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Original Article

Physiotherapy Section

Muscle Strength in Type-2 Diabetes Mellitus and its Relationship with Biochemical Parameters and Microvascular Complications

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ABSTRACT

Introduction: Sensory symptoms and deficits are frequently observed in diabetic polyneuropathy, but motor deficits are more difficult to recognise or often neglected. As a part of a rehabilitation team, we observed altered muscle strength in Type-2 Diabetes Mellitus (T2DM) in relation to neuropathy. Weakness in muscles in DM has significant effects on patient's daily living activities.

Aim: To find the relationship of muscle strength in diabetes subjects characterised by microvascular complications (retinopathy, nephropathy and peripheral neuropathy associated) and biochemical measurements.

Materials and Methods: The present observational study was conducted at the Department of Orthopaedics, Srinivas Institute of Medical Sciences, Mangaluru, Karnataka, India for a period of nine months from February 2020 to November 2020. Study included 72 patients divided into T2DM subjects (n=36) and non diabetic controls (n=36) with age <75 years, with a diabetic history ≥5 years. By using standard laboratory methods, biochemical measurements were taken, which included Fasting Blood Sugar (FBS) level, Glycated Haemoglobin (HbA1c), serum creatine, serum insulin, C-peptide and albumin excretion rate. The retinal status of the diabetic subjects were classified as normal, non proliferative and proliferative retinopathy, renal status classified as incipient and overt nephropathy and neuropathy as asymptomatic and symptomatic by ophthalmologist, nephrologist and neurologist respectively. Muscle strength of the upper extremities and lower extremities were measured by using hand-held dynamometer (Baseline® LiTE®).

Results: Out of total 72 subjects, the mean age of diabetic and non diabetic group was 55.69±5.50 years and 55.91±5.21 years, respectively. In diabetic subjects, the median value of serum creatine was 1.04 mg/dL , FBS was 171 mg/dL, HbA1c was 9.1%,serum insulin was 24.62 mU/L, C-peptide was 1.13 ng/mL and albumin excretion rate was 57.6 mg/24 hours. Approximately, 10.5% reduction was observed at ankle dorsiflexion and plantar flexion of both sides, 7% reduction of knee extension (both side), and right knee flexion, whereas, the left knee shows a marked 10.81% reduction in muscle strength.

Conclusion: Type-2 diabetes subjects have weakness of extensors and flexors of the upper and lower extremity (shoulder and hip strength not assessed in this study) with predominant reduction of muscle strength in the lower limbs.

Keywords: Creatine, Fasting blood sugar, Glycated haemoglobin, Neuropathy, Retinopathy

INTRODUCTION

Type-2 diabetes mellitus affects the motor system, which includes muscles, tendons, ligaments and motor neurons. These lead to changes in the motor function of the lower and upper extremities depending on the severity of T2DM, the extent of damage to the motor system and the chronic nature of T2DM. Symptoms of diabetes related motor system manifestations in long term diabetes subjects include muscular pain or myalgia, noxious joints, stiff or restricted movements of the joints, swelling of joints, deformities and pin and needle sensation in the hand and feet.

Musculoskeletal complications of diabetes can be classified into joint disorders, muscle related disorders and skeletal disorders, along with other microvascular complications like diabetic neuropathy, retinopathy and peripheral nephropathy [1]. Sensory symptoms and deficits are frequently observed in diabetic polyneuropathy, but motor deficits are more difficult to recognise or often neglected by physicians.

As a part of the rehabilitation team, authors observed altered muscle strength in T2DM in relation with the severity of neuropathy. Andersen H et al., in their study reported that motor system dysfunction is known to occur however, the severity and distribution of weakness have not been well established in the literatures [2].

Sarcopenia, an age reliant reduction of muscle mass, is a common condition affecting the aged community and this cause gradual onset of physical inactivity. Subjects with T2DM as age progress are more susceptible to muscle mass reduction and the literature explains various mechanisms for that. In general, T2DM can be described as an inadequate action of the insulin hormone. Functions of insulin are not only reducing plasma sugar levels, but also encourage the growth and proliferation of cells. Inadequate activity of insulin results in inhibition of growth and proliferation of muscle cells which results in the reduction of skeletal muscle mass. Diabetic subjects not only have less muscle mass but their muscles are also deposited by fat molecules, which further leads to reduced force production, aggravating the weakness.

Weakness in muscles following DM has significant inference which implies that the subject will come across daily living activities more complicated and stress themselves to accomplish a task, thereby commence a pessimistic sequence of activity reduction and in turn worsen the diabetic condition in sedentary life style subjects.

