Research Article

The Effects of Ankle Joint Position on Deep Peroneal Nerve Latencies

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Running Title: Ankle Joint Position and Nerve Latencies

Abstract

Purpose: Joint positioning can impact nerve function. Few studies have explored the effects of ankle positions on deep peroneal nerve conduction. This cross-sectional study aimed to investigate the influence of different ankle joint positions on distal motor and sensory onset latencies of the deep peroneal nerve.

Materials and Methods: Thirty one healthy adults (23.4 ±3.9 years) underwent deep peroneal nerve conduction study. Distal motor and sensory onset latencies were measured at neutral (0°), dorsiflexion (20°), and plantarflexion (40°) ankle positions.

Results: Changing ankle position significantly affected distal motor (p=0.001) and sensory onset latencies (p=0.001). Latencies were shortest in dorsiflexion (motor: 3.8±0.46 ms; sensory: 2.4±0.2 ms), followed by neutral (motor: 4.2±0.5 ms; sensory: 2.6±0.3 ms), and longest in plantarflexion (motor: 5±0.6 ms; sensory: 3.3±0.2 ms).

Conclusion: Ankle position impacts deep peroneal nerve conduction. Dorsiflexion and neutral positions reduced distal motor and sensory latencies compared to plantarflexion. These findings provide preliminary evidence that may help optimize ankle positioning in electrodiagnostic testing. Further blinded research with larger, more diverse samples is warranted.
Keywords: Ankle; Ankle Joint, Electromyography, Peroneal Nerve, Nerve Conduction Studies

Introduction

Peripheral nerves possess viscoelastic properties enabling adaptation to repetitive force and positional changes imposed by limb movements [1]. As joints move through range, associated nerves must stretch and slide to accommodate changes in length [2]. The deep peroneal nerve innervates muscles controlling ankle position and movement [3]. Dorsiflexion is primarily mediated by deep peroneal-innervated tibialis anterior, while plantarflexion relies more on triceps surae muscles supplied by the tibial nerve [4]. Given its role at the ankle, the function and conduction of the deep peroneal nerve may be impacted by ankle joint positioning [5]

Several studies have revealed that joint positions affect conduction parameters of associated nerves. Sustained elbow flexion prolongs ulnar motor distal latency[6]. Similarly, median sensory latency increases with wrist hyperextension [7]. At the lower limb, common peroneal latency varies with knee and hip position [8]. Yet few studies have specifically investigated the impact of ankle angles on deep peroneal nerve function. This represents a gap in current literature.

With ankle motions, the deep peroneal nerve must slide longitudinally and transverse within its interface to avoid excessive strain [9] However, if positioned in slack or excessive tension for prolonged periods, adverse neural effects may occur. Animal studies reveal that 6-15% tensile strain on nerves reduces action potential amplitude and axonal transport [10]. In humans, prolonged nerve bed elongation increases interfascicular pressure and slows conduction velocities [11].

At the ankle, the deep peroneal nerve is under greatest tension in plantarflexion as muscle origins and insertions are pulled apart [12]. In contrast, dorsiflexion may slacken the nerve as muscle length decreases [13]. If plantarflexion is sustained, heightened strain could perturb deep peroneal conduction [14]. This concept is supported by trials in carpal tunnel syndrome showing that wrist flexion stresses the median nerve, delaying distal latencies [15]. However, few electrodiagnostic studies have specifically assessed deep peroneal conduction in different ankle positions.

Quantifying the impacts of ankle angles is relevant given certain occupations require prolonged postures. For example, high heel shoes worn by many women maintain the ankle in plantarflexion [16]. Prolonged driving can also sustain dorsiflexion [17]. If ankle positions affect deep peroneal conduction acutely, long-term effects may manifest in those with occupational ankle postures.

Clinically, optimizing ankle positioning during electrodiagnostic testing could maximize nerve conductions. This may enhance diagnostic sensitivity in conditions like deep peroneal neuropathy. Furthermore, recognizing detrimental positions could better inform conservative care. Patients with deep peroneal entrapment often receive stretching and footwear advice [18]. Guiding exercise and ergonomics based on ankle angles that minimize nerve strain may improve rehabilitation.

This study aimed to address the gap in literature by investigating the effects of different ankle positions on deep peroneal nerve distal motor and sensory latencies. We hypothesized that plantarflexion would prolong latencies relative to neutral and dorsiflexion angles due to heightened nerve strain. The findings may have implications for electrodiagnostic testing, conservative management, and ergonomic guidance in deep peroneal neuropathy.

