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Research Article

Nerve Conduction Studies in Diabetic Polyneuropathy: A Comparative Analysis of Asymptomatic and Symptomatic Patients

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Abstract
This study aimed to compare motor nerve conduction parameters in diabetic patients with and without signs of diabetic polyneuropathy (DPN). The study was carried out on 80 participants- 40 asymptomatic and 40 symptomatic patients, and employed motor nerve conduction studies (NCS) on the right and left tibial and ulnar nerves. The results showed that symptomatic patients had decreased motor nerve amplitudes and increased F-wave latencies in both tibial and ulnar nerves compared to asymptomatic patients. Symptomatic patients had reduced amplitudes of nerve responses and increased latency, but conduction velocities were similar to those of asymptomatic patients. These results have emphasized selective nerve dysfunction in symptomatic patients and have emphasized that nerve amplitude and latency should be the focus of nerve integrity in diabetic neuropathy.

Keywords: Diabetic polyneuropathy, Tibial nerve, Ulnar nerve, F-wave

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INTRODUCTION

NCS is a very essential and effective diagnostic tool in DPN (Albers & Pop-Busui, 2014). NCS offers quantitative information through the degree and frequency of electrical response across a nerve after stimulation (Lee *et al*., 2020). Reduced conduction velocity, reduced amplitude and increased distal latency suggest axonal loss in DPN as well as demyelination (Callaghan *et al*., 2012). NCS is useful in diagnosing DPN in its early stages when it remains asymptomatic, but the nerve injury is evident; this enables early intervention to prevent further complications (Charles *et al*., 2010). This ability makes NCS useful when assessing other high-risk people like those with diabetes (Lee *et al*., 2020). Distal symmetrical polyneuropathy (DSPN) is more common in patients with a longer duration of diabetes, but it has been observed even in those who were newly diagnosed and therefore early screening is of paramount importance (Pop-Busui *et a*l., 2017). Indeed, a cross-sectional study revealed that newly diagnosed diabetic patients who participated in the study had abnormal NCS indicating subclinical DPN (Chander., 2021). One survey revealed that, from a cohort of asymptomatic diabetic patients, 20% had polyneuropathy according to NCS (Kastre & Guntupalli, 1999). This shows how early NCS can be in useful in detecting subclinical diseases among the affected population. This study points out a comparison between NCS abnormalities in symptomatic and asymptomatic diabetics to establish the reliability of NCS in early DPN detection. The last method is symptom scoring which is employed as a screening tool to check for DPN and their subjective symptoms including pain, numbness, and tingling (Pop-Busui *et al*., 2009). However, the sensitivity to diagnosis using symptoms alone is not very high. Actually, in the study by Charles *et al*., (2010), it was demonstrated that 34% of patients with abnormal NCS were asymptomatic. In the same way, Perkins *et al*. 2001 observed that 39% of patients with neuropathy, confirmed by electrophysiological testing did not show any signs of the

condition. This points to some of the concerns surrounding solely basing DPN diagnosis on symptoms and signifies the extra value of employing quantitative NCS as a diagnostic criterion. There have also been other correlations with glycemic control expressed by HbA1c levels and severity of DPN and nerve damage identified with NCS (Albers & Pop-Busui, 2014; Charles *et al.*, 2010). High blood glucose concentrations are thought to directly contribute to the development of diabetic neuropathy by causing imbalances in blood supply through increased oxidative stress and formation of advanced glycation end products (Callaghan *et al.*, 2012). Better HbA1c management has been associated with a decreased incidence of DPN and could enable interventions before the progression to irreversible nerve damage (Pop-Busui *et al.*, 2017). The differences in HbA1c levels between patients with and without symptoms of diabetic neuropathy and/or NCS abnormalities would help in understanding the relationship of glycemic control. Other NCS parameters such as F-wave latencies may enhance the diagnostic yield of early DPN, although this concept is still a matter of debate. These studies involve the use of F-waves that can evaluate proximal nerve segments and the central parts of the nervous system, which is otherwise not possible with routine NCS (Lee *et al*., 2020). The F-wave latency is often used as a marker of early nerve involvement, and an increased F-wave latency beyond the reference value is often taken to indicate early nerve dysfunction (Dumitru, 2012). Specifically, Charles *et al.*, (2010) established that there are more significant F-wave changes compared to the routine NCS values in early DPN patients. Including F-wave assessment may therefore increase recognition of subclinical cases. This investigation plan is to assess and compare the abnormalities of NCS in symptomatic and asymptomatic diabetic patients to determine the applicability of the NCS in diagnosing early DPN. Secondary measures also involve the evaluation of symptom scoring for diagnostic assessment, the impact of HbA1c control on DPN intensity, and the usefulness of F-wave assessment in the diagnosis of DPN.

Literature Review

Diabetic polyneuropathy (DPN) is one of the most common diabetic complications with a prevalence that ranges from 40% to 50% of diabetic patients (Pop-Busui *et al.*, 2017). It tends to be chronic- exhibiting minimal signs of toxicity in the nerves for years before manifesting symptoms (Callaghan *et al*., 2012). There are generalizations in the early detection of DPN to reduce further degeneration of the nerves through glycemic control and other measures (Bril, 2017).

Electrophysiological examination including nerve conduction studies (NCS) is an objective and quantitative downstream testing for the type and severity of peripheral arterial disease in DPN (Charles *et al.*, 2010; England *et al.*, 2005). Motor NCS specifically allows for the identification and assessment of abnormalities in motor nerves through mapping when the nerve is stimulated (Krishnan & Kiernan, 2005). Some of the parameters determined from motor NCS include- distal motor latency; motor conduction velocity; amplitude and F-wave response. Low amplitude and increased latency of compound muscle action potential (CMAP) along with the slowing of conduction velocities are the conventional features of demyelinating neuropathy in early diabetes DPN (Karmally *et al.*,2018).

Some studies have examined the use of motor NCS in the diagnosis and assessment of DPN. Dyck *et al* found that asymptomatic diabetic patients had recordings of peroneal and median motor nerve conduction velocities which were 10% faster than those of the symptomatic group. Furthermore, some inflammatory markers of axonal loss and demyelination were higher in the symptomatic group than in the asymptomatic group. The researchers noted that motor NCS is a useful approach to diagnosing subclinical and early DPN, as evidenced by Young et al. These results are further corroborated by Wiggin *et al.*, (2009) who found that ulnar nerves had a higher degree of conduction than diabetic symptomatic patients as compared to asymptomatic patients.

Studies published in the recent past have concentrated on improving diagnostic resolution for detection of early DPN by employing motor NCS. This also involves the creation of new parameters and models. For example, Vranić *et al.*, (2016) put forward a new marker called the "index of motor distal latency reduction" and demonstrated that it had a higher accuracy in terms of diagnosis than earlier markers.

Concrete data about certain motor nerve conduction characteristics that would differentiate between the asymptomatic and the symptomatic stages of DPN have not been provided. The existence of regular neurophysiological profiles could be helpful to medical management decisions for screening and early intervention in high-risk diabetic patients (Pop-Busui *et al.*, 2017). As a result, larger studies are needed to refine specific diagnostic thresholds as well as multivariate motor NCS indices of early DPN progression based on predictive models.

Methodology

Study Design and Participants

This cross-sectional study included a total of 80 participants divided into two groups: 40 patients with diabetes mellitus with no symptoms of DPN and 40 patients with diabetes mellitus who had symptoms of DPN. Subjects were identified through outpatient clinics of Government Medical College, Kottayam. Consent was obtained from all participants before participating in the study. The current study was reviewed and granted clearance by the Institutional Review Board at Government Medical College,Kottayam.

Inclusion and Exclusion Criteria

Sample inclusion criteria included participants aged 18-70 years old diagnosed with diabetes mellitus without a record of neurological disorders (Perez *et al.*, 2021). Using exclusion criteria, participants with other diseases causing impaired conduction, individuals on medications that may affect conduction or those with a history of prior limb surgery or trauma were excluded (Verma *et al.*, 2019).

Motor Nerve Conduction Study

Motor nerve conduction studies were performed using standard techniques (Preston & Shapiro, 2013) to evaluate parameters of the tibial and ulnar nerves bilaterally: Amplitude, Latency, Conduction velocity, F-wave latency.

3.4 Procedure: The nerve conduction tests were conducted using the Natus Ultrapro S100 machine from Natus Medical, Inc., Pleasanton, CA as recommended (Falls, 2022). Subdermal electrodes were positioned on desired muscles for stimulation and analysis (Buschbacher, 2022). The nerves were compared for amplitudes, latencies, conduction velocities, and F-wave latencies.

Statistical Analysis

Differences in nerve conduction parameters were determined by independent samples t-test using SPSS version 27 (IBM Corporation, Armonk, New York). p-value of < .05 was used as the cut-off level in determining the statistical significance.

Results and Discussions

Comparison of Motor Nerve Conduction Parameters of Right Tibial Nerve

Table 1 shows motor nerve conduction studies of the right tibial nerve were performed on 40 asymptomatic subjects and 40 patients with symptomatic neuropathy. The parameters that were assessed were right tibial motor amplitude (RTAMP), right tibial motor latency (RTLAT), right tibial motor conduction velocity (RTCV), and right tibial F wave latency (RTF). The findings of the asymptomatic group were compared with the findings of the symptomatic group using statistical tests to determine the differences. The symptomatic group had a lower mean RTAMP of 5. 17 (±2. 63) and the asymptomatic group had a mean of 7. 47 (± 2. 58, p = 0. 000). The RTF value was much higher in the symptomatic group with a mean of 51. 70 (±7. 07) while the asymptomatic group had a mean of 48. 06 (±4. 74, p=0. 010). However, there were no significant differences between the groups for RTLAT and RTCV, with p-values of 0. 135 and 0. 277, respectively. These results indicate that motor nerve amplitude is reduced in the right tibial nerve in the symptomatic group, although motor latency and conduction velocity are unaltered (figure 1).

Table 1: Comparison of Motor Nerve Conduction Parameters of Right Tibial Nerve

Parameter	Asymptomatic (n=40) Mean ± SD	Symptomatic (n=40) Mean ± SD	t	p
RTAMP	7.47 ± 2.58	5.17 ± 2.63	3.918	0.000
RTLAT	3.61 ± 0.60	3.92 ± 1.08	1.509	0.135
RTCV	51.12 ± 5.42	49.67 ± 6.23	1.096	0.277
RTF	48.06 ± 4.74	51.70 ± 7.07	2.640	0.010

(RTAMP-Right tibial nerve amplitude (CMAP), RTLAT-right tibial nerve latency, RTCV- Right tibial nerve conduction velocity, RTF-Right tibial nerve F-wave latency)