In the present study, authors assessed the motor performance of the distal part of the upper and lower extremities (shoulder and hip not included) quantitatively in T2DM by using Hand-Held Dynamometry (HHD) (Baseline® LiTE®). The aim of the present study was to find the relationship of muscle strength in diabetes subjects characterised by microvascular complications (retinopathy, nephropathy and peripheral neuropathy associated with diabetes) and biochemical measurements.

MATERIALS AND METHODS

The present observational study was conducted at the Department of Orthopaedics, Srinivas Institute of Medical Sciences, Mangaluru, Karnataka, India for a period of nine months from February 2020 to November 2020. All T2DM subjects and controls given informed consent for participating in the study. Ethical approval was given by Institutional Ethics Committee of Srinivas University, Mangaluru, Karnataka, India (Ref: SUEC 2020/004 dated 02/01/2020).

Sample size calculation: Sample size was calculated by using formula, $n = \{(Z_{\alpha/2}+2\beta)^2\times 2\sigma^2\}/d^2$, where, $Z_{\alpha/2}$ is 1.96, 2β is 80%, σ is 0.23 and d is 10%}. For finding the reference value of muscle strength, another 65 non diabetes subjects were selected to avoid bias {sample size calculated by using $n = \{(Z_{\alpha/2})^2\times\sigma^2\}/E^2$, where $Z_{\alpha/2}$ is 1.96, σ is 0.2 and E is 0.05}.

Inclusion criteria: Subjects with T2DM aged less than 75 years with a diabetic history ≥5 years were included in the study.

Exclusion criteria: Subjects with chronic cardiorespiratory disorders, neuroendocrine disorders, chronic musculoskeletal disorders, severe symptomatic vascular disorders, any previous lower limb or upper limb weakness and recent fractures in the extremities were excluded from the study.

All diabetic subjects were evaluated by an endocrinologist, neurologists, nephrologist, and ophthalmologists to confirm and classify neuropathy, nephropathy and retinopathy (Researcher side initiated the evaluation). By using standard laboratory methods, biochemical measurements were taken which included FBS level, HbA1c, serum creatine, serum insulin, C-peptide and albumin excretion rate. The retinal status of the diabetic subjects was classified as normal, non proliferative and proliferative retinopathy [3], renal status classified as incipient and overt nephropathy [4], and neuropathy as asymptomatic and symptomatic [5], by ophthalmologist, nephrologist and neurologist respectively.

Muscle strength of the upper extremity and lower extremity were measured by using HHD. Details of the test positions and dynamometer placements used during the testing of the eight muscle groups are summarised in [Table/Fig-1] [6]. Muscle strength of extensor and flexor groups of ankle, knee, wrist and elbow of the right and left side in each subject were assessed three times and the average values was used for the evaluation.

Joint and muscle action	Joint positions/Test positions	Location of HHD application
Ankle		
Dorsiflexion	Neutral ankle with hip and knee fully extended (Supine lying)	Proximal to MTP joint (Dorsum of foot)
Plantar flexion	Neutral ankle with hip extended and knee flexed to 900 (Prone lying)	Proximal to MTP joint (Plantar aspect)
Knee		
Extension	Hip and knee flexed to 900 (Sitting)	Anterior aspect of distal tibia
Flexion	Hip and knee fully extended (Prone lying)	Posterior aspect of distal tibia
Wrist		
Extension	Neutral shoulder, 900 elbow flexed, forearm pronated with wrist in neutral.	Proximal to MCP joint (Dorsum of hand)
Flexion	Neutral shoulder, 900 elbow flexed, forearm supinated with wrist in neutral.	Proximal to MCP Joint (Palmar aspect)
Elbow		
Extension	Neutral shoulder, 900 elbow flexed, with wrist in neutral.	Posterior aspect of distal forearm
Flexion	Neutral shoulder, elbow extended, forearm supinated with wrist in neutral.	Anterior aspect of distal forearm

[Table/Fig-1]: Test positions of extremities and HHD placement used during the assessment.
HHD: Hand-held dynamometry

Biochemical Parameters

Fasting blood sugar: FBS measures blood sugar after an overnight fast. A FBS value of ≤99 mg/dL is considered as normal and a value of ≥126 mg/dL indicates diabetes and a value between 100-125 mg/dL indicates prediabetes state [7].

Glycated Haemoglobin (HbA1c): HbA1c test was also called as glycated haemoglobin test that gives a good indication of how well diabetes is being controlled. This is one of the tests used to diagnose T2DM. The World Health Organisation (WHO) suggests diagnostic guidelines for diabetes with a value of HbA1c greater than 6.5% indicates diabetes; less than 6% indicates non diabetes and value 6.0 to 6.4% indicates impaired glucose tolerance or prediabetes state [8].

Serum creatine: Serum creatine test is advised to check the proper functioning of kidneys. Creatine values more than 1.3 mg/dL in men and 1.1 mg/dL in women indicate altered kidney function or reduced blood flow to the kidneys due to shock, congestive heart failure or as a complication of diabetes (diabetic nephropathy) [9].

Serum insulin: Serum insulin is the hormone that upholds glucose uptake, glycogenesis, lipogenesis, and protein synthesis of skeletal muscle and fat tissue through the tyrosine kinase receptor pathway. High level (>25 mU/L) of insulin is an established risk factor for T2DM [10].

C-peptide levels: C-peptide is a widely used measure of pancreatic beta cell function. A higher value of C-peptide (normal 0.5-2 ng/mL) indicates either insulin resistance (as seen in T2DM) or usage of too much of a certain classes of medicine to treat T2DM (Sulfonylureas). Additionally, a lower value of C-peptide is associated with poor diabetic control and which in turn increased the glycated haemoglobin values [11].

Albumin excretion rate: Albumin excretion rate (normal: <30 mg/24 hrs) is a recognised interpreter of poor renal function in patients with T2DM. A higher excretion rate leads to classify the subjects into microalbuminuria (30-300 mg/24 hrs) and macroalbuminuria (>300 mg/24 hrs) [12].

STATISTICAL ANALYSIS

Statistical analysis was done by using SPSS software version 21.0. The data were summarised in mean, Standard Deviation (SD) and median. For finding the reference value of muscle strength used mean ±2 SD. Unpaired t-test were used to compare the muscle strength between T2DM subjects and non diabetic subjects. Mann-Whitney U tests were used in the comparison of muscle strength among neuropathy and non neuropathy subjects, between asymptomatic and symptomatic neuropathy subjects, among nephropathy and non nephropathy subjects, between incipient and overt nephropathy subjects, among the microvascular complications and among the duration of T2DM. To estimate the correlation between biochemical parameters and muscle strength, Karl Pearson's coefficients of correlation were used. The significance level of this study was at 5% (p-value ≤0.05).

RESULTS

Out of total 72 subjects, the mean age of diabetic and non diabetic group was 55.69±5.50 years and 55.91±5.21 years, respectively. Summarised clinical data of the T2DM subjects and their matched control subjects are given in [Table/Fig-2]. For finding the reference range of muscle strength assessed matched non diabetic subjects at ankle, knees, wrist and elbows from both sides. The muscle strength evaluated by HHD is expressed in force (Newton) and is displayed in [Table/Fig-3].

Biochemical parameters in T2DM subjects: The diabetic subjects had median values of 1.04 mg/dL of serum creatine, 171 mg/dL of FBS, 9.1% of HbA1c, 24.62 mU/L of serum insulin, 1.13 ng/mL of C-peptide and 57.6 mg/24 hours of albumin excretion rate. Mean and SD of biochemical parameters in diabetes subjects and between neuropathic and non neuropathic subjects were expressed in [Table/Fig-4].

Demographic variables	Group	Mean±SD
Age (years)	Diabetic group (N=36)	55.69±5.50
	Non diabetic group (N=36)	55.91±5.21
Weight (Kgs)	Diabetic group (N=36)	70.27±12.66
	Non diabetic group (N=36)	71.12±12.42
Height (cms)	Diabetic group (N=36)	165.44±9.45
	Non diabetic group (N=36)	165.58±9.68

[Table/Fig-2]: Demographic data showing mean and std. deviation of study subjects.

Joint	Muscle strength	Force (N)
Ankle	Dorsiflexor (R)	253.16-288.58
	Dorsiflexor (L)	252.77-287.29
	Plantar flexor (R)	286.39-339.86
	Plantar flexor (L)	284.69-339.53
Knee	Extensor (R)	396.04-442.91
	Extensor (L)	393.04-443.38
	Flexor (R)	365.09-400.48
	Flexor (L)	363.26-400.48
Wrist	Extensor (R)	128.12-161.33
	Extensor (L)	126.64-159.65
	Flexor (R)	146.59-173.44
	Flexor (L)	145.57-173.64
Elbow	Extensor (R)	150.25-178.15
	Extensor (L)	149.17-178.24
	Flexor (R)	175.54-246.33
	Flexor (L)	173.95-246.61

[Table/Fig-3]: Reference range of muscle strength in age group between 48-75 years.