Materials and Methods

Study Design

This was an observational cross-sectional study design involving one group of participants measured at three different ankle positions. The independent variable was ankle position with three levels - neutral, 20° dorsiflexion, and 40° plantarflexion. The dependent variables were the distal motor latency and sensory onset latency of the deep peroneal nerve measured bilaterally at each ankle position.

Setting

The study took place in the physical therapy laboratory at Ahram Canadian University between December 5, 2022 and January 3, 2023. All data collection and procedures were conducted in a controlled laboratory environment. Participants were positioned supine on a plinth with their lower leg exposed for electrode placement and stimulation procedures.

Participants

Thirty-one participants aged 20-40 years with a BMI of 18.5-24.9 kg/m2 and no history of obesity, diabetes, hypertension, peripheral nerve injury or dysfunction, or previous lower extremity fracture or surgery were recruited by convenience sampling from the local university population.

A priori power analysis using G*Power 3.1 determined a sample size of 28 was required to detect a medium effect size of 0.25 at an alpha of 0.05 and power of 0.80 for the primary outcome measure of deep peroneal nerve distal motor latency. Accounting for 10% dropouts, the final sample size was 31 participants. This sample size was sufficiently powered to detect clinically meaningful differences between ankle positions for the primary outcome measure.

Standardization Procedures

To reduce measurement variability, the principal investigator performed all experimental preparation, instructions, electrode placement, ankle goniometry, and data collection. Electrode placement was determined using precise anatomical landmarks according to surface electromyography for a non-invasive assessment of muscles (SENIAM) guidelines to improve inter-rater reliability [19]. Participants were given standardized instructions for positioning and relaxation. Trials were discarded and repeated if submaximal effort was observed. Room temperature was closely monitored and controlled throughout data collection. Room temperature was confirmed to be within 22°C (+-2°C) range.

Outcome Measures

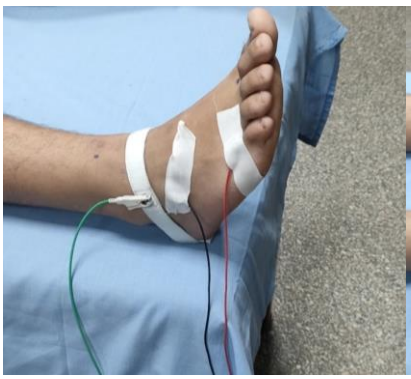
Distal Motor Latency

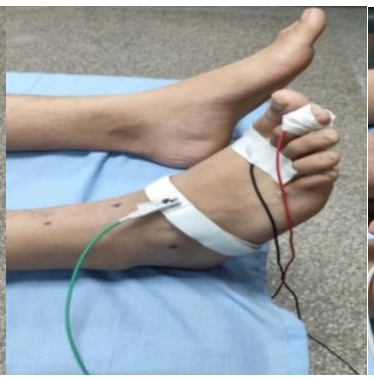
Distal motor latency of the deep peroneal nerve was the primary outcome measure, quantifying the time from stimulation to onset of muscle response in the extensor digitorum brevis [20].

Neuropack S1 MEB-9004 NIHON KODEN, JAPAN was utilized to provide an objective evaluation of both motor distal and sensory onset latencies. It’s made up of a main unit with high performance 2-channel amplifiers, a junction box with an articulated arm. The recording, stimulating, earth electrodes are attached to the junctional box (Figure 1).

Figure 1: Neuropack S1 MEB-9004 NIHON KODEN, JAPAN

The electrodes attached to the junctional box are divided into: Ground electrode used to prevent or minimize noise (Figure 2), two recording electrodes one is negative and black in color while the other is positive and red in color (Figure 3) and are used to pick up signal. The last electrode is the stimulating one which is used to stimulate nerve at certain predetermined site (Figure 4).





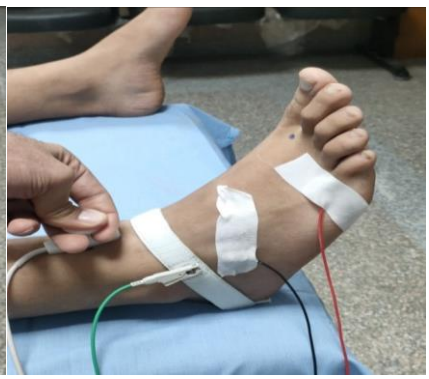


Figure 2: Ground electrode **Figure 3: Recording electrodes** **Figure 4: Stimulating electrode**

The active recording electrode was positioned over the muscle belly of extensor digitorum brevis, identified through palpation and muscle contraction during toe extension [21]. Correct placement was confirmed by observing the largest motor response on the EMG monitor during low intensity stimulation. The reference electrode was placed at the fifth metatarsophalangeal joint, in an electrically neutral position. The ground electrode was secured around the ankle joint to reduce interference. Stimulation of the deep peroneal nerve was performed using a surface stimulator. The cathode was positioned over the deep peroneal nerve at the level of the fibular head, slightly anterior to the biceps femoris tendon. The anode was placed 2 cm distal to the cathode. A square-

wave pulse with duration of 0.2 ms was used for stimulation. To minimize the risk of movement of the stimulating electrodes, they were secured in place with adhesive tape (Figure 5).
Latency was measured from onset of the stimulus artifact to the first major negative deflection of the compound muscle action potential, indicating muscle depolarization [22]. Sensitivity was set at 1 mV per division as recommended for motor nerve conduction studies to accurately detect the compound muscle action potential response without exceeding the amplifier limits [23]. Signals were amplified with a gain of up to 10,000 to sufficiently resolve the waveform for onset latency and amplitude measurements [23]. Latency values were measured in milliseconds (ms) with 100 microsecond precision. Latency was measured from the origin of the stimulus artifact to the first positive deflection of the sensory nerve action potential. Prolonged latencies indicate slowed nerve conduction velocity. Normal distal motor latency values range from 3.5-6.0 ms [24].

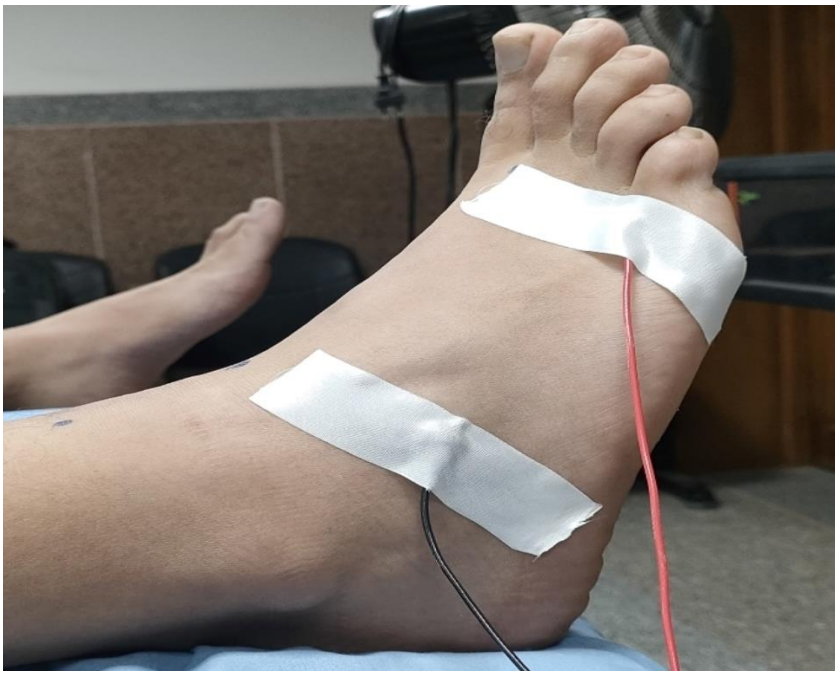


Figure 5: Placement of recording electrodes for motor branch of DPN

Sensory Onset Latency

The active recording electrode was positioned in the first web space between the metatarsal heads of digits 1 and 2 [25].This maximized the sensory response from digital nerve fibers of the deep peroneal nerve under the extensor hallucis brevis. The reference electrode was placed 3cm distal to detect the potential travelling towards the recording electrode. The ground electrode reduced interference (Figure 6).

A minimum of 50 traces were averaged for each sensory nerve action potential recording to obtain a robust response for accurate latency and amplitude measurements, as recommended for low amplitude potentials [23,26]. The initially acquired signals at a gain of 20 μV/division were further amplified by a factor of 3x during analysis, resulting in a final amplification of 60 μV/division used for measuring the averaged waveform parameters [23]. Latency was measured from stimulation onset to the first major positive deflection of the sensory nerve action potential [27]. Latency values were recorded in ms with 100 microsecond precision. Normal upper limits are <4.5ms [24].

