Oregon Health & Science University
School of Medicine

Scholarly Projects Final Report

Title *(Must match poster title; include key words in the title to improve electronic search capabilities.)*

Systematic Review of Lower Extremity Myotomes

Student Investigator's Name

Mahtab Brar

Date of Submission *(mm/dd/yyyy)*

03/16/24

Graduation Year

2024

Project Course *(Indicate whether the project was conducted in the Scholarly Projects Curriculum; Physician Scientist Experience; Combined Degree Program [MD/MPH, MD/PhD]; or other course.)*

Scholarly Projects Curriculum

Co-Investigators *(Names, departments; institution if not OHSU)*

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Mentor's Name

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Mentor's Department

Physical Medicine and Rehabilitation

Scholarly Project Final Report

Concentration Lead's Name

Mark Baskerville

Project/Research Question

What is the current understanding of myotomal innervation of the upper and lower extremity muscles and what evidence was used to construct such pattern?

Type of Project *(Best description of your project; e.g., research study, quality improvement project, engineering project, etc.)*

Systematic Review

Key words *(4-10 words describing key aspects of your project)*

Systematic, Review, Lower Extremity, Myotomes, Compilation, Pattern

Meeting Presentations
If your project was presented at a meeting besides the OHSU Capstone, please provide the meeting(s) name, location, date, and presentation format below (poster vs. podium presentation or other).

N/A

Publications *(Abstract, article, other)*
If your project was published, please provide reference(s) below in JAMA style.

N/A

Submission to Archive
Final reports will be archived in a central library to benefit other students and colleagues. Describe any restrictions below (e.g., hold until publication of article on a specific date).

N/A

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Next Steps

What are possible next steps that would build upon the results of this project? Could any data or tools resulting from the project have the potential to be used to answer new research questions by future medical students?

Future Directions:
Compile current work with previous work on upper extremity for publication
Work to explore myotomal patterns for muscles with little to no investigation

Please follow the link below and complete the archival process for your Project in addition to submitting your final report.

https://ohsu.ca1.qualtrics.com/jfe/form/SV_3ls2z8V0goKiHZP

Student's Signature/Date *(Electronic signatures on this form are acceptable.)*
This report describes work that I conducted in the Scholarly Projects Curriculum or alternative academic program at the OHSU School of Medicine. By typing my signature below, I attest to its authenticity and originality and agree to submit it to the Archive.

Recoverable Signature

X Mahtab Brar 3/16/24

Student's full name

Signed by: 9e989694-6273-48bd-b709-2b6a1aee138c

Mentor's Approval *(Signature/date)*

X

Mentor Name

Scholarly Project Final Report

Report: *Information in the report should be consistent with the poster, but could include additional material. Insert text in the following sections targeting 1500-3000 words overall; include key figures and tables. Use Calibri 11-point font, single spaced and 1-inch margin; follow JAMA style conventions as detailed in the full instructions.*

Introduction *(≥250 words)*

A myotome is the muscle area supplied by a spinal nerve root, defined as "the portion of embryonic somite that gives rise to somatic (striated) muscles." Knowledge of these myotomes as well as their sensory counterpart, dermatomes, assist in evaluating the source of the neurologic injuries. Clinically, neurologic conditions may present with changes in strength and sensation as well as muscle tone and reflexes. The pattern of the myotomal and dermatomal deficit directs clinicians in localizing the lesion. Clinical utility of a workup including history and physical exam findings are essential for evaluating any condition. Delays in making the correct diagnosis may adversely impact outcomes. Therefore, it is paramount that the knowledge used for establishing a diagnosis is accurate and unambiguous. Diagnostic accuracy benefits patients by decreasing the costs and burdens associated with missed or delayed diagnoses (access to medical care, transportation, co-payments, appointment times and fears associated with medical care). Unlike dermatomes, which have been widely evaluated and are well established, myotomes remain somewhat ambiguous with variability among referenced textbooks and articles. This discrepancy and lack of definitive data has led to several studies in order to validate various spinal root innervations whether through dissection, review of electrodiagnostic studies, imaging, surgical exposure and/or stimulation of spinal roots, which involve a limited number of spinal roots. A definitive large scale study to examine myotome innervation through direct spinal root stimulation is not practical with respect to patient invasiveness and cost. Given the importance of the myotomal innervations and the variability of how these have been determined and passed down over the years, it is worthwhile to review the current state of the literature in order to obtain a comprehensive assessment of the current knowledge of the myotomes. This project will generate a comprehensive table of the myotomes that considers the pre-existing data, recognizes the discrepancies, and uses the overlapping evidence to evaluate the consistency of the reported innervations. The upper extremity has already been completed as a part of this larger body of work, while this systematic review focuses on the lower extremity. This may improve clinical accuracy and provide clinicians with a consistent and comprehensive myotomal map that can be utilized in many fields of medicine particularly those in physical medicine and rehab, sports medicine, neurologists, orthopedists, generalists, as well as those in the fields of physical and occupational rehabilitation.

