness obtained from the performance of fatigue tasks accumulates and influences variably among the participants. Hereupon the last four post-30 % MVC and the post-MVC dependencies are situated in a wider range. The fatigue in the post-MVC was the most noticeable, and the values were between 2 and 18 (Fig. 2e, f). The RMS values of the person 1 performing post-rest and post-loaded posture condition tasks (Fig. 2b, c), as well as the last four 30 % MVC and Post-MVC tasks (Fig. 2e, f) were significantly higher than the values of the other patients. We suppose that the reason for this is the personal physical activity and weariness that occurs during the fatigue tasks as this participant did the longest test. This assumption is confirmed by the amplitude values of the persons 2 and 5.

IV. Conclusions

The analysis of the physiological tremor' characteristics is hampered for several reasons – the number of participants is small and the age diapason of the participants is big; their BMI and levels of physical activity are very different. As a result of all these participants' features, their ability to do the tasks is varying, as well as the duration of the performed tests is very different. However, we have identified and have found possible reasons for the following features. In this study, the frequency and amplitude analysis of hand tremors during the fatigue test was performed. The fatigue was induced via an intermittent submaximal isometric handgrip protocol, normalized for individual grip strength, until voluntary exhaustion. The acceleration data was collected from the wrist of the dominant hand of the 5 diabetic types 1 and 2 participants using a sensing device designed by us. It was established that during the performance of maximum voluntary contraction tasks, the physiologic tremor in the 10-14 Hz frequency range was clearly expressed. The power spectral density showed a uniform distribution during the postural and pre-MVC tasks. Our future work is focused on collecting the acceleration data during the hypoglycemic event.

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