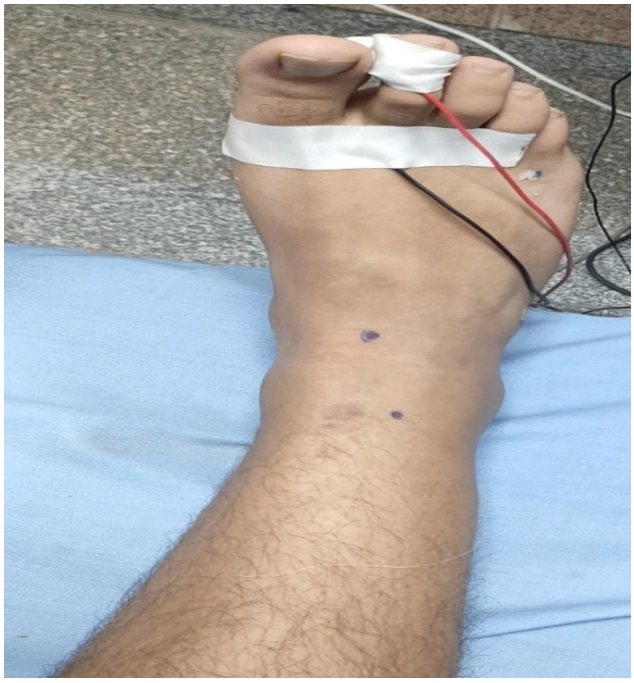


Figure 6: Placement of recording electrodes for sensory branch of DPN

Instrumentation

A Neuropack S1 MEB-9004 EMG system (Nihon Kohden, Japan) was used to record distal motor latency and sensory onset latency of the deep peroneal nerve. For distal motor latency recordings, filters were set at 10 Hz to 10 kHz and sweep speed was 5 ms/division to accurately capture the compound muscle action potential. Signals were sampled at 5 kHz to satisfy Nyquist rate. For distal sensory latency recordings, filters were set at 20 Hz to 2 kHz and sweep speed was 1 ms/division to maximize resolution of the lower amplitude sensory nerve action potential. Signals were sampled at 5 kHz to satisfy Nyquist rate. Latency values were measured in milliseconds (ms). A handheld universal goniometer was used to measure maximal ankle joint range of motion.

Experimental Protocol

Participants first underwent a familiarization session where electrode placement was determined. Participants were seated comfortably with their legs exposed. Skin preparation involved shaving and cleaning with alcohol pads at electrode sites. Additionally, participants were required to acclimate in the room for 10 minutes prior to testing Before starting data collection, the skin temperature was measured over the anterior ankle region, 5 cm proximal to the stimulation site for the deep peroneal nerve, using an infrared thermometer. The temperature was confirmed to be within the range of 33-35°C.

After electrode placement, participants were positioned supine on the plinth with hips and knees in neutral rotation and 0° flexion. The ankle was positioned in neutral (0°) plantar/dorsiflexion with the foot relaxed.

To reduce potential bias during latency measurement, EMG recordings were anonymized and analyzed by an assessor blinded to ankle positioning. The principal investigator set up the ankle positioning, delivered electrical stimulations, and collected the EMG recordings. To facilitate blinding, the order of ankle positioning was randomized across participants. The secondary assessor was not present in the room during data collection. This assessor received the de-

identified EMG recordings and measured onset latencies. The assessor was blinded to the ankle position associated with each recording until after all latency measurements were completed.
The ankle was positioned in neutral, full dorsiflexion, or full plantarflexion and held continuously for 5 minutes. After 5 minutes of sustained positioning, electrophysiological stimulation and recording was performed for each position. Distal motor latency was recorded first, followed by sensory onset latency measurements at the neutral ankle position. The ankle was then moved into maximal dorsiflexion, latencies were measured, then into maximal plantarflexion with repeat measurements at each position. A 30 second rest was provided between ankle repositioning to avoid fatigue. After final measurements, maximal ankle dorsiflexion and plantarflexion range of motion was recorded.

Data Processing and Statistical Analysis

Latency values were averaged across 3 trials at each ankle position. Normality was confirmed with the Shapiro-Wilk test. Repeated measures ANOVA was used to compare mean distal motor and sensory onset latencies between the three ankle positions. Pairwise comparisons were made with Bonferroni correction. Pearson correlation coefficients were calculated between latency values and maximal ankle range of motion. Statistical significance was set at $p<0.05$. All analyses were performed using SPSS version 25.