Methods *(≥250 words)*

This comprehensive literature review of the lower extremity involved compilation of resources including textbooks and journal articles that contained information about nerve root innervation of specific muscles. Databases used for compilation of such resources included PubMed and Ovid. Search used for retrieving this literature on PubMed was ("myotome" OR "spinal nerve distribution" OR "spinal innervation" OR "spinal root innervation") AND ("lower extremity" OR "lower limb" OR "thigh" OR "leg" OR "foot" OR "quadriceps" OR "hamstrings")

((*lower extremity/ir or *thigh/ir or *hip girdle/ir or *knee/ir or *leg/ir or *foot/ir or *toes/ir or *metatarsus/ir or *hip/ir or *ankle/ir) OR ("lower adj2 limb" or "upper adj2 extremity" or thigh or hip girdle or knee or leg or foot or toes or metatarsus or hip or ankle)) AND (myotome*or spinal nerve distribution* or (spinal and innerv*) or (spinal and nerv:))

The above string of inquiries led to a total output of 10,283 between Pubmed (3187) and Ovid (7096), which were reviewed, and the relevant articles were retrieved based on whether they contained information about myotomal patterns (i.e. spinal root innervation of muscles). In addition to these online databases, we investigated anatomy and electromyography textbooks available in our department of Physical Medicine and Rehabilitation or OHSU library. For each source, the references they cited were traced, reviewed, and included if relevant. We were able to compile 28 relevant sources. Of these, 15 were retrieved through the OHSU interlibrary loan service, either scanned or borrowed, others were purchased, while some were not accessible due to significant time since publication, incomplete citation, cost, or inability to obtain English translations. Using the retrieved sources, the relevant lower extremity myotomal information including the muscles, nerves and their respective spinal root innervation were organized and recorded in an Excel spreadsheet. Our muscle and peripheral innervation pattern was organized based on Gray's Anatomy and Kimura's textbooks with muscles and respective nerves in rows and the spinal roots in columns. After compiling every source within this document, the data was reformatted and analyzed to see how many times a muscle was investigated (n) and what percentage of sources listed each spinal root. We also kept a record of the methods used by each source when they were specified. The methods identified where then divided into 6 categories (Table 1).

Table 1: Methods of Myotome Identification

Method	**Definition**
Dissection	Anatomic localization of the myotome by dissection/necropsy
Electrodiagnostic	Clinical electromyography (EMG) and/or nerve conduction study findings consistent with nerve root injury
Imaging	X-ray, MRI, CT, myelography, etc. for visualization of nerve root compression/injury
Operative	Surgically visualize the nerve root for direct stimulation or decompression
Physical exam	Motor exam correlation of the operative, imaging, electrodiagnostic findings as an outcome measure
Stimulation	Intraoperative stimulation of nerve roots with correlation to muscle response.

Operative methods were separated from stimulation because while some operations led to direct stimulation of the root involved, others were used to visualize the spinal roots in order to decompress the involved root without direct stimulation. Dissection was defined as cadaver studies while operative methods were performed on living humans or animals. Electrodiagnostic studies involved electromyography and/or nerve conduction studies to localize the site of injury. Imaging was included when any imaging modality (MRI, CT, myelography, etc was used). The physical exam designation was used if a study used clinical exam findings, such as weakness in specific muscle groups to clinically correlate imaging, EMG or other findings for localization.

Results *(≥500 words)*

Our literature search led to the discovery of 28 relevant sources, 15 of which were anatomical and electrodiagnostic texts from the OHSU Library and/or the OHSU Department of Orthopedics and Rehabilitation and another 13 published articles from reviewing the 10,283 results of our PubMed and OVID search terms.