Parameters		Serum creatine (mg/dL)	Fasting blood sugar (mg/dL)	HbA1c (%)	Serum Insulin (mU/L)	C-Peptide (ng/mL)	Albumin excretion rate (mg/24 hrs)
T2DM subjects (N=36)	Mean± SD	1.05± 0.28	212.45± 106.63	9.61± 2.17	37.11± 35.98	2.34± 5.96	112.51± 101.57
	Median	1.04	171.00	9.10	24.62	1.135	57.60
Non neuropathic subjects (N=14)	Mean	0.87	162.00	8.26	26.08	4.12	75.80
	Median	0.91	159.30	7.95	24.62	1.54	66.24
Neuropathic subjects (N=22)	Mean	1.17	244.55	10.48	44.13	1.22	135.88
	Median	1.11	198.00	9.95	23.25	1.07	57.60

[Table/Fig-4]: Biochemical parameters among T2DM with neuropathic and non neuropathic subjects.

Muscle strength in T2DM subjects: At ankle, the mean dorsiflexion strength at right was 227.25 N, and left was 226.56 N, plantar flexion strength at right was 256.56 N, and left was 255.75 N. At knee, the mean extension strength at right was 368.72 N, and left was 367.78 N, flexion strength at right was 341.14 N, and left was 323.97 N. At wrist, the mean extension strength at right was 137.33 N and left was 135.81 N, flexion strength at right was 153.53 N and left was 153.14 N. At elbow, the mean extension strength at right was 154.16 N and left was 151.97 N, flexion strength at right was 201.86 N and left was 199.08 N.

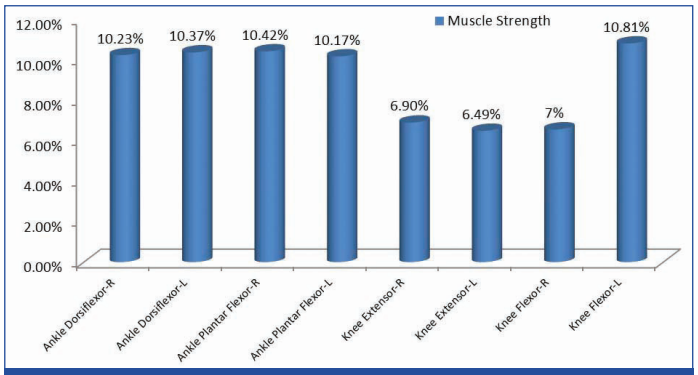
The muscle strength of ankle dorsiflexion and plantar flexion, knee extension and flexion, wrist extension and flexion, and elbow extension and flexion of both sides showed a reduction in T2DM subjects compared with non diabetic group [Table/Fig-5]. This reduction in muscle strength was statistically significant (p-value <0.05). The study result shows that there is no statistically significant difference observed in upper extremity muscle strength among the control and diabetic subjects.

However, authors observed a significant decline of muscle strength in lower extremity muscles in diabetic subjects. Approximately,

Joints	Muscle strength	Diabetic group (N=36) Mean±SD	Non diabetic group (N=36) Mean±SD	Significance (2-tailed)
Ankle	Dorsiflexor (R)	227.25±7.62	270.50±9.09	p<0.001*
	Dorsiflexor (L)	226.56±7.46	269.64±8.91	p<0.001*
	Plantar Flexor (R)	256.56±11.21	312.78±13.64	p<0.001*
	Plantar Flexor (R)	255.75±11.42	311.77±13.95	p<0.001*
Knee	Extensor (R)	368.72±10.97	418.97±12.44	p<0.001*
	Extensor (L)	367.78±11.59	417.86±13.10	p<0.001*
	Flexor (R)	341.14±6.09	382.47±9.09	p<0.001*
	Flexor (L)	323.97±7.99	381.14±9.38	p<0.001*
Wrist	Extensor (R)	137.33±8.27	144.42±8.63	p<0.001*
	Extensor (L)	135.81±8.02	142.86±8.42	p<0.001*
	Flexor (R)	153.53±6.61	159.86±7.01	p<0.001*
	Flexor (L)	153.14±6.92	159.50±7.33	p<0.001*
Elbow	Extensor (R)	154.16±6.82	163.94±7.21	p<0.001*
	Extensor (L)	151.97±7.06	163.44±7.53	p<0.001*
	Flexor (R)	201.86±17.18	210.22±17.89	p=0.044*
	Flexor (L)	199.08±17.28	209.58±18.24	p=0.014*

[Table/Fig-5]: Comparison of muscle strength between the T2DM and non diabetic group.
*p-value less than 0.05 were considered statistically significant

