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ORIGINAL

Muscle Function Path Analysis through Muscle Activity Analysis of Human Myofascial Meridians

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Objective: The purpose of this study was to perform a muscle function path analysis of muscle function on myofascial meridians.

Method: Seven male students (mean age: 22 ± 3.46 years; mean mass: 72.71 ± 8.19 kg; mean height: 174 ± 4.39 cm) without a history of musculoskeletal system symptoms or injuries were recruited for this study. The measurement muscle of the myofascial line was selected along with the muscle presented in "anatomy trains (Thomas W. Myers. 2014)", and the attachment of the surface EMG (Telemyo 2400T G2, USA) pad was determined according to "EMG analysis (Kim Tae Wan et al., 2013)". The subjects underwent maximum volumetric contraction of their fascia line end muscles three times in lying and standing postures and were subjected to the maximum number of contractions of the myofascial line muscle three times in the lying and standing postures. The sampling rate of the EMG signal was set to 1,000 Hz, and the bandwidth was 20 to 350 Hz. The activity of each muscle was quantitated using the Pearson correlation coefficient, and SPSS 22.0 was used for data analysis.

Results: In myofascial meridians, a positive correlation in the myofascial connection and a negative correlation in the mechanical connection were observed.

Conclusion: Muscles that show significant contract correlations with one another may be expected to be used as an effective clinical marker in muscle strengthening or relaxation therapy, and rehabilitative training. In this study, the correlation of total myofascial meridians may differ without consideration of functional posture. Future studies need to consider these points.

Keywords: Muscle activity, Myofascial meridian, Myofascial connection

INTRODUCTION

Studies on individual muscle exercise have attempted to evaluate muscle exercises on the basis of the new concept of myofascial continuity. Myofascial continuity can be defined as a connection between two structures that are aligned in the same direction within a myofascial webbing (Myers, 2009). Wilke and Banzer (2017) found that the range of motion of the neck increases in the sagittal plane following the stretching of the muscle triceps surae (calf's ms.) and hamstring. Weisman et al. (2014) revealed muscle contraction correlations by using electromyography (EMG) of muscles along the back side of the body [superficial back line, Myers (2001)]. In addition, Huijing (2007) reported cases of epimuscular myofascial force transmission. This fascial webbing is associated with the widespread motor system of fibrous connective tissues, and transfers an impact to distal structures (Wike, Krause, Vogt and Banzer, 2016).

The concept of myofascial meridians proposed by Myers (2001), who studies the Rolfing technique, divides the body into continuous myofascial meridians. He illustrated the fascial webbing in myofascial meridians with an anatomical image for easier understanding (Figure 1).

In a recent study that used myofascial meridians, myofascial meridian stretching led to more-significant improvements in the performance of Taekwondo side kick than in individual muscle stretching (Jeong, 2017). Moreover, myofascial meridian relaxation techniques improved the gait and balance ability of stroke patients (Han, 2015), and myofascial meridian massage led to increased range of motion of the neck (Cheon, 2012). However, studies on myofascial meridians have used myofascial meridian stretching or massage only, and research on correlations relating to myofascial continuity is lacking.

In this study, muscle contraction correlations between the muscles along 8 myofascial meridians that vertically connect the body were analyzed by contracting the terminal muscles of the myofascial meridians in the supine and upright positions. By doing so, we aimed to assess the possibility for functional compensation among muscles, and provide research data for clinical applications in the field of kinesiology and rehabilitative medicine.

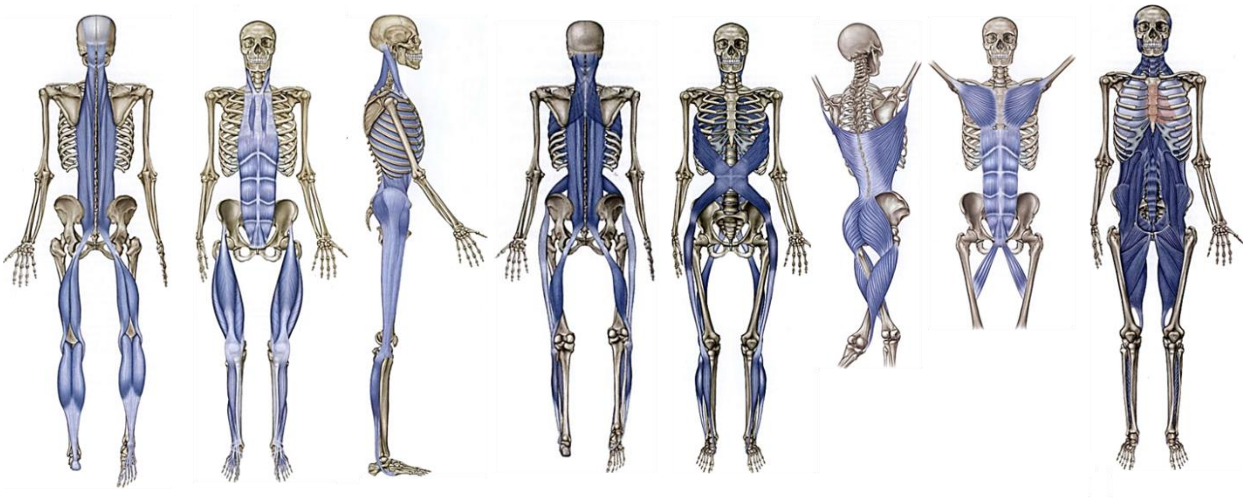

Figure 1. The fascia meridian that connects the body vertically. From the left superficial back line (SBL), superficial front line (SFL), lateral line (LL), spiral line [back] (SL[B]), spiral line [front] (SL[F]), functional line [back] (FL[Back]), functional line [front] (FL[Front]), deep front line (DFL) (Myers, 2009).