Table 2 describes the methods of the included sources in determining their myotomal patterns. These methods include direct nerve root stimulation, imaging techniques such as MRI, CT, and myelography, electrodiagnostics such as EMG, correlating with physical exam findings, or cadaveric human dissection. Due to 2 studies using multiple methods such as a combination of operative, imaging, and electrodiagnosis, the number of studies with specified methods is greater than the number of sources that specified their methods in Table 2. Of the 28 sources, 13 (47%) specified their methods while 15 (53%) did not specify their methods. It should be noted that the sources were frequently unclear in their methods. Many textbooks would simply list the myotomes without an explanation as to how they were ascertained. While going through the data returned by our search terms, papers frequently would cite myotomes without a clear explanation as to how they got that data experimentally. For example, they would simply state that it was determined intraoperatively and the exact method of determination often had to be inferred from other data in the papers or via the discussion section of the paper.

For each muscle there was an average of 3 sources with specified methods. That being said, there were 7 muscles with 0 original investigations or specified methods for their myotomal distribution. These muscles were the Pectineus, Piriformis, Obturator Internus, Inferior Gemellus, Superior Gemellus, Quadratus Femoris, and Popliteus. This trend continued throughout our data, as some sources exclusively worked with select muscles while other sources covered all muscles of the lower extremity. This led to an inconsistent sample size throughout our data with some muscles being studied over 20 times while others had less than 10 studies (Table 3).

Using all of these data points, we compiled this data into a comprehensive lower extremity myotomal innervation as summarized by Table 3 and its accompanying key below. Table 3 is organized according to a standardized format as presented by Kimura's and Gray's Anatomy textbooks. The first column describes the nerve innervating a particular group of muscles, followed by those muscles in the next column. N describes the total number of sources that were used to compile the myotomal pattern for that muscle while the next column describes the number of sources with specified methods used for that muscle. The 5th column describes the specific methods used to determine the myotomal pattern for that muscle and the number of sources which used every method. The "myotomes" columns describes the contribution of each nerve root to the myotomal distribution of that muscle. These columns have also been color coded in dark blue to reflect ≥ 70% agreement, light blue for = 30-69% agreement, and left unshaded for <30% agreement between the various sources.

Table 2 – Methods of Identified Sources						
	Operative	**Stimulation**	**Imaging**	**Electrodiagnostic**	**Physical Exam**	**Dissection**
Specified	**N = 13**					
	2	**9**	**2**	**2**	**0**	**2**
Unspecified	**N = 15**					
Table 2 – The methods used to determine myotomal patterns in identified sources						

Table 3: Lower Extremity Myotome Innervation and Sources													
Nerve	Muscle	N	# Sources Where Method of Myotom	Method of Myotome Identification When Specified (n)	Myotomes								
					Percentage of Sources, Method of Identification								
					T12	L1	L2	L3	L4	L5	S1	S2	S3

			e Identification Specified (n)	D = Dissection S = Stimulation O = Operative I = Imaging E = Eelectrodiagnostic P = Physical Exam W=E+I+O T=O+S X=I+O+P U=O+P Y=E+I+P V=E+I Z=I+O+P+S									
Femoral	Psoas Major	17	4	S(3), D(1)	6%	47%	100%	100%	58%	6%	6%		
	Iliacus	16	3	S(2), W(1)	6%	31%	100%	100%	56%	6%	6%		
	Iliopsoas												
	Rectus Femoris	22	8	S(7), W(1)	5%	9%	72%	86%	100%	27%	5%	5%	
	Pectineus	10	0				100%	100%	50%				
	Sartorius	12	1	S(1)		8%	100%	100%	33%				
	Vastus Lateralis	23	9	S(8), W(1)	4%	9%	78%	87%	100%	26%	4%	4%	
	Vastus Medialis	23	9	S(8), W(1)	4%	9%	74%	91%	100%	26%	4%	4%	
	Vastus Intermedius	20	6	S(6)	5%	10%	80%	95%	100%	25%	5%	%	
OBTURATOR	Adductor Magnus	17	4	S(4)		6%	71%	100%	100%	29%	18%		
	Adductor Brevis	18	5	S(4), D(1)		6%	83%	100%	100%	11%	6%		
	Gracilis	10	1	S(1)			100%	100%	70%				
SUPERIOR GLUTEAL NERVE	Gluteus Medius	17	3	S(2), W(1)					88%	100%	94%	12%	
	Gluteus Minimus	12	1	S(1)					100%	100%	100%		
	Tensor Fasciae Latae	14	2	S(1), W(1)					93%	93%	65%		
INFERIOR GLUTEAL NERVE	Gluteus Maximus	19	5	S(4), W(1)		5%			26%	95%	100%	79%	
SACRAL PLEXUS	Piriformis	9	0							33%	100%	89%	

