

RESEARCH ARTICLE

A comparative study of skeletal muscle fatigue in diabetic and non-diabetic human beings

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ABSTRACT

Background: Diabetes mellitus has now emerged as a global cause of concern. Fatigue is a widespread and persistent complaint among diabetics. It is associated with a decreased ability to manage day to day activities. Muscles that are used intensively are more likely to get fatigued. Since the flexors of the fingers are used intensively even in an otherwise sedentary lifestyle, this group of muscles are assessed in this study. **Aims and Objectives:** The study was done to compare the skeletal muscle fatigue in non-diabetics and controlled diabetics. **Materials and Methods:** The study population consists of two groups of male participants in the age group of 30–40 years. The control group consists of 50 healthy volunteers. The test group consists of 50 controlled diabetics. Mosso's ergography was done to assess the performance of flexors of the fingers of the non-dominant hand. Duration of onset of fatigue was noted. Work done was calculated. Windostat version 9.2 software was used for all statistical analysis. Comparison of variables between the two study groups was done using ANOVA. **Results:** The duration of onset of fatigue and work done was significantly higher ($P < 0.005$) in non-diabetics than diabetics. **Conclusions:** Normal non-diabetics had an ability to do more work without getting rapidly fatigued. Controlled diabetics got rapidly fatigued.


KEY WORDS: Diabetes; Skeletal Muscle; Fatigue; Flexors; Ergography

INTRODUCTION

Fatigue is a universally experienced phenomenon which occurs in day to day life. It is associated with a variety of physiological and psychological conditions. Fatigue is defined as an inability to maintain required amount of force.^[1] It may occur due to a decreased rate of energy supply to meet the demands.^[2] Physical and mental exertion and lack of sleep may result in fatigue. It

may be classified as acute and chronic fatigue. Acute fatigue is temporary and is relieved with rest. However, chronic fatigue may be pathological and may not be relieved even after rest.^[3-5] Oxidative stress marker levels are often elevated in chronic fatigue. Diabetics are usually affected by such fatigue.^[6,7]

Diabetes mellitus is now a global cause of concern. According to recent estimates, the number of diabetic subjects throughout the world is expected to rise to 592 million by the year 2035.^[8] A large number of adults in India are affected with diabetes. In the recent times, the age of onset of diabetes has come down drastically, and younger adults are also being affected by it.^[9] Fatigue is a common presentation among diabetic subjects either with or without any comorbid pathology and is associated with a decreased ability to perform day to day activities.^[10] In diabetics, fatigue may be due to physiological, psychological or lifestyle related factors. Physiological

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factors such as increase or decrease in blood glucose levels may result in the development of fatigue. Postprandial glucose fluctuations may cause an elevation in pro-inflammatory markers. Psychological factors such as emotional stress or depression can also lead to fatigue. Sedentary lifestyle and obesity are common in type 2 diabetics.^[11]

Skeletal muscle is primarily involved in body movements. Its primary function is to generate force or movement in response to a physiological stimulus. It is responsible for the voluntary movement of bones that underlie locomotion and work production. Energy production in skeletal muscle cells occurs by the process of oxidative phosphorylation.^[12] Glucose enters into the skeletal myocytes by the process of facilitated diffusion. It is mediated by the glucose transporters (GLUTs) GLUT 1 and GLUT 4. Factors such as insulin levels, blood glucose levels, and contraction of muscle cells control the GLUT proteins. Insulin promotes glucose transport into the muscle cells by incorporating GLUT 4 from an intracellular pool to the cell membrane.^[13,14] Peripheral resistance to insulin is the common pathological feature of both insulin dependent and non-insulin dependent diabetes. Insulin-induced glucose utilization by the skeletal muscle cells is reduced in human diabetics leading to metabolic changes such as adenosine triphosphate (ATP) depletion, lactic acid accumulation, and fall in pH and glycogen depletion. As muscle fibers require ATP for contraction and relaxation, depletion in ATP results in fatigue.^[15]

There is limited research about diabetes-related fatigue. This may be attributed to non-specific symptoms of fatigue. Furthermore, a standardized definition, measurement or diagnostic criteria for fatigue are yet to be established.^[11] Research in this area may be immensely useful to the diabetic subjects as it may help them overcome fatigue and aid in efficient performance of their day to day activities. This motivated us to take up this topic to explore the relationship between fatigue and diabetes. Flexors of the fingers are the most intensively used muscles by a number of individuals. The software professionals use this group of muscles during their work time. Furthermore, these are the most intensively used muscles by gadget freaks. In an otherwise sedentary lifestyle, this group of muscles is still being used intensively. With a large number of people taking up software as a career option and also increasing number of gadgets coming up into markets each day, it is the flexors of fingers that would be used frequently. This motivated us to assess the fatigability of this group of muscles.

MATERIALS AND METHODS

Participants

A sample size of 100 male subjects in the age group of 30–40 years is assessed. The control group consists of 50 healthy volunteers, and the test group consists of 50 controlled diabetics on oral hypoglycemics.

Inclusion Criteria

Male participants aged between 30 and 40 years with Hemoglobin A1C (HbA1c) value <6.5% are included in the study. Non-diabetic group includes healthy, well-nourished, and normotensive individuals. The diabetic group includes controlled diabetics on oral hypoglycemics, with a minimum duration of onset of diabetes of 2 years and with random blood sugar (RBS) value <150 mg/dl ½ h before the study.

Exclusion Criteria

Patients with thyroid dysfunction, anemia, and neuromuscular disorders are excluded from the study.

Trained individuals are excluded from the study. Participants on medication other than oral hypoglycemics are excluded.

Study Design

It is a case–control study ($n = 100$) comprising of male participants aged 30–40 years, conducted from November 2011 to November 2013 in the Department of Physiology, Medciti Institute of Medical Sciences. The study population consisted of two groups of male participants in the age group of 30–40 years. The control group consisted of 50 healthy volunteers. The test group consisted of 50 controlled diabetics. The participants were recruited from Medciti Institute of Medical Sciences and surrounding areas of Ghanpur village, Medchal Mandal. Before recruitment, informed consent was taken from all the participants. The study was approved by the Institutional Ethical Committee. HbA1c test was done 2 days before the day of the experiment to establish the glycaemic status of the participants. All the participants were instructed not to consume any central nervous system stimulants on the day of the experiment. RBS was tested ½ h before the experiment in diabetics to rule out hypoglycemia. The experiment was conducted with a time lag of 3–4 h after breakfast. Mosso's ergography was done to assess the performance of flexors of the fingers of the non-dominant hand against a load of 2.5 kg.

Measurement of Muscle Function

The device used to measure the muscle function is Mosso's ergograph. Nowadays, this equipment is available in a number of advanced forms and has become a nearly inevitable tool for muscle function studies. Ergography is the recording of an ergogram. Ergogram is the recording of voluntary contractions of the skeletal muscles of a human being. Mosso's ergography is done to assess the performance of the flexors of the fingers of the hand. It is also useful to study the phenomenon of fatigue in human skeletal muscle. In Mosso's ergography, fatigue is affected by the weight to be lifted and the frequency of contractions.

The participant is asked to place the index and ring finger into the fixed tube holders of the instrument. The middle

finger is left free to pull the load. The sling is connected to the middle finger. The subject is asked to lift the load by maximal contraction of the flexors of the middle finger. He is asked to repeat lifting the load every 2 s. A stopwatch is provided for this purpose. The subject is asked to continue lifting the load until the load can no longer be lifted.

Calculation of Indices of Muscle Function

Duration of onset of fatigue

It constitutes the time in minutes from the point the flexors of the middle finger of the non-dominant hand start to lift the load by maximal contraction to the point when they cannot lift the load anymore.

Work done

The muscle contractions of the flexors of the middle finger are registered on a piece of paper in the form of a graph which is then assessed to calculate the work done. The distance covered in meters (D) is measured using a measuring scale. Force (F) constitutes the load in Kg against which the muscle contracts. Work done in Kg M is then calculated using the formula: Work done = Force × Distance.

Statistical Analysis

Statistical analysis was done using Windostat version 9.2 software. The data were summarized using descriptive statistics (i.e., means and standard deviations). Comparison of variables between the two study groups was done using ANOVA. Throughout the study, the statistical significance was set at $P < 0.05$ using two-sided tests for all analyses.

RESULTS

Findings of this study are depicted in Table 1.

DISCUSSION

Table 1 shows the mean values of the duration of onset of fatigue in minutes and work done in Kg m in the control and test groups. In the present study, the duration of onset of

fatigue was significantly higher in non-diabetics than diabetics ($P < 0.005$). The mean value was 3.45 min in non-diabetics and 2.47 min in diabetics. The work done was significantly higher in non-diabetics than diabetics ($P < 0.005$). The mean value was 5.825 kg m in non-diabetics and 4.086 kg m in diabetics. The duration of exercise is shorter in diabetics than controls. The ability to produce strength is lower in diabetics than controls.

Fatigue in diabetes may be multifactorial. Although numerous lifestyle factors may contribute to fatigue, obesity and sedentary habits may have profound effect. Obesity is a common feature in insulin-resistant type 2 diabetics.^[16] Body mass index (BMI) in diabetics was found to be significantly higher than non-diabetics^[17] suggesting that assessment of anthropometric parameters from time to time may be helpful in managing diabetes-related symptoms. Obese diabetics experience higher degree of fatigue.^[18-20] Although correlation between obesity and fatigue has not been completely established, literature suggests that elevated levels of pro-inflammatory cytokines in obese subjects may play a prominent role in the development of fatigue.^[21-23] Furthermore, marked peripheral resistance to insulin is observed in both obesity and diabetes mellitus. Studies using magnetic resonance spectroscopy have shown an increase in intramyocellular triglyceride accumulation in the skeletal muscle of such individuals. This finding strongly correlates to muscle insulin resistance.^[24-26] Metabolic shift from glucose to fatty acids contributes to the pathophysiological development of muscle fatigue.^[27]

Most studies sought to study the effects of fatigue in diabetics suggested that the participants attributed their decline in ability to perform daily routine activities to fatigue. Fatigue was one of the primary concerns expressed by type 2 diabetic African American women, which according to them interfered with their daily life.^[28] Australian women with type 2 diabetes opined that they had to confine their social activities due to fatigue.^[29] Day to day activities such as preparation of food, physical activities, and measuring blood glucose levels were affected due to fatigue as reported by a study performed on community-dwelling type 2 diabetic adults.^[30] Fatigue was found to be reasonably correlated with type 2 diabetic industrial workers in India. Various clinical parameters of diabetes including duration of illness, alteration in blood glucose level, BMI, and diabetic complications are strongly associated with fatigue.^[31]

The limitations of the present study are, it is restricted to only one group of muscles and cannot be interpolated to all muscle groups. Muscle biopsy is not done because it is an invasive procedure. Muscle area is not obtained using computed tomography scan. Muscle fatigue is assessed only on functional factors.

Table 1: Comparison of mean values of calculated parameters across two groups

Variable	Mean±SE		T-test	P
	Control	Diabetic		
Duration of onset of fatigue (min)	3.450±0.174	2.470±0.145	4.333	0.000*
Work done (Kg m)	5.825±0.304	4.086±0.188	4.869	0.000*

$P < 0.05$: Significant difference, SE: Standard error

CONCLUSION

The study was sought to evaluate the fatigue in controlled diabetics and non-diabetics.

Normal non-diabetics had an ability to do more work without getting rapidly fatigued. Controlled diabetics got rapidly fatigued.

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