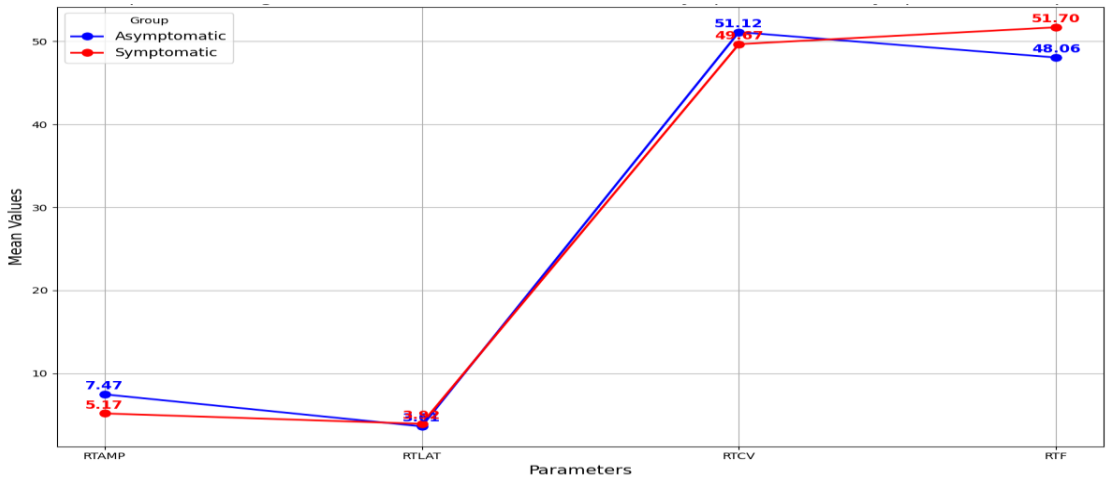

Figure 1: Motor Nerve Conduction Parameters of Right Tibial Nerve

Comparison of Motor Nerve Conduction Parameters of Left Tibial Nerve

Table 2 shows the motor nerve conduction of the left tibial nerve in forty symptomatic and forty asymptomatic patients. It was also found that the groups differed significantly for some of the parameters. More precisely, LTAMP was statistically different, with the asymptomatic group having a mean of 7. 18 ± 2. 35, compared to 5. 46 ± 3. 20 in the symptomatic group (p = 0. 009). Furthermore, LTCV was markedly different, with the asymptomatic group having a mean of 52. 24 ± 6. 05 and the symptomatic group had a mean of 48. 46 ± 6. 32 (p = 0. 008). The LTF values were significantly different, with the asymptomatic group having a mean of 48. 15 ± 5. 04 and the symptomatic group a mean of 51. 62 ± 5. 39 (p = 0. 004). However, LTLAT did not reveal a significant difference between the groups, p = 0. 477. The differences in LTAMP, LTCV, and LTF indicate that there are differences in motor nerve conduction in asymptomatic and symptomatic patients, however, LTLAT did not change (figure 2).

Table 2: Comparison of Motor Nerve Conduction Parameters of Left tibial Nerve

Parameter	Asymptomatic (n=40) Mean ± SD	Symptomatic (n=40) Mean ± SD	t	p
LTAMP	7.18 ± 2.35	5.46 ± 3.20	2.676	0.009
LTLAT	3.72 ± 0.55	3.92 ± 1.58	0.715	0.477
LTCV	52.24 ± 6.05	48.46 ± 6.32	2.719	0.008
LTF	48.15 ± 5.04	51.62 ± 5.39	2.950	0.004

(LTAMP Left tibial nerve amplitude (CMAP), LTLAT Left tibial nerve latency, LTCV Left tibial nerve conduction velocity, LTF Left tibial nerve F-wave latency)