	Obterator Internus	9	0						11%	100%	89%	89%	22%
	Inferior Gemellus	9	0						89%	100%	100%	33%	
	Superior Gemellus	8	0						13%	100%	100%	88%	25%
	Quadratus Femoris	9	0				11%	11%	89%	89%	89%	11%	
PERONEAL NERVE													
PERONEAL DIVISION SCI TR	Biceps Femoris Short Head	20	6	S(5), W(1)				10%	40%	90%	95%	70%	5%
DEEP PERONEAL NERVE	Tibialis Anterior	23	11	S(9), W(2)			4%	9%	82%	100%	57%		
	Extensor Digitorum Longus	13	1	S(1)					62%	92%	92%	15%	
	Extensor Hallucis Longus	14	3	S(2), W(1)					47%	100%	93%		
	Peroneus Tertius	8	1	S(1)					50%	100%	100%		
	Extensor Digitorum Brevis	14	4	S(3), W(1)						93%	93%	21%	7%
SUPERFICIAL PERONEAL NERVE	Peroneus Longus	18	6	S(3)			6%	6%	33%	89%	94%	17%	
	Peroneus Brevis	13	1	S(1)					31%	92%	100%	15%	
TIBIAL NERVE													
TIBIAL DIVISION SCIATIC	Semimembranous	16	2	S(2)			6%	6%	56%	100%	88%	69%	12%
	Semitendinosus	17	3	S(2), W(1)					53%	100%	88%	82%	18%
	Biceps Femoris Long Head	21	6	S(5), W(1)			5%	10%	38%	81%	90%	14%	
TIBIAL NERVE	Gastroc. Medial Head	21	8	S(7), W(1)				5%	9%	38%	100%	76%	
	Gastroc. Lateral Head	21	8	S(7), W(1)				5%	14%	43%	90%	68%	
	Plantaris	7	1	S(1)					57%	100%	100%	43%	14%
	Soleus	16	3	S(3)					6%	69%	100%	94%	6%
	Popliteus	11	0						63%	100%	91%		

	Tibialis Posterior	14	1	S(1)					21%	100%	79%	14%	
	Flexor Digitorum Longus	14	3	S(2), W(1)						79%	93%	57%	14%
	Flexor Hallucis Longus	13	2	S(2)						77%	92%	92%	8%
MEDIAL PLANTAR NERVE	Flexor Digitorum Brevis	15	3	S(3)					20%	66%	93%	47%	13%
	Flexor Hallucis Brevis	12	2	S(2)					25%	67%	100%	42%	8%
	Abductor Hallucis	17	6	S(5), W(1)				6%	6%	82%	100%	35%	6%
	Lumbricals 1	9	1	S(1)					33%	78%	78%	33%	11%
LATERAL PLANTAR NERVE	Abductor Digiti Minimi	11	1	W(1)							100%	91%	
	Flexor Digiti Minimi	9	1	S(1)							100%	100%	
	Interosseii	10	1	S(1)							90%	100%	10%
	Quadratus Plantae	7	1	S(1)							86%	100%	14%
	Lumbricals 2, 3, 4	9	1	S(1)						11%	89%	100%	11%

Table 3 – Key

Type of Myotome Identification Key

D = Dissection: anatomic localization of the myotome by dissection/necropsy

E = Electrodiagnostic: clinical electromyography and/or nerve conduction study findings consistent with nerve root injury

I = Imaging: X-ray, MRI, CT Myelography, etc for visualization of nerve root compression/injury

O = Operative: surgically visualize the nerve root for direct stimulation or decompression

P = Physical Exam: motor exam correlation of the operative, imaging, electrodiagnostic findings as an outcome measure

S = Stimulation: intraoperative stimulation of nerve roots with correlation to muscle response

Combination of method identification key:

T=O+S U=O+P V=E+I W=E+I+O X=I+O+P Y=E+I+P Z=I+O+P+S

Color Key:

≤29% of sources report myotome contribution	(white)	30-69% of sources report myotome contribution	(light blue)	≥ 70% of sources report myotome contribution	(blue)

Columns Key:

The columns show each lower extremity nerve and the respective muscles (columns 1 and 2); the total number of sources that included the muscle in their report (column 3); the number of sources that specified how the myotome was identified (column 4); the method of identification with respective number of sources (column 5); the percentage of sources that identify the specific myotome, the method of identification, and supporting reference (myotome columns T12-S3)

Discussion *(≥500 words)*

During the course of medical education we are frequently taught myotomes as concrete, predefined nerve roots that contribute to a muscle group. In reality, many patients present with deficits that are not consistent with this inflexible paradigm that is presented during the course of our schooling. The goal of this study was to compile all of the original investigations and literature available on lower extremity myotomes and synthesize the information to create an outline of the most common myotomal variations. By completing this work, we hope to create a resource for clinicians to reference while evaluating and localizing lower extremity lesions.

In order to create this resource, we referenced anatomy and electromyography textbooks in the OHSU Orthopedics Library in addition to 10,283 original investigations returned by our search terms in Pubmed and OVID. The most important result from our study is that we can see that our hypothesis of there being extensive myotomal variation is true. Looking over the table, many examples of frequent innervation beyond what is typically taught in medical school is evident. One such example is of the Gastrocnemius, where many texts simply cite that it is innervated by spinal nerve roots S1 and S2. While we did find that the medial and lateral heads were innervated by S1 100% and 90% of the time respectively in addition to S2 76 and 68% of the time respectively, we found other significant contributors. We found that the medial and lateral heads are innervated by L5 38% and 43% of the time respectively. In addition to this, we found that L4 and L3 can contribute to both heads as well in a minority of cases. This trend continues throughout our results showing that there is a large amount of agreement on certain myotomes but many muscles have significant variance. Given this new understanding that many muscles have significant contributions from multiple nerve roots which may not be classically taught, clinicians should integrate this knowledge into their clinical decision making.

However there were some limitations to our study and areas for improvement. Many of the studies used for this analysis of the lower extremity myotomes were stimulation studies. Using a greater variety of modalities to to analyze nerve root distributions may increase the accuracy of results. Additionally, some muscles need more original investigations. Some, such as the Quadratus Plantae for example, only had 1 original investigation and 6 reference texts to determine its innervation. Others, such as the Pectineus had 0 specified sources amongst 10 sources overall. We had similar results for 6 other muscles. In contrast, the Tibialis Anterior and Quadriceps muscle group had over 20 sources with specified methods to reference for our compilation. While we acknowledge that some muscle groups are more easily tested than others, having adequate data for all would create better results. Lastly, some studies were unclear in their exact methods for analyzing myotomes. Some studies would merely say that innervations were determined intraoperatively without describing whether the nerve roots were stimulated, directly visualized, imaged, or some combination of those three modalities. Better descriptions of the methods of these papers would allow for a more accurate systematic review in addition to a more accurate classification of methods used in our own table.

Conclusions *(2-3 summary sentences)*

Accurate myotomal knowledge is an essential part of evaluating and treating neurological lesions. This systematic review of the current literature surrounding lower extremity myotomal patterns showed significant variability in myotomal patterns which shows that myotomes are not universal. This compiled resource (Table 3) can aid clinicians in their clinical decision making as they attempt to localize lower extremity lesions in addition to being an educational resource.

References *(JAMA style format)*

1. Asma Lotfi, Comprehensive Review of Upper Extremity Myotomal Patterns; 2021
2. Georgoulis G, Sindou M. Muscle responses to radicular stimulation during lumbo-sacral dorsal rhizotomy for spastic diplegia: Insights to myotome innervation. *Clin Neurophysiol*. 2020;131(5):1075-1086. doi:10.1016/j.clinph.2020.02.007
3. London D, Birkenfeld B, Thomas J, et al. A broad and variable lumbosacral myotome map uncovered by foraminal nerve root stimulation. *J Neurosurg Spine*. Published online May 13, 2022. doi:10.3171/2022.3.SPINE2212
4. Zhu L, Lin HD, Chen AM. Accurate segmental motor innervation of human lower-extremity skeletal muscles. *Acta Neurochir (Wien)*. 2015;157(1):123-128. doi:10.1007/s00701-014-2258-7
5. Tsao BE, Levin KH, Bodner RA. Comparison of surgical and electrodiagnostic findings in single root lumbosacral radiculopathies. *Muscle Nerve*. 2003;27(1):60-64. doi:10.1002/mus.10291
6. Miura M, Nakamura E, Kato S, Usui T, Miyauchi R. The true nature of the adductor brevis dually innervated by the anterior and posterior branches of the obturator nerve in humans. *Okajimas Folia Anat Jpn*. 1994;71(2-3):67-82. doi:10.2535/ofaj1936.71.2-3_67
7. SHARRARD WJ. THE SEGMENTAL INNERVATION OF THE LOWER LIMB MUSCLES IN MAN. *Ann R Coll Surg Engl*. 1964;35(2):106-122.
8. Schirmer CM, Shils JL, Arle JE, et al. Heuristic map of myotomal innervation in humans using direct intraoperative nerve root stimulation. *J Neurosurg Spine*. 2011;15(1):64-70. doi:10.3171/2011.2.SPINE1068
9. Thage O. The myotomes L2--S2 in man. *Acta Neurol Scand Suppl*. 1965;13 Pt 1:241-243. doi:10.1111/j.1600-0404.1965.tb01878.x
10. Liguori R, Krarup C, Trojaborg W. Determination of the segmental sensory and motor innervation of the lumbosacral spinal nerves. An electrophysiological study. *Brain*. 1992;115 (Pt 3):915-934. doi:10.1093/brain/115.3.915
11. Phillips LH 2nd, Park TS. Electrophysiologic mapping of the segmental anatomy of the muscles of the lower extremity. *Muscle Nerve*. 1991;14(12):1213-1218. doi:10.1002/mus.880141213
12. Mahan MA, Sanders LE, Guan J, Dailey AT, Taylor W, Morton DA. Anatomy of psoas muscle innervation: Cadaveric study. *Clin Anat*. 2017;30(4):479-486. doi:10.1002/ca.22879
13. Voermans NC, Koetsveld AC, Zwarts MJ. Segmental overlap: foot drop in S1 radiculopathy. *Acta Neurochir (Wien)*. 2006;148(7):809-813. doi:10.1007/s00701-006-0754-0
14. Young A, Getty J, Jackson A, Kirwan E, Sullivan M, Parry CW. Variations in the pattern of muscle innervation by the L5 and S1 nerve roots. *Spine (Phila Pa 1976)*. 1983;8(6):616-624. doi:10.1097/00007632-198309000-00007
15. Brown WF & Bolton CF. Clinical Electromyography, 2nd edition. Boston: Butterworth-Heineman; 1993.
16. Kimura J. Electrodiagnosis in diseases of nerve and muscle : principles & practice. 3rd ed. New York: Oxford University Press; 2001.
17. Hoppenfeld S. Physical Examination of the Spine and Extremities. Appleton & Lange Prentice-Hall; 1976.
18. Goodgold J. Anatomical Correlates of Clinical Electromyography. 1st ed. Baltimore, MD: Williams and Wilkins; 1974.

19. Goodgold J. Anatomical Correlates of Clinical Electromyography. 2nd ed. Baltimore, MD: Williams and Wilkins; 1984.
20. Kendall FP, McCreary EK. Muscles: Testing and Function. 3rd ed. Baltimore, MD: Williams & Wilkins; 1983.
21. Spalteholz W. Hand Atlas of Anatomy. Vol II & III. 6th ed. London: J. B. Lippincott; 1938.
22. Brown WF, Bolton CF. Clinical Electromyography. 1st ed. Boston: Butterworth; 1987.
23. Brown WF, Bolton CF. Clinical Electromyography. 2nd ed. Stoneham, MA: Butterworth-Heinemann; 1993.
24. Jenkins DB. Hollinshead's Functional Anatomy of the Limbs and Back. 8th ed. Philadelphia, Pennsylvania: Saunders; 2002.
25. Delagi EF, Perotto A. Anatomic Guide for the Electromyographer. 2nd ed. Springfiled, IL: Charles C. Thomas; 1975 & 1980
26. Haymaker W, Woodhall B. Peripheral Nerve Injuries: Principles of Diagnosis. 2nd ed. Philadelphia: W. B. Saunders Company; 1953
27. Carpenter MB. Human Neuroanatomy. 8th ed. Baltimore: Williams & Wilkins; 1983.
28. Truex RC. *Human Neuroanatomy Sixth Edition; 1969*
29. Fyfe LH. *Anatomy of the Human Body.* J.B. Lippincott; 1959.