Results

As shown in Table (1), the mean ±SD of distal motor latency of the deep peroneal nerve at neutral, planter flexion and dorsi-flexion positions were (4.2± 0.5), (5± 0.6) and (3.8± 0.46) respectively. The univariate tests of repeated measure ANOVA revealed that there was statistically significant difference in distal motor latency of the deep peroneal nerve among the three measurements (F=30.39, p<0.001), Cohen's f = 0.727). As well as, pairwise comparison (Post hoc test) as observed in Table (2), revealed that; there were significant differences between distal motor latency at neutral position and planter flexion position, neutral position and dorsi-flexion, between planter flexion and dorsi-flexion (P=0.001). This significant reduction in favor to ankle dorsiflexion position and ankle neutral position compared to ankle plantarflexion position.

Table 1: Repeated measure ANOVA for measured variables

Ankle position / **Deep peroneal nerve**	**Neutral position**	**Planter flexion**	**Dorsi-flexion**	**f-value**	**P-value**	**Effect size** Cohen's f
Distal motor latency (ms)	4.2± 0.5	5± 0.6	3.8± 0.46	30.39	0.001*	0.727
Sensory onset latency (ms)	2.6± 0.3	3.3± 0.2	2.4± 0.2	25.9	0.001	0.700

SD: Standard deviation *: significance

Also as shown in Table (1), the mean ±SD of sensory onset latency of the deep peroneal nerve at neutral, planter flexion and dorsi-flexion positions were (2.6± 0.3), (3.3± 0.2) and (2.4± 0.2) respectively. The univariate tests of repeated measure ANOVA revealed that there was statistically significant difference in sensory onset latency of the deep peroneal nerve among the three measurements (F=25.9, P=0.001, Cohen's f = 0.700). As well as, pairwise comparison (Post hoc test) as observed in Table (2), revealed that; there were significant differences between

sensory onset latency at neutral position and planter flexion position, neutral position and dorsi-flexion, between planter flexion and dorsi-flexion (P=0.001). This significant reduction in favor to ankle dorsiflexion position and ankle neutral position compared to ankle plantarflexion position.

Table 2: Post hoc test between different positions

Variables		**Distal motor latency**	**Sensory onset latency**
Neutral versus PF	**difference**	-0.75	-0.7
	P-value	0.001*	0.001*
Neutral versus DF		0.4	0.2
	P-value	0.001*	0.001*
PF versus DF		1.2	0.7
	P-value	0.001*	0.001*

PF: planter flexion DF: dorsi-flexion *: significant

Discussion

The ability of peripheral nerves to extend and slide is essential for maintaining proper neural function [1]. As a key nerve controlling ankle dorsiflexion and foot inversion, the deep peroneal nerve must adapt its position within surrounding tissues in response to biomechanical loads from routine joint motions like walking or more extreme ankle positions [28].

Our study reveals that ankle joint position significantly influences deep peroneal motor and sensory nerve conduction. Specifically, we found that 20° dorsiflexion and neutral positions reduced distal motor and sensory onset latencies compared to 40° plantarflexion. The significant reduction in latencies at 20° dorsiflexion and neutral positions compared to 40° plantarflexion was consistent across measurements, suggesting that the position itself, rather than the duration in that position, was the primary factor influencing nerve conduction. Our findings suggest that the mechanical and physiological changes associated with different ankle positions, such as stretching or compression of the nerve, can acutely affect nerve conduction properties. This is an important consideration for clinical nerve conduction studies, where the position of the limb being tested could potentially influence the results.

Our findings suggest that the ankle position can significantly affect distal motor and sensory latencies of the deep peroneal nerve. Therefore, it is possible that the standard practice of performing neurographic studies with the ankle in a neutral position may not provide a complete or accurate assessment of nerve function. One potential implication of our study is that clinicians and technicians who perform neurographic studies of the deep peroneal nerve may want to consider assessing nerve function in multiple ankle positions to obtain a more comprehensive understanding of nerve function. However, we acknowledge that changing the standard practice of neurographic assessment is not a decision to be taken lightly.