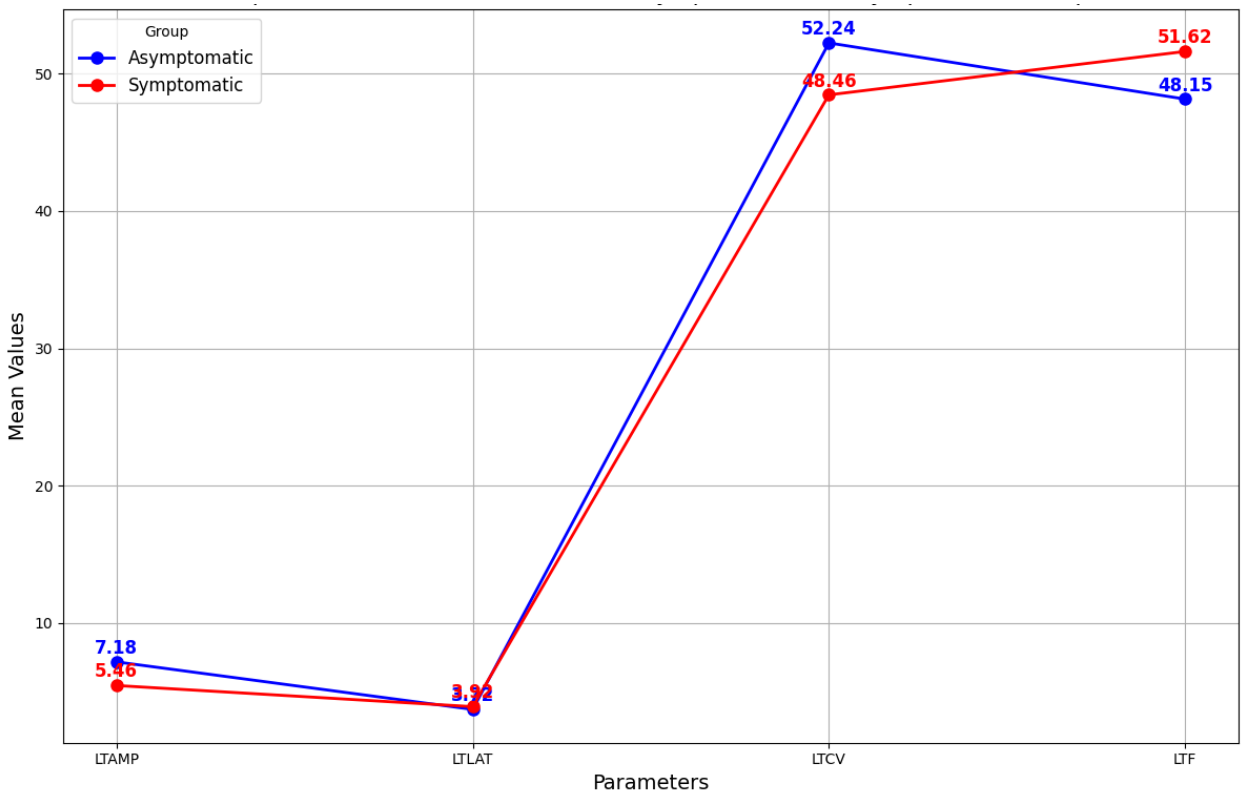

Figure 2: Motor Nerve Conduction Parameters of Left Tibial Nerve

Comparison of Motor Nerve Conduction Parameters of Right Ulnar Nerve

Table 3 shows the motor nerve conduction measurements of the right ulnar nerve in 40 asymptomatic patients for neuropathy and 40 symptomatic participants. Four parameters were compared- amplitude (RUAMP), latency (RULAT), conduction velocity (RUCV), and F wave latency (RUF). Analysis of the data obtained in the study reveals that the mean amplitude and conduction velocity values were similar in the two groups. However, there were found differences in the latency of response (p=0.039) and F-wave latency (p= 0.014) between a group of asymptomatic individuals and a group of symptomatic ones. More specifically, the mean latency was longer, and the mean F wave latency was slower in the symptomatic group as compared to the asymptomatic group. Additionally, to make a better understanding and confirmation of these findings on nerve dysfunction, further research studies involving larger samples should be conducted. However, it is evident from this table that there are significant distinctions in nerve conduction between asymptomatic and symptomatic patients as far as right ulnar nerve function is concerned (figure 3).

Table 3: Comparison of Motor Nerve Conduction Parameters of Right Ulnar Nerve

Parameter	Asymptomatic (n=40) Mean ± SD	Symptomatic (n=40) Mean ± SD	t	p
RUAMP	10.1 ± 3.9	9.0 ± 4.0	1.275	0.207
RULAT	3.5 ± 0.7	4.0 ± 1.2	2.105	0.039
RUCV	54.5 ± 5.1	52.3 ± 6.4	1.754	0.084
RUF	26.5 ± 2.9	28.6 ± 3.2	2.523	0.014