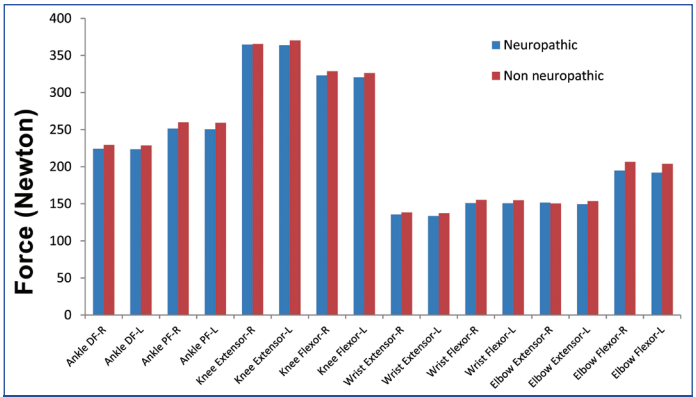
10.5% reduction was observed at ankle dorsiflexion and plantar flexion of both sides, 7% reduction of knee extension (both sides), and right knee flexion, whereas, the left knee shows a marked 10.81% reduction in muscle strength [Table/Fig-6].



[Table/Fig-6]: Muscle strength reduction in T2DM subjects.

Muscle strength among diabetic neuropathy subjects: This study observed significant differences between muscle strength between neuropathic and non neuropathic T2DM subjects at ankle plantar flexion and knee flexion. The median value of plantar flexion was 246.5 N at the right side and 247 N at the left side in diabetic neuropathy subjects and 263 N at the right side and 263 N at the left side in diabetic non neuropathy subjects. The p-value of ankle plantar flexion at the right side was 0.021 and left side was 0.031. The median value of knee flexion was 377.5 N at the right side and 320.5 N at the left side in diabetic neuropathy subjects and 387 N at the right side and 329 N at the left side in diabetic non neuropathic subjects. The p-value of knee flexion at the right side was 0.035 and left side was 0.032. This indicates diabetic neuropathic subjects have marked reduction muscle strength at plantar flexion of the ankle and flexion of knee. The differences in muscle strength for each muscle group were explained in [Table/Fig-7].

The muscle strength of symptomatic diabetic neuropathy subjects demonstrated a statistically significant reduction in muscle strength at ankle plantar flexion, knee flexion and extension, wrist flexion and extension and elbow flexion and extension at both sides while comparing with asymptomatic diabetic neuropathy subjects (p-value <0.05 in all muscle groups except at ankle dorsiflexion). The summarised details of muscle strength among symptomatic and asymptomatic diabetic neuropathy subjects are in [Table/Fig-8].

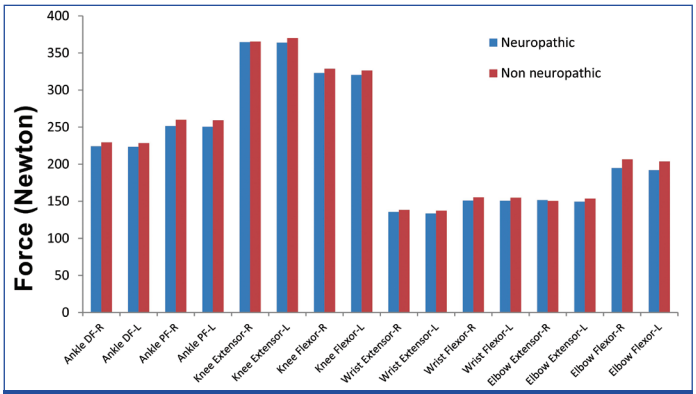


[Table/Fig-7]: Differences in muscle strength between neuropathic and non neuropathic T2DM subjects.

Joints	Muscle strength	Symptomatic Mean±SD	Asymptomatic Mean±SD	Significance (2-tailed)
Ankle	Dorsiflexor (R)	227.27±7.73	231.27±6.45	0.156
	Dorsiflexor (L)	226.45±7.63	230.54±6.15	0.157
	Plantar flexor (R)	255±9.85	264.81±8.90	0.015*
	Plantar flexor (L)	253.63±9.75	264.54±9.33	0.009*
Knee	Extensor (R)	366.09±9.59	379.63±8.10	0.011*
	Extensor (L)	364.54±10.03	375.90±8.15	0.011*
	Flexor (R)	336.09±5.99	344.09±5.31	0.005*
	Flexor (L)	321.90±7.06	330.54±6.63	0.008*
Wrist	Extensor (R)	133.63±8.01	143.18±6.70	0.006*
	Extensor (L)	132.27±7.52	142.18±6.09	0.003*
	Flexor (R)	151.81±4.95	158.54±7.06	0.021*
	Flexor (L)	151.27±5.53	158.18±7.61	0.032*
Elbow	Extensor (R)	152.81±6.40	158.72±6.16	0.030*
	Extensor (L)	150.54±6.37	156.72±6.54	0.027*
	Flexor (R)	197.90±14.43	214.90±13.67	0.006*
	Flexor (L)	195.27±14.69	212.09±13.30	0.006*

[Table/Fig-8]: Comparison of muscle strength between symptomatic and asymptomatic diabetic neuropathy subjects.
*p-value less than 0.05 were considered statistically significant

Muscle strength among diabetic nephropathy subjects: The study also showed a significant differences in muscle strength at ankle plantar flexion (p-value <0.05) and elbow flexion (p-value <0.05) among diabetic nephropathy subjects [Table/Fig-9]. These indicate diabetic nephropathy subjects have a reduction in muscle strength at all the tested/evaluated joints, but marked reductions were observed at ankle plantar flexion and elbow flexion compared to the non diabetic subjects.



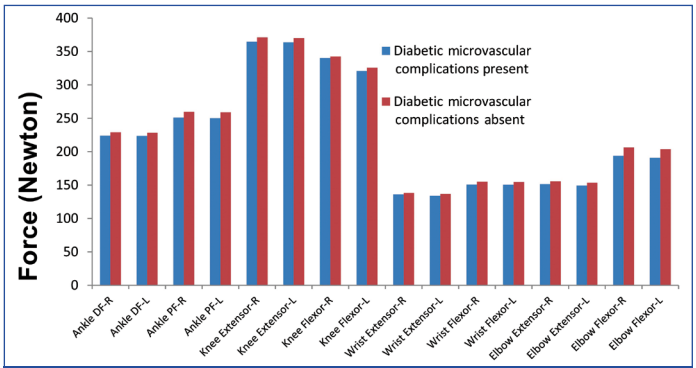
[Table/Fig-9]: Differences in muscle strength between nephropathic and non nephropathic T2DM subjects.

The muscle strength of incipient and overt diabetic nephropathy subjects demonstrated no significant difference in muscle strength at the test joints (p-value >0.05). This indicates diabetic nephropathy leads to a reduction in skeletal muscle strength irrespective of the severity (incipient or overt) of diabetic nephropathy [Table/Fig-10]. So result reveals diabetic nephropathy subjects are more prone to reduction of skeletal muscle strength than diabetes subjects not having nephropathy.

Region	Muscle strength	Incipient nephropathy Mean±SD	Overt nephropathy Mean±SD	Significance (2-tailed)
Ankle	Dorsiflexor (R)	231±5.30	224±8.88	0.114
	Dorsiflexor (L)	229.8±5.36	224±9.05	0.161
	Plantar flexor (R)	262.66±7.88	255.6±14.34	0.484
	Plantar flexor (L)	261.93±8.11	255±15.04	0.512
Knee	Extensor (R)	373.93±8.77	364.6±12.66	0.162
	Extensor (L)	373.06±8.91	363.6±13.33	0.137
	Flexor (R)	341.42±5.57	340.73±6.95	0.735
	Flexor (L)	326.6±7.56	323.4±10.78	0.540
Wrist	Extensor (R)	139.13±8.45	136±10.30	0.569
	Extensor (L)	137.8±8.38	135.6±9.71	0.726
	Flexor (R)	156.2±6.14	153.6±9.18	0.484
	Flexor (L)	155.9±6.41	152.8±10.13	0.483
Elbow	Extensor (R)	157.26±5.16	152.8±10.25	0.294
	Extensor (L)	155.2±5.58	150.4±9.93	0.238
	Flexor (R)	210.6±11.15	201±23.94	0.512
	Flexor (L)	207.93±11.24	198.6±23.43	0.570

[Table/Fig-10]: Comparison of muscle strength between incipient and overt diabetic nephropathy subjects.

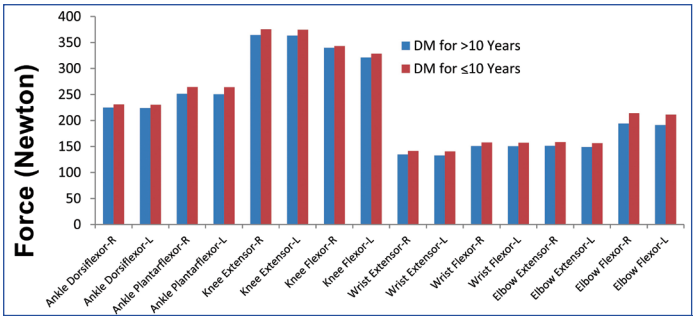
Muscle strength in diabetic microvascular complications: The T2DM subjects with the three microvascular (neuropathy, nephropathy and retinopathy) complications and without complications show a reduction in muscle strength when compared with the control group. The reduction in muscle strength within the diabetic group (without complications) shows no much significant difference with those who are having the microvascular complications (p>0.05) except at the ankle (p-value=0.022 and 0.031 at the right and left side) plantar flexion [Table/Fig-11].



[Table/Fig-11]: Muscle strength in diabetic microvascular complications.

Muscle strength in relation to diabetic duration: The diabetic groups were divided into two groups based on the duration of T2DM (≤10 years and >10 years). Subjects with T2DM >10 years show a statistically significant reduction (p-value <0.05) in muscle strength at all joints than subjects with T2DM ≤10 years [Table/Fig-12]. This reveals that the duration of T2DM has a significant role in muscle strength. The correlation with T2DM and duration shows a negative relationship with statistical significance (p-value <0.05) at ankle, knee, wrist and elbow. This indicates as diabetes duration increases (long standing T2DM or ≤10 years), muscle strength decreases in T2DM subjects.

Muscle strength relation with biochemical parameters: The diabetic neuropathy subjects had a mean values of serum creatine 1.17 mg/dL, FBS 244.55 mg/dL, HbA1c 10.48%, serum insulin 44.13 mU/L, C-peptide 1.12 ng/mL and albumin excretion rate of



[Table/Fig-12]: Difference in muscle strength with T2DM duration.

135.88 mg/24 hours. While analysing the biochemical parameters relationship with muscle strength, this study result explains that there is no significant relationship (p-value >0.05) with muscle strength and biochemical parameters except albumin excretion rate (p-value <0.05). The negative statistically significant relationship of albumin excretion rate indicates the muscle strength reduction at the joints when the albumin excretion rate increases in T2DM subjects [Table/Fig-13].

activities of daily living. The functional shortcomings are not only due to polyneuropathy (proprioceptive deficit) but also changes in the motor system (weakness of muscle, joint hypomobility) contribute more severity along with other diabetic microvascular complications (nephropathy and retinopathy) [14].

The observations within the study showed the reduction in muscle strength was not only because of neuropathic complications, but also related to the duration of diabetes and rate of albumin excretion. Andersen H et al., reported that muscle weakness in T2DM was due to diabetic polyneuropathy [2]. But in the current study two more factors (duration and albumin excretion rate) were included. The biochemical parameters of neuropathic subjects showed a median value of 9.95% of HbA1c, 23.25 mU/L of serum insulin and 135.88 mg/24 hours. This indicates poor diabetic control, poor pharmacological support or medicines not effective to the subjects and excessive loss of protein leading to muscle weakness.

Park SW et al., reported in 2006 that T2DM with longer duration (≥6 years) and poor control of diabetes (>8.0% of HbA1c) shows poor muscle quality, leading to decline in strength of the muscle,

Joint	Muscle strength	Serum creatine (mg/dL)		Blood glucose (mg/dL)		HbA1c (%)		Serum insulin (mU/L)		C-Peptide (ng/ML)		Albumin excretion rate (mg/24 Hrs)	
		r-value	p-value	r-value	p- value	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Ankle	Dorsiflexor (R)	0.273	0.218	-0.092	0.683	0.070	0.755	-0.198	0.378	0.121	0.593	0.471	0.027*
	Dorsiflexor (L)	0.281	0.206	-0.060	0.792	0.092	0.684	-0.205	0.361	0.131	0.563	0.475	0.026*
	Plantar flexor (R)	0.367	0.093	0.055	0.809	0.219	0.328	-0.373	0.087	-0.127	0.574	0.604	0.003*
	Plantar flexor (L)	0.397	0.081	0.108	0.632	0.275	0.215	-0.396	0.068	-0.135	0.549	0.631	0.002*
Knee	Extensor (R)	0.296	0.180	-0.107	0.635	0.131	0.560	-0.345	0.116	-0.070	0.758	0.641	0.001*
	Extensor (L)	0.293	0.185	-0.107	0.636	0.137	0.542	-0.345	0.116	-0.063	0.780	0.654	0.001*
	Flexor (R)	0.255	0.252	-0.027	0.427	0.196	0.367	-0.288	0.191	-0.153	0.329	0.590	0.004*
	Flexor (L)	0.339	0.123	-0.002	0.991	0.190	0.397	-0.289	0.192	-0.289	0.563	0.664	0.001*
Wrist	Extensor (R)	0.339	0.123	-0.026	0.910	0.215	0.337	-0.407	0.060	-0.232	0.299	0.663	0.001*
	Extensor (L)	0.394	0.069	-0.035	0.877	0.261	0.241	-0.441	0.061	-0.232	0.303	0.687	0.001*
	Flexor (R)	0.289	0.192	-0.010	0.966	0.152	0.500	-0.269	0.226	-0.138	0.541	0.521	0.013*
	Flexor (L)	0.292	0.188	-0.018	0.937	0.148	0.511	-0.248	0.266	-0.111	0.623	0.495	0.019*
Elbow	Extensor (R)	0.329	0.135	-0.065	0.775	0.176	0.434	-0.297	0.179	-0.143	0.527	0.537	0.010*
	Extensor (L)	0.332	0.132	-0.048	0.834	0.195	0.385	-0.278	0.210	-0.173	0.540	0.565	0.006*
	Flexor (R)	0.366	0.094	-0.005	0.983	0.180	0.422	-0.388	0.075	-0.057	0.802	0.603	0.003*
	Flexor (L)	0.361	0.099	-0.009	0.968	0.180	0.423	-0.379	0.082	-0.057	0.802	0.596	0.003*