The physiological basis for the effects of ankle position on deep peroneal nerve conduction likely involves the biomechanical impacts on the nerve itself. In plantarflexion, the nerve comes under increased tensile stretch as the posterior calf muscles like gastrocnemius elongate [29]. This places a traction force on the deep peroneal nerve since it runs adjacent to and innervates muscles in the anterior compartment [30]. The tensile load alters nerve function through mechanical effects on axonal microtubules and neurofilaments that transmit the nerve impulse [31,32]. Beyond around 8-15% elongation, vascular perfusion within the nerve also becomes impaired, compounding the functional effects [33].

In contrast, neutral position likely avoids excessive stretch, while dorsiflexion may allow slight relaxation of the nerve [34]. The nerve is able to glide more optimally with less mechanical

deformation of axonal cytoskeletal elements [35]. This helps preserve conduction velocity and activation timing [36].

The prolonged latency with plantarflexion can be explained by the increased stretch force imposed on the nerve in this position [37]. This tensile load likely alters nerve function and conduction by increasing the distance signals must travel from the stimulation to recording site [38]. With time, sustained stretch may also decrease nerve conduction velocity by causing intraneural changes like reduced blood flow [39]. Cadaveric research shows peripheral nerves can elongate around 6% before adverse impacts occur, including decreased action potential amplitude, venule flow reduction at 8% strain, and intramural vascular occlusion at 15% strain [1]. Prolonged elongation increases interfascicular pressure and slows conduction time [40].

Numerous studies support that nerve positioning in a lengthened state negatively affects conduction parameters [6] found prolonged ulnar nerve stretching from elbow flexion during phone use reduced motor conduction velocity and increased latency, especially in those with ulnar neuropathy [7] showed wrist hyperextension positioning the median nerve under stretch worsened motor and sensory conduction while preparing for radial catheterization. Prolonged hyperextension could progress to full conduction block.

However, one study by [41] found no impact of elbow flexion up to 120° on ulnar latency, amplitude, or action potential duration. But this disagreement may stem from their narrow 18–25-year-old sample. Lack of temperature control during testing may also explain their discrepancy.

This preliminary study has limitations. First, the study was cross-sectional in design. Therefore, we cannot determine whether the differences in DML and DSL values between the different ankle positions are due to a causal relationship or to other factors. Second, the study exclusively enrolled young healthy adults, and different effects may be observed in older populations. Third, we did not control for potential confounding factors such as physical activity level and medical history. Practical issues also exist. Those with tight gastrocnemius may not tolerate 20° dorsiflexion, suggesting neutral position may be optimal. Having subjects actively hold dorsiflexion is difficult and passive positioning by a brace or examiner may be required.

Our preliminary findings reveal ankle position significantly impacts deep peroneal nerve conduction. Prolonged plantarflexion appears to adversely affect parameters, while neutral and dorsiflexion are more optimal. We also emphasize the importance of consistent positioning when collecting normative nerve conduction data. Further research could examine effects on older adults, obese populations, and those with pre-existing neuropathies.

Conclusion

In conclusion, this preliminary study shows prolonged ankle plantarflexion worsens deep peroneal nerve conduction compared to neutral or dorsiflexed positions, likely due to increased nerve stretch.

Ethical Considerations

Compliance with ethical guidelines

The study received ethical approval from the Faculty of Physical Therapy Research Ethics Committee (approval number: P.T.REC/012/004076). All participants read and signed a written informed consent before testing. The study participants were informed about the purpose of the research and were assured of their information’s confidentiality. Moreover, they were allowed to discontinue participation in the study as desired. The trial was prospectively registered on ClinicalTrials.gov (ID: NCT05635721) prior to participant recruitment.

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Authors contributions

Conceptualization: Mohamed Hussein El-Gendy, Mahmoud Salah Abd El- Fattah and Yasser Ramzy Lasheen; Methodology: Mohamed Magdy El Meligie and Efrem Kentiba; Investigation, formal analysis and writing-original draft:, Mahmoud Salah Abd El- Fattah and Efrem Kentiba; Supervision: Mohamed Hussein El-Gendy and Yasser Ramzy Lasheen; review and editing: Mohamed Hussein El-Gendy, Mahmoud Salah Abd El- Fattah and Yasser Ramzy Lasheen. All authors read the final manuscript.

Conflict of interest

No financial, legal, or political conflict involving third parties (government, companies, private foundations, etc.) has been declared for any aspect of the work sub mitted (including, but not limited to, grants and funding, board membership consulting, study design, manuscript preparation, statistical analysis, etc.).

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