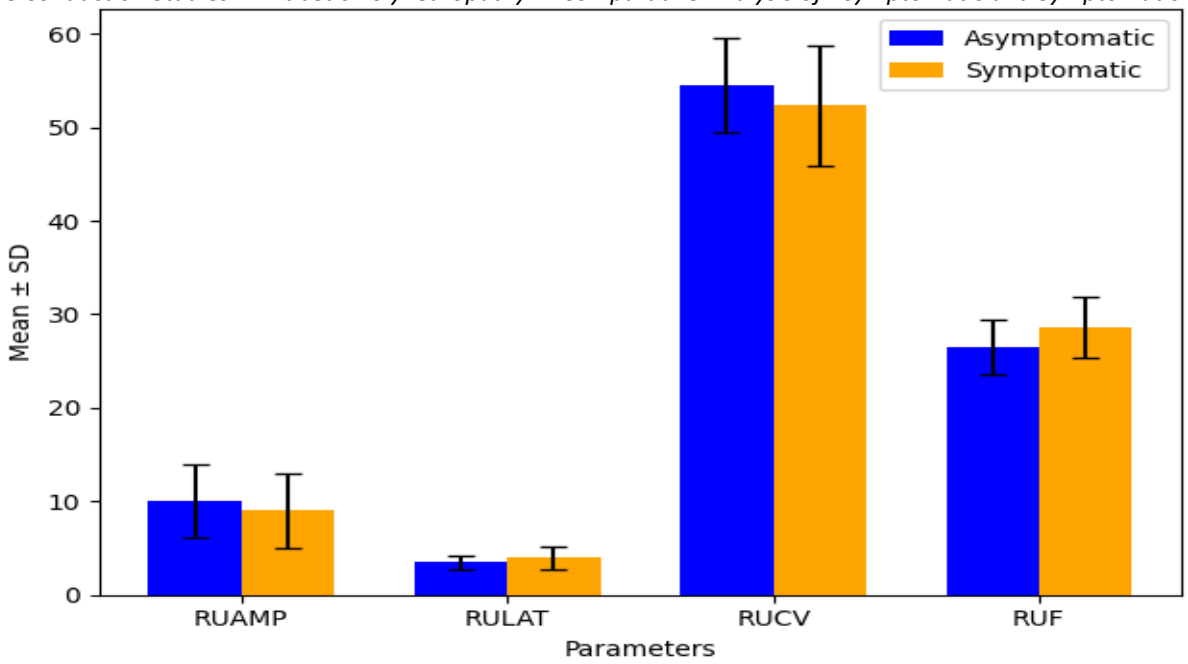

Figure 3: Motor Nerve Conduction Parameters of Right Ulnar Nerve

Comparison of Motor Nerve Conduction Parameters of Left Ulnar Nerve

Table 4: The motor nerve conduction parameters of the left ulnar nerve were compared between 40 asymptomatic participants and 40 symptomatic individuals. The analysis revealed that the left ulnar nerve amplitude (LUAMP) in symptomatic participants, had a mean value of 8.9 ± 4.1, compared to 10.2± 3.8 in the asymptomatic group (t = 1.349, p = 0.183). Left ulnar latency (LULAT) and conduction velocity (LUCV) between the two groups showed values of t= 2.043, p = 0.044 and t=1.688 and p=0.097 respectively. The F-wave latency (LUF) was significantly prolonged in the symptomatic group, with a mean latency of 28.5 ± 3.1 ms, in contrast to 26.7 ± 2.8 ms in the asymptomatic participants (t = 2.467, p = 0.016). These findings suggest that symptomatic individuals exhibit prolonged latency and F-wave latency, indicating potential nerve dysfunction (figure 4).

Table 4: Comparison of Motor Nerve Conduction Parameters of Left Ulnar Nerve

Parameter	Asymptomatic (n=40) Mean ± SD	Symptomatic (n=40) Mean ± SD	t	p
LUAMP	10.2 ± 3.8	8.9 ± 4.1	1.349	0.183
LULAT	3.6 ± 0.8	4.1 ± 1.1	2.043	0.044
LUCV	54.4 ± 5.0	52.1 ± 6.3	1.688	0.097
LUF	26.7 ± 2.8	28.5 ± 3.1	2.467	0.016