METHODS

1. Research participants and period

Seven male students who were studying physical education at Konkuk University participated in this study between September 15, 2017, and September 22, 2017. Students who had a muscle disorder or pain in the neck and ankle, received treatment for musculoskeletal disease in the last 6 months, undergone surgery of the neck or ankles, a previous or current history of neurological problems, or a cardiopulmonary disease were excluded. All the participants received an explanation about the purpose and methods of this study, and provided informed consent. The general characteristics of the participants are summarized in (Table 1).

Table 1. General characteristics of the participants (n = 7)

Demographic	Mean ± SD	Range
Age (yr)	22 ± 3.46	20~28
Height (cm)	174 ± 4.39	168~180
Body weight (kg)	72.71 ± 8.19	62~87

2. Electrode placement

Muscles along the myofascial meridians to be assessed were selected on the basis of the anatomy of myofascial meridians (Myers, 2009). Electrodes were attached to the muscles along the spiral line (SL) that connects the body in a diagonal line and the functional line (FL) on both the right and left sides of the body. Surface electrode pads were attached at the most developed parts of the muscles by referring to the electromyogram analysis (Table 2, Figure 2) (Kim et al., 2013).

Table 2. Electrode attaching muscle according to myofascial meridians

MM	Attachment muscle
SBL	(Rt.) Gastrocnemius, biceps femoris, lumbar elector, thoracic erector, semispinalis capitis
SFL	(Rt.) Tibialis anterior, rectus femoris, rectus abdomen lower, rectus abdomen upper, pectoralis major, sternocleidomastoid
LL	(Rt.) Peroneus longus, tensor fascia lata, gluteus medius, external abdominal oblique, sternocleidomastoid
SL(B)	(Rt.) Peroneus longus, biceps femoris, lumbar erector, thoracic erector, semispinalis capitis
SL(F)	(Rt.) Tibialis anterior, tensor fascia lata, internal abdominal oblique, splenius capitis (Lt.) External abdominal oblique, serratus anterior, rhomboids
FL(B)	(Rt.) Latissimus dorsi, thoracic erector (Lt.) Lumbar elector, gluteus maximus, vastus lateralis
FL(F)	(Rt.) Pectoralis major, rectus abdomen upper (Lt.) Rectus abdomen lower, adductor longus
DFL	(Rt.) Tibialis posterior, adductor magnus, iliopsoas, scalenes

MM: myofascial meridians, SBL: superficial back line, SFL: superficial front line, LL: lateral line, SL(B): spiral line (back), SL(F): spiral line (Front), FL(B): functional line (back), FL(F): functional line (front), DFL: deep front line

3. Measurement procedure

All the participants received an explanation of the purpose and precautions for the experiment, and provided written consent. They were then instructed on how to perform exercise movements precisely.

Figure 2. Measurements of muscle activity in prone and standing postures (left: FL[B], right: SBL)

1) MVC

For the normalization of EMG data, maximum voluntary isometric contraction was performed for all muscles along each myofascial meridian prior to the measurement (Kendall, 2001).

2) Measurement of muscle activity along the myofascial meridian

To assess the muscle contraction correlations of each muscle, active voluntary contraction was performed for 1 second three times after matching muscle functioning between the two sides. For the superficial front line (SFL), lateral line (LL), superficial front line (SL[F]), functional front line (FL[F]), and deep front line (DFL), contraction was performed in the supine and upright positions. For the superficial back line (SBL), superficial back line (SL[B]), and functional back line (FL[B]), contraction was performed in the prone and upright positions. During the measurement, the legs were spread apart at shoulder width, and the lower limbs, trunk, and neck were linearly aligned. During the measurement in the prone position, the feet were kept outside the bed. During the measurement in the supine position, the feet were spread apart at shoulder width, and measurements were obtained while the participant looked straight ahead. For the muscles of the lower legs, ankle exercise was performed. For the neck muscles, neck exercise was performed to measure muscle contraction. The latissimus dorsi and pectoralis major, which are muscles of the upper body, were measured while the examiner put resistance at the angle of maximum contraction. Contraction of the muscles of the hip joints, namely the adductor longus and adductor magnus, were measured while the examiner applied resistance in the

Table 3. Measurement method of each myofascial meridians activity

	Supine position	Prone position	Standing position	Action muscle
SBL		Ankle plantar flexion	Heel lift	Tibialis posterior
		Neck extension	Neck extension	Semi-spinalis
SFL	Ankle dorsiflexion		Ankle dorsiflexion	Tibialis anterior
	Neck flexion		Neck flