ORIGINAL ARTICLE

Nr 2022;12 (2):173-180

Role of Posterior Layer of Thoracolumbar Fascia in Epimuscular Myofascial Force Transmission From Gluteus Maximus to Latissimus Dorsi and Lower Trapezius

S. Marpalli[1], M. Rao K. G.[1], P. Venkatesan[2], B. M. George[1]

[1] *Department of Anatomy, Melaka Manipal Medical College (Manipal Campus), Manipal Academy of Higher Education (MAHE), Manipal, India*

[2] *Department of Physiotherapy, Manipal College of Health Professions (Bangalore campus), Manipal Academy of Higher Education (MAHE), Manipal, India*

CORRESPONDING AUTHOR:
Bincy M. George
Department of Anatomy
Melaka Manipal Medical College (Manipal Campus)
Manipal Academy of Higher Education (MAHE)
Madhav Nagar, Manipal
Udupi District
Karnataka State, India
E-mail: bincy.george@manipal.edu

DOI:
10.32098/mltj.02.2022.11

LEVEL OF EVIDENCE: 3

SUMMARY

Purpose. Posterior layer of thoracolumbar fascia (PTLF) is the part of the deep fascia of back of the trunk which connects the trunk, upper and lower limb muscles. PTLF is the major myofascial linkage where myofascial force transmission can take place between the muscles attached to it. The present study evaluates the force transmission through PTLF to the right and left latissimus dorsi, and right and left lower trapezius muscles during isometric contraction of right and left gluteus maximus.

Materials and methods. Present descriptive observational study was conducted on 40 male adult healthy volunteers aged between 30 to 45 years. The Root mean square (RMS) value of EMG signal of the bilateral gluteus maximus, latissimus dorsi and lower trapezius muscles was collected using surface Electromyographic sensors. The Electromyographic assessment was carried out at normal contraction, at minimum resistance (load of 1 kg) and at maximum voluntary contraction with resistance (2-5.5 kg) of gluteus maximus.

Results. When left gluteus maximus contracts normally (without any resistance), the mean RMS value was found to be 16.28 ± 3.15 µV and on maximum voluntary contraction (MVC) with resistance it was 28.95 ± 4.89 µV. When right gluteus maximus contracts normally without any resistance, the mean RMS value was found to be 25.83 ± 4.48 µV and MVC with resistance was 43.70 ± 2.60 µV. This showed around 30-70% increase in RMS value from normal contraction to MVC with resistance. The relative activation at different isometric contractions of right and left gluteal muscles were compared to the right and left latissimus dorsi and right and left lower trapezius muscles. A significant ($p < 0.001$) Pearson's correlation was observed between the muscles.

Conclusions. Epimuscular myofascial force is transferred from the gluteus maximus muscles to other muscles attached to PTLF directly or indirectly to the same side as well as to the opposite side. The connection via PTLF to the muscles attached to it may affect the sensory feedback and thereby the neuromuscular control. In pathological conditions, same myofascial linkage may contribute to altered biomechanics of the back of the trunk.

KEY WORDS

Electromyography; gluteus maximus; isometric contraction; myofascial force transmission; posterior layer of thoracolumbar fascia.

INTRODUCTION

Myofascial system is a protective material of the body (1). Posterior layer of thoracolumbar fascia (PTLF) is a part of this myofascial linkage which covers the muscles of the trunk and continues upwards as investing layer of the deep cervical fascia of the neck. Below, it continues with the fascia covering the gluteus maximus muscle. It also covers the extensor muscles of the vertebral column. Thus, PTLF is a major fascial connection between the trunk and both extremities. A potentially significant fraction of muscle fibe force is transmitted myofascially, so the PTLF controls, facilitates and restricts the musculofascial function and load transfer for proper functioning of the body (2). The knowledge of this connection between these major muscles and the fasciae plays a significant role in understanding the impairment of the musculoskeletal deformity (3).

The gluteus maximus muscle is a powerful extensor of the body and is considered as the primary muscle responsible for the movement of the body from sitting to standing position (4). The latissimus dorsi muscle acts mainly on shoulder joint where it helps in extension, adduction, and abduction at horizontal axis. The altered function of latissimus dorsi has been shown to be one of the causes of chronic shoulder pain and chronic back pain (5). Lower fibres of trapezius take origin from spinous processes of 6th to 12th thoracic vertebrae and are inserted to a tubercle at the apex of the spine of the scapula. Lower fibers of trapezius play a vital role in shoulder functioning by moving and posturing the scapula. They also play a dynamic role in scapula stability and load transferring to the shoulder joint (6).

A normal muscle at rest is electrically silent and at activation or at contraction electrical potentials are produced and it can be noted in the surface EMG. Surface EMG has a lot of relevance in sports science and rehabilitation medicine (7). The myoelectrical activity of individual muscle depends on contractions of muscle attached directly or indirectly through the fascia. Myofascial force transmission is defined as the force transmitted to bone via electrical activity of individual muscle bounded by the epimysium and fascia connected to it (8).

Epimuscular force is transmitted between the adjacent muscle belly interface in two pathways: 1) intermuscular force transmission through the connective tissue; 2) Extra-muscular force transmission between epimysium of a muscle and surrounding non muscular structures. Thus, muscles are unquestionably linked for force transmission (9). It has been proved that the connection between muscles and fasciae plays a significant role in understanding the etiopathogenesis of several musculoskeletal diseases (10). The studies regarding the evidence of force transmission across PTLF to the major connecting muscles during gluteus maximus contraction, by means of surface electromyography is not found in the literature. Hence, the present study aims to measure the epimuscular myofascial force transmission between gluteus maximus, latissimus dorsi and lower trapezius muscles during isometric contraction of gluteus maximus muscles using surface electromyography on healthy human adults.

The surface electromyogram (SEMG) depicts the most important bioelectric signals generated by the muscles. The SEMG signal is the statistical sum of the motor unit action potentials generated by the active motor units and detected over the skin. The RMS values extracted from the SEMG indicate overall and, rarely, individual motor unit (MU) activity of the muscle being tested (11).

MATERIALS AND METHODS

Forty healthy male adult volunteers aged 35 ± 3.80 years with BMI of 24 ± 1.92 kg/m^2 participated in the study (**table I**). Human Ethical Committee approval was obtained from the Institutional Ethical Committee (Kasturba Medical College and Kasturba Hospital Institutional Committee) [Registration No. ECR/146/Inst/KA/2013- IEC141/2016 - Date of approval: 8/03/2016; amendment on 06/03/2021] and a written informed consent was obtained from all the participants.

Table I. Mean ± SD of age, height weight and BMI (Body Mass Index).

	Height in feet	Weight in Kg	BMI	Age in years
Mean N = 40	5.66 ± 035	71.32 ± 8.32	24.12 ± 1.92	35.32 ± 3.82

All subjects were informed about the set of experiments prior to the study. For all the tests, the subjects were made to lie in the prone position and were asked to follow the investigator's instructions during the procedure. The experiments were conducted at 3 levels of contractions of gluteus maximus:

1) normal contraction of unilateral gluteus maximus without resistance (a);
2) isometric contraction of unilateral gluteus maximus with minimum resistance of the load 1 kg (A);
3) isometric contraction of unilateral gluteus maximus with maximum resistance of the load 2 kg to 5.5 kg (AA).

These procedures were performed bilaterally. All data were collected during a single testing session for each subject to minimize test-retest variability. The resistance applied were measured by using calibrated, modified load cell-handheld dynamometer.

EMG instrumentation

Completely wireless Trigno™ Lab and Trigno™ digital systems of surface Electromyography (SEMG) machines were used in the study. RMS values of the individual muscles attached to the PTLF; gluteus maximus (GMx), latissimus dorsi (LD) and lower fibers of trapezius (LTz) on right and left sides were documented. Placement of electrodes were standardized before the beginning of the study and were determined in accordance with the SENIAM (surface EMG for a non-invasive assessment of muscle) (12). For GMx muscle the sensors were placed at mid-point of the line between the first sacral vertebral segment and the greater trochanter of the femur. This position corresponds to the greatest prominence of the middle of the buttocks well above the visible bulge of the greater trochanter. For LD muscle, the sensors were placed 3 cm below and lateral to the inferior angle of the scapula. Sensors for the LTz muscle were placed at two-thirds of the way from the trigonum spinea to the eighth thoracic vertebra (**figure 1**). EMG signals were captured at 0 to 500 Hz, pre-amplified (01.5 mV) using Delsys Trigno wireless biofeedback system EMG works Acquisition.

Data collection and analysis

Delsys EMG works Analysis module was used for analyzing the data. By selecting data series and data files from the workspace, the calculation was applied to the required data series. RMS value of each muscle was snapped and exported to excel and then analyzed using SPSS software version 16. Mean RMS ± SD of all the muscles were compared individually and Pearson's correlation test was performed to see if there is significant ($p < 0.01$) correlation between the muscles at different contractions.

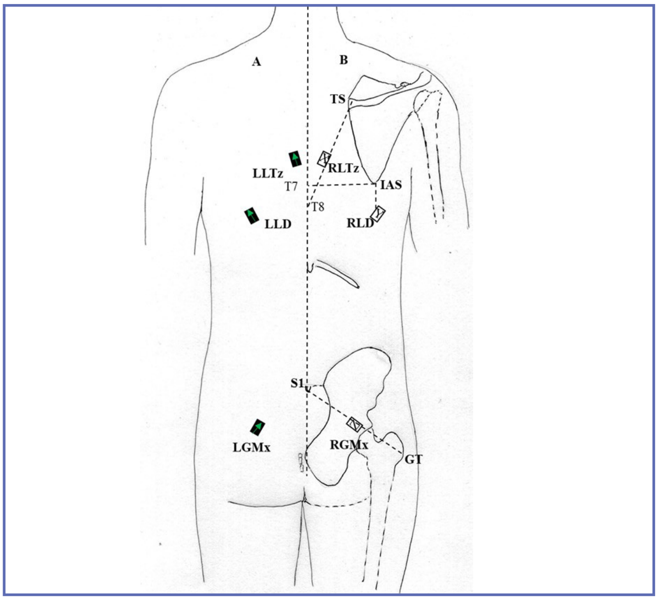


Figure 1. (A) Diagrammatic representation of placement of sensors. The arrow of the sensors was placed parallel to the muscle fibers. **(B)** Bony landmark of placement of sensors.

TS: Trigonum Spinae of Scapula; IAS: Inferior Angle of Scapula; GT: Grater Trochanter of Femur; T7, T8, S1: Vertebral levels; LLTz: Left Lower Trapezius; RLTz (X): Right Lower Trapezius; LLD: Left Latissimus Dorsi; RLD (Y): Right Latissimus DORSI; LGMx: Left Gluteus Maximus; RGMx (Z): Right Gluteus Maximus.

Testing position of the gluteus maximus muscle (13, 14)

Skin of the back of the trunk where the sensors to be placed was cleaned using ethyl alcohol. The testing positions of the muscles and method followed during testing have been described (**table II**) with a schematic representation (**figure 2**).

Table II. Position of the thigh and leg for recording EMG of Gluteus Maximus.

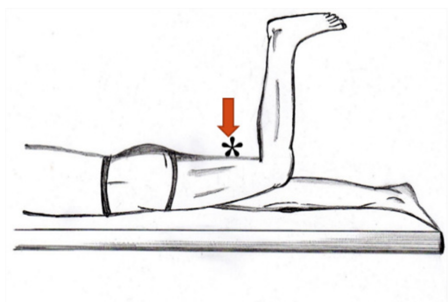
Muscle	Gluteus maximus	Diagrammatic representation
Position	Prone	 Figure 2
Action	The subject lying in prone position with his knee flexed up to 90°	
Investigator	The investigator standing next to the subject with his/her hand placed proximal to the subject's popliteal fossa as indicated in the diagram*.	

Figure 2. Diagrammatic representation of the subject showing the position of the thigh and the leg while recording the Electromyography of gluteus maximus. Star and arrow marked proximal to the popliteal fossa indicates the site and direction of resistance applied by the investigator using handheld dynamometer.

RESULTS

Left gluteus maximus contraction

Mean RMS ± SD values of the muscle during the contraction of LGMx were shown in the **table III**. The mean RMS values at minimal contraction (A) and maximum contraction (AA) was found increased about 40-70% compared to the normal contraction (**figures 4, 5**). The RGMx, LLD, RLD LLTz, RLTz were also showed some change in the generation of action potential. The percentage of EMG signal found in terms of RMS values noted in other muscles attached to PTLF when the left gluteus maximus contract are as follows. RGMx 10-17%, RLD 18-30%, RLTz 20-40%, LLD 14-30%, and LLTz 11-17%. During the contraction of LGMx, the superficial muscles in the back of the trunk displayed significant (Pearson's) correlation between them (**figure 3**).

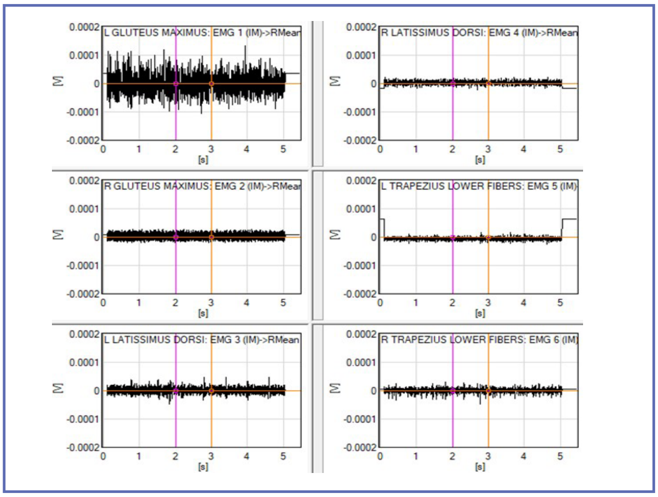


Figure 4. Representative graphs of raw EMG signals of the different muscles in volts (V) during normal contraction of left gluteus maximus.

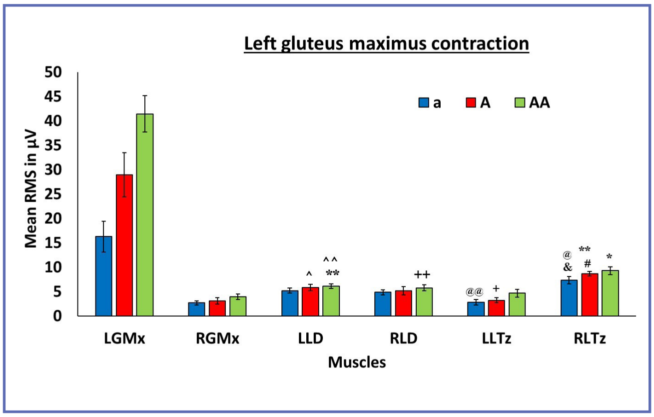


Figure 3. Graph shows the mean RMS (in µV) ± SD of the muscles during the contraction of left gluteus maximus muscle.

*: LGMx *vs* RLTz - AA ($p < 0.02$); &: LGMx - A *vs* RLTz ($p < 0.004$); **: LGMx - A *vs* LLD - AA ($p < 0.004$); #: LGMx - AA *vs* RLTz - A ($p < 0.015$); +: RGMx *vs* LLTz - A ($p < 0.02$); ++: RGMx *vs* RLD - AA ($p < 0.04$); ^: RGMx-A *vs* LLD - A ($p < 0.015$); ^^: RGMx - AA *vs* LLD - AA ($p < 0.04$); @: LLD *vs* RLTz ($p < 0.03$); @@: LLTz - A *vs* LLD ($p < 0.04$).

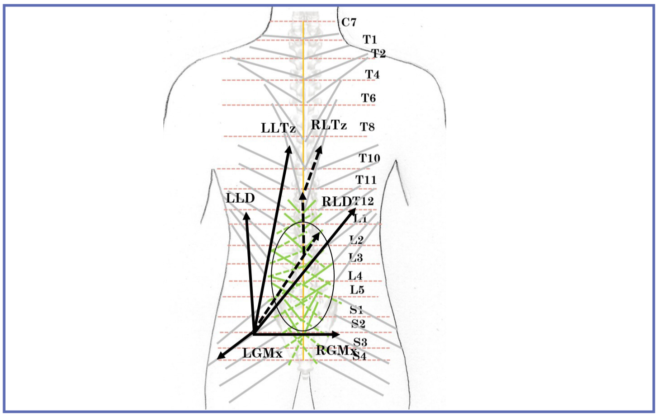


Figure 5. Diagrammatic representation of back of the trunk showing the PTLF (oval encircled area) and the superficial muscles attached to it. It also shows the fiber direction of the fascia and muscles.

LLTz: Left Lower Trapezius; RLTz: Right Lower Trapezius; LLD: Left Latissimus Dorsi; RLD: Right Latissimus Dorsi; LGMx: Left Gluteus Maximus; RGMx: Right Gluteus Maximus.

Table III. Mean RMS ± SD of the muscles during the contraction of left gluteus maximus. Values are given in µV.

	a	A	AA
LGMx	16.28 ± 3.15	28.95 ± 4.89	41.43 ± 4.94
RGMx	2.71 ± 0.432	3.107 ± 0.59	3.946 ± 0.60
LLD	5.197 ± 0.51	5.85 ± 0.64	6.13 ± 0.48
RLD	4.85 ± 0.48	5.21 ± 0.58	5.78 ± 0.58
LLTz	2.837 ± 0. 72	3.22 ± 0.54	4.70 ± 0.59
RLTz	7.340 ± 0.80	8.684 ± 0.7	9.31 ± 0.428

LGMx: Left Gluteus Maximus; RGMx: Right Gluteus Maximus; LLD: Left Latissimus Dorsi; RLD: Right Latissimus Dorsi; LLTz: Left Lower Trapezius; RLTz: Right lower Trapezius; a: normal contraction; A: contraction with the resistance of 1 kg of weight; AA: contraction with the resistance of 2- 5.5 kg of weight.

Right gluteus maximus contracts

Mean RMS (in µV) ± SD values of the muscles during the contraction of RGMx are shown in the **table IV**. The mean RMS values were found increased about 20-60% at contraction A and contraction AA. The LGMx, LLD, RLD LLTz, RLTz also displayed the change in action potential in the same pattern as that of the experiment conducted on LGMx. The percentage increase in RMS value noted in the other muscles attached to PTLF are as follows: LGMx 10-15%, LLD 18-28%, LLTz 20-45%, RLD 14-25%, and RLTz 11-15%. These superficial muscles in the back of the trunk exhibited significant (Pearson's) correlation between the muscles when RGMx was made to contract (**figures 6, 7**).

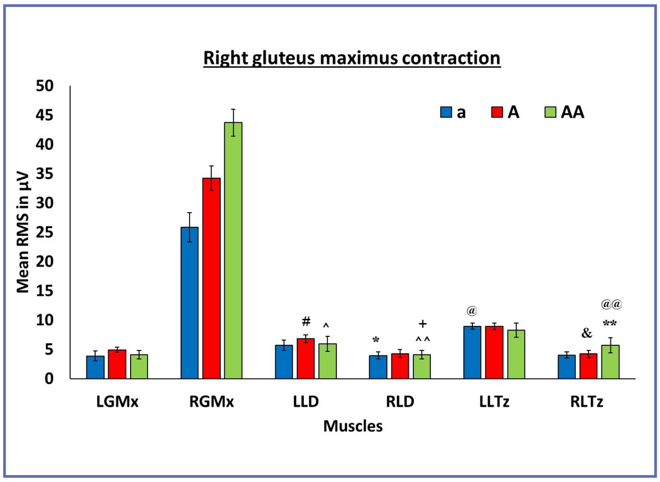


Figure 6. Graph shows the mean RMS (in µV) ± SD of the muscles during the contraction of right gluteus maximus muscle.

#: LGMx *vs* LLD - A ($p < 0.005$); @: LGMx *vs* LLTz ($p < 0.025$); ^: LGMx - AA *vs* LLD - AA ($p < 0.028$); ^^: LGMx - AA *vs* RLD - AA ($p < 0.025$); *: RGMx *vs* RLD ($p < 0.001$); **: RGMx *vs* RLTz - AA ($p < 0.014$); +: LLD - AA *vs* RLD - AA ($p < 0.040$); @@: RLD - AA *vs* RLTz - AA ($p < 0.007$); &: RLTz *vs* RLTz - A ($p < 0.041$).

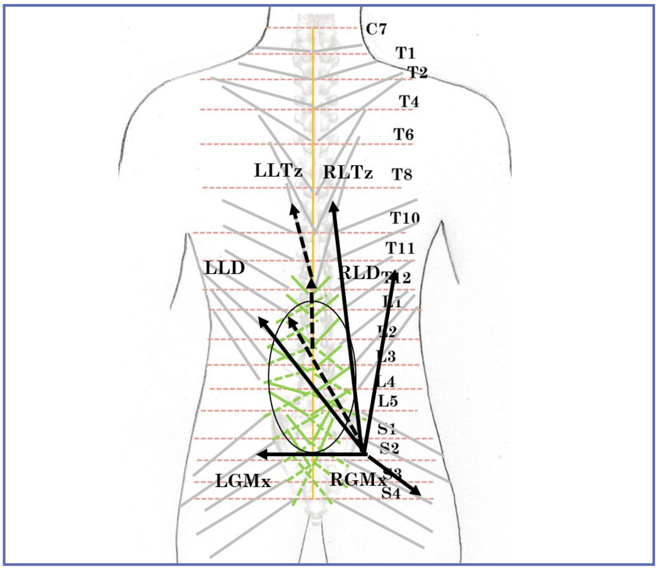


Figure 7. Diagrammatic representation of back of the trunk showing the PTLF (oval encircled area) and the superficial muscles attached to it. It also shows the fiber direction of the fascia and muscles.

LLTz: Left Lower Trapezius; RLTz: Right Lower Trapezius; LLD: Left Latissimus Dorsi; RLD: Right Latissimus Dorsi; LGMx: Left Gluteus Maximus; RGMx: Right Gluteus Maximus.

DISCUSSION

There are two types of deep fasciae in human body: aponeurotic fascia and epimysial fascia. They are different in their functions and mechanical properties (15). The aponeurotic fascia envelops various muscles and keeps them in place and connect them together (16). Whereas, the epimysial fascia is specific for each muscle and strongly connects the muscle fibers and connects those

Table IV. Mean RMS (in µV) ± SD of the muscles attached to PTLF during the contraction of right gluteus maximus.

	a	A	AA
LGMx	3.86 ± 0.84	4.90 ± 0.43	4.10 ± 0.73
RGMx	25.83 ± 4.48	34.20 ± 3.11	43.70 ± 2.60
LLD	5.70 ± 0.86	6.85 ± 0.64	5.93 ± 1.28
RLD	3.965 ± 0.61	4.27 ± 0.698	4.10 ± 0.74
LLTz	8.96 ± 0. 49	8.83 ± 0.55	8.25 ± 1.21
RLTz	4. 04 ± 0.54	4.21 ± 0.58	5.68 ± 1.29

LGMx: Left Gluteus Maximus; RGMx: Right Gluteus Maximus; LLD: Left Latissimus Dorsi; RLD: Right Latissimus Dorsi; LLTz: Left Lower Trapezius; RLTz: Right lower Trapezius; a: normal contraction; A: contraction with the resistance of 1 kg of weight; AA: contraction with the resistance of 2- 5.5 kg of weight.

with the bones attached to it (17). Studies show that the aponeurotic fascia has higher percentage of innervated area, high density of branching points and more nerve structures compared to the epimysial fascia. On the other hand, the epimysial fascia is totally adherent to the underlying muscle and is connected with the stretch receptors such as muscle spindle and Golgi tendon organs (18). It is a well-known fact that these stretch receptors are totally in continuity with the perimysium and endomysium of the muscle. Thus, the epimysial fascia with these stretch receptors works to coordinate the actions of the various motor units of the underlying muscles (19).

Posterior layer of thoracolumbar fascia is an aponeurotic fascia which acts as a major fascial connection between the superficial muscles of trunk and muscles of upper and lower limbs. TLF plays main role in transmitting forces from the lower to the upper limbs and *vice versa*. This is one of the most studied aponeurotic fascia because of its relations with nonspecific low back pain (20). But the quantification of force transmission through the aponeurotic posterior layer of thoracolumbar fascia was lacking in the literature. In our study, we quantified the force transmission in terms of electrical activity of the muscles attached to PTLF. The result shows that there is significant correlation between the force transmission among the muscles directly attached to PTLF (between GMx and LD) bilaterally.

RMS value of surface EMG is related to the amount of force produced in the muscle (21). In an experimental setup, when the gluteus maximus contracts, if there is bilateral contraction of the latissimus dorsi, the force transmission needs to be through the connecting link, that is the posterior layer of thoracolumbar fascia (22). We aimed to find the force transmission through PTLF and found that a considerable amount of force is transmitted from one side gluteus maximus to the muscles attached to the same side as well as the other side of PTLF. It was interesting to note that when gluteus maximus contracts unilaterally, the contralateral lower trapezius shows the highest RMS value among the superficial muscles of the back. Gluteus maximus of one side is connected via aponeurotic fascia (PTLF) and epimuscular fascia of the lower trapezius bilaterally through the thoracic spines. We assume that epimuscular myofascial force is transmitted from gluteus maximus to the lower trapezius of both sides. But the significantly high correlation between one side gluteus maximus and opposite side lower trapezius may be explained by the direction of fibers of PTLF and that of the epimuscular fascia, and muscle fiber directions of the lower trapezius. The average angulation of fibers in sacral level is much less compared to thoracic and lumbar vertebral levels (23). The probable line of force transmission is from the gluteus maximus to the lumbar and thoracic spines through the PTLF and from thoracic spines to the epimuscular fascia of the lower trapezius. We postulate that this arrangement of fibers contributes to the difference in force transmission in different regions of the posterior layer of thoracolumbar fascia.

In our study, the considerable variation of RMS value in the muscles attached to PTLF when one side gluteus maximus contracts can be explained by the discrepancies concerning the tissue type and the degree of morphological continuity. The possibility of force transfer in these muscles through PTLF encourages clinicians to target the entire myofascial linkage in the evaluation process and treatment of myofascial pathologies of the lower back.

CONCLUSIONS

This study shows that there is bilateral force transmission from gluteus maximus to the latissimus dorsi and lower trapezius muscles. These muscles are connected by the fascial network of the back. The gluteus maximus and latissimus dorsi share the origin from the aponeurotic posterior layer of the thoracolumbar fascia. So, the change in RMS value in latissimus dorsi while gluteus maximus contracts, indicates the amount of force transmission through the aponeurotic posterior layer of thoracolumbar fascia. The difference seen in RMS value of the muscles in right and left sides can be explained with the help of direction and angulation of the fibers of posterior layer of thoracolumbar fascia. The comparative increase in RMS values in lower trapezius clearly explains the epimuscular myofascial force transmission from gluteus maximus via the PTLF and the thoracic spines to the lower trapezius. The present research challenges the traditional view that the muscles of the back function as independent units during a particular movement. In conditions like idiopathic back pain, radiating pain, *etc*., instead of focusing on single structures like a muscle or a fascia, more holistic approaches seem appropriate. In pathological conditions, the connection through PTLF may contribute to altered biomechanics of the back of the trunk.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

SM: EMG: recordings taken, drafting. KGMR, PV: data analysis and drafting. BMG: conceptualization, monitoring of the procedures, data analysis and drafting.

ACKNOWLEDGEMENTS

We would like to acknowledge the Department of Anatomy, Melaka Manipal Medical College, Manipal, India for providing lab facility for this study

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Wilke J, Schleip R, Yucesoy CA, Banzer W. Not merely a protective packing organ? A review of fascia and its force transmission capacity. J Appl Physiol (1985) 2018;124(1):234-44.
2. Vleeming A, Pool-Goudzwaard AL, Stoeckart R, van Wingerden JP, Snijders CJ. The posterior layer of the thoracolumbar fascia. Its function in load transfer from spine to legs. Spine (Phila Pa 1976) 1995;20(7):753-8.
3. Marinho HVR, Amaral GM, Moreira BS, *et al*. Myofascial force transmission in the lower limb: An in vivo experiment. J Biomech 2017;63:55-60.
4. Neto WK, Soares EG, Vieira TL, *et al*. Gluteus Maximus Activation during Common Strength and Hypertrophy Exercises: A Systematic Review. J Sports Sci Med 2020;19(1):195-203.
5. Bhatt CR, Prajapati B, Patil DS, Patel VD, Singh BGP, Mehta CD. Variation in the insertion of the latissimus dorsi & its clinical importance. J Orthop 2013;10(1):25-8.
6. McCabe RA, Orishimo KF, McHugh MP, Nicholas SJ. Surface electromygraphic analysis of the lower trapezius muscle during exercises performed below ninety degrees of shoulder elevation in healthy subjects. N Am J Sports Phys Ther 2007;2(1):34-43.
7. Bigland Ritchie B, Johansson R, Lippold OCJ, Woods JJ. Contractile speed and EMG changes during fatigue of sustained maximal voluntary contractions. J Neurophysiol 1983;50(1):313-24.
8. Qiao J, Zhang SL, Zhang J, Feng D. A study on the paraspinal muscle surface electromyography in acute nonspecific lower back pain. Medicine (Baltimore). 2019;98(34):e16904.
9. Maas H, Sandercock TG. Force transmission between synergistic skeletal muscles through connective tissue linkages. J Biomed Biotechnol 2010;2010:575672.
10. Ajimsha MS, Shenoy PD, Gampawar N. Role of fascial connectivity in musculoskeletal dysfunctions: A narrative review. J Bodyw Mov Ther 2020;24(4):423-31.
11. Bishop BN, Greenstein J, Etnoyer-Slaski JL, Sterling H, Topp R. Electromyographic Analysis of Gluteus Maximus, Gluteus Medius, and Tensor Fascia Latae During Therapeutic Exercises With and Without Elastic Resistance. Int J Sports Phys Ther 2018;13(4):668-75.
12. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 2000;10(5):361-74.
13. Bishop BN, Greenstein J, Etnoyer-Slaski JL, Sterling H, Topp R. Electromyographic Analysis of Gluteus Maximus, Gluteus Medius, and Tensor Fascia Latae During Therapeutic Exercises With and Without Elastic Resistance. Int J Sports Phys Ther 2018;13(4):668-75.
14. Contreras B, Vigotsky AD, Schoenfeld BJ, Beardsley C, Cronin J. A comparison of two gluteus maximus EMG maximum voluntary isometric contraction positions. PeerJ 2015;3:e1261.
15. Carmichael SW. Fasciae of the back. In: Stecco C (ed). Functional Atlas of the Human Fascial System. Edinburgh: Churchill Livingstone Elsevier, 2015: pp. 185-210.
16. Fede C, Petrelli L, Guidolin D, *et al*. Evidence of a new hidden neural network into deep fasciae. Sci Rep 2021;11(1):12623.
17. Pirri C, Fede C, Stecco A, *et al*. Ultrasound Imaging of Crural Fascia and Epimysial Fascia Thicknesses in Basketball Players with Previous Ankle Sprains Versus Healthy Subjects. Diagnostics (Basel) 2021;11(2):177.
18. Schleip R, Zorn A, Klingler W. Biomechanical properties of fascial tissues and their role as pain generators. J Musculoskelet Pain 2010;18(4):393-5.
19. Stecco C, Gagey O, Belloni A, *et al*. Anatomy of the deep fascia of the upper limb. Second part: study of innervation. Morphologie 2007;91(292):38-43.
20. Wilke J, Schleip R, Klingler W, Stecco C. The Lumbodorsal Fascia as a Potential Source of Low Back Pain: A Narrative Review. Biomed Res Int 2017;2017:5349620.
21. Willard FH, Vleeming A, Schuenke MD, Danneels L, Schleip R. The thoracolumbar fascia: anatomy, function and clinical considerations. J Anat 2012;221(6):507-36.

22. Fukuda TY, Echeimberg JO, Pompeu JE, *et al.* Root mean square value of the electromyographic signal in the isometric torque of the quadriceps, hamstrings and brachial biceps muscles in female subjects. J Appl Res 2010;10(1):32-9.

23. Marpalli S, Mohandas Rao KG, Venkatesan P, George BM. The morphological and microscopical characteristics of posterior layer of human thoracolumbar fascia; A potential source of low back pain. Morphologie 2021;105(351):308-15.