[Table/Fig-13]: Correlation of muscle strength with biochemical parameters of diabetic neuropathy subjects.
*indicates p values less than 0.05 (Statistically significant)

DISCUSSION

The present study initiated that T2DM could have a reduction in muscle strength at ankle, knee, elbow and wrist while comparing with the matched non diabetic subjects. However, the marked reduction in muscle strength had observed at the ankle (Dorsiflexor (R)=227.25±7.62 and (L)=226.56±7.46, Plantar flexor (R)=256.56±11.21 and (L)=255.75±11.42), and knee (Extensor (R)=368.72±10.97 and (L)=367.78±11.59, Flexor (R)=341.14±6.09 and (L)=323.97±7.99) and with upper limb extremity muscle strength within the reference range. As to the core concept, in this study, the reduction of muscle strength was related to the severity, duration of neuropathy and albumin excretion rate rather than the extent of diabetic nephropathy or other biochemical parameters.

Polyneuropathy secondary to T2DM is the most common microvascular complication, with a prevalence of 40% after 10 years of diabetes [13]. Diabetic polyneuropathies are generally considered as a sensory neuropathy by clinicians and are often associated with the risk of falls and associated fractures, foot ulcers and amputations. The changes in the motor system following diabetic neuropathy were often neglected or studied inadequately. Because of these changes, T2DM subjects have difficulties in functional activities or

which was in concordance with the present study [15]. On the other hand Halvatsiotis P et al., reported in their study that muscle strength was unaffected by diabetes or glycemic levels, which was contradictory to the current study [16].

In 2003, Smith LL et al., stated their views on musculoskeletal manifestations in T2DM in terms of glycemic control, diet control, importance of exercise and current study give the eye opening to all the medical practitioners to encourage T2DM subjects to follow supervised exercise regimens or physiotherapy to prevent or to avoid worsening of the complications [17].

Petrova N L and Shanahan CM studied about the neuropathy and vascular complications in diabetes and reported about the severe form of complication called as Charcot osteoarthropathy characterised by the vascular calcification and bone lysis (abnormalities) [18]. Prevention of such complications by early evaluation and proper rehabilitation to diabetes subjects are essential to avoid the likelihood of disabilities. Current study shows dramatic changes of muscle strength in neuropathic subjects and negligence of these issues will lead to more disability. In a study by Choi HK and Ford ES included pain in joints variable and stated pain may be due to hyperuricaemia related to T2DM, derived relationship

between HbA1c and uric acid level [19]. The present study did not include pain in joints.

Limitation(s)

Limitations of the present study are pain in joints variable was not included. History of physical activity levels of the subjects were not asked, which may have effect on muscle mass. Age related muscle mass reduction (sarcopenia) is well known and if sarcopenia is accelerated due to diabetes was not assessed. Muscle mass effects due to fat deposition and impact of pharmacological interventions on muscle mass were not assessed.

CONCLUSION(S)

This study concludes that T2DM subjects have weakness of extensors and flexors in all the tested muscle groups (ankle dorsiflexors and plantar flexors, knee extensors and flexors, wrist extensors and flexors, elbow flexors and extensors) with predominant reduction of muscle strength in the ankle and knee musculatures. The motor dysfunction among diabetes has not addressed well in literatures and this study will be an eye-opener for managing the motor system in diabetes. The reduction of muscle strength was related to the severity, duration of neuropathy and albumin excretion rate rather than the extent of diabetic nephropathy or other biochemical parameters in T2DM subjects.

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