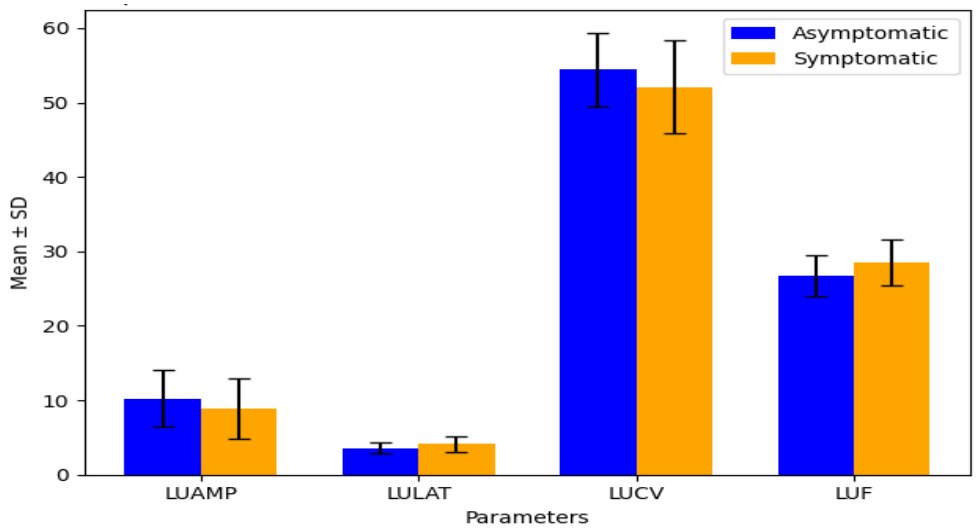

Figure4: Comparison of motor nerve conduction parameters of Left Ulnar Nerve

Discussion

This paper sought to compare motor nerve conduction parameters in 80 diabetic patients-40 asymptomatic and 40 symptomatic for neuropathy and found differences in nerve function between the two groups. The right tibial nerve parameters were different with a higher value for the asymptomatic group. The mean RTAMP was significantly reduced in the symptomatic patients and was 5. 17 ± 2. 63 compared to 7. 47 ± 2. 58 in asymptomatic patients (p = 0. 000). This reduction implies a decrease in motor nerve fiber activity or more peripheral nerve injury. Also, the right tibial F-wave latency (RTF) was significantly increased in the symptomatic group with a mean of 51. 70 ± 7. 07 ms versus 48. 06 ± 4. 74 ms in asymptomatic patients (p = 0. 010), indicating that conduction was slower in the symptomatic group. However, there were no significant differences in right tibial motor latency (RTLAT) and conduction velocity (RTCV) which shows that these two parameters are not much affected by symptoms. In the left tibial nerve, differences were noted in LTAMP, LTCV, and LTF. In particular, LTAMP was significantly lower in symptomatic patients (5. 46 ± 3. 20) than in asymptomatic ones (7. 18 ± 2. 35, p = 0. 009). LTCV also varied; symptomatic patients had lower scores (48. 46 ± 6. 32) than asymptomatic patients (52. 24 ± 6. 05; p = 0. 008). Also, LTF was longer in the symptomatic patients (51. 62 ± 5. 39) than in the asymptomatic patients (48. 15 ± 5. 04, p = 0. 004). These findings imply that DPN has a wider effect on nerve function in terms of amplitude and conduction velocity. In the right ulnar nerve, the significant findings were in latency and F wave latency. The symptomatic patients had a higher right ulnar latency (RULAT) with a mean of 4. 0 ± 1. 2 ms as compared to 3. 5 ± 0. 7 ms in asymptomatic patients (p = 0. 039), and an increased F wave latency (RUF) with a mean of 28. 6 ± 3. 2 ms versus 26. 5 ± 2. 9 ms in asymptomatic patients (p = 0. 014). However, no significant alterations were found in amplitude (RUAMP) or conduction velocity (RUCV). In the left ulnar nerve, latency (LULAT) had a value of 3.6 ± 0.8 in asymptomatic group compared to 4.1 ± 1.1in symptomatic group showing that latency is affected. In addition, LUF was delayed in symptomatic patients (28. 5 ± 3. 1 ms) compared to asymptomatic patients (26. 7 ± 2. 8 ms, p = 0. 016). There were no differences in LULAT and LUCV, indicating that symptomatic patients have specific abnormalities in nerve latency.

Conclusion

The present investigation has revealed some important differences in motor nerve conduction between the symptomatic and asymptomatic groups. The motor nerve amplitudes of the right tibial nerve were significantly decreased and F wave latencies of both right tibial and left tibial nerves were significantly increased in the symptomatic patients. In particular, the amplitude of the right tibial nerve was significantly decreased in symptomatic patients, which points to the disturbance of nerve impulses, and the F wave latency was significantly increased, which indicates the delay in nerve response. Also, the left tibial nerve had similar changes in amplitude and latency to symptomatic patients as the right tibial nerve. In the case of ulnar nerve, latency was seen to be affected bilaterally. These results indicate that although amplitude and latency are affected significantly in different nerves in the symptomatic patients, conduction velocity is not significantly different from that of the asymptomatic patients. These results support the concept of selective nerve dysfunction in symptomatic patients, and the importance of targeted assessment of nerve amplitude and latency in the evaluation of nerve integrity. This insight is crucial for the general knowledge about consequences of nerve dysfunction and for further research that can be focused on more effective interventions and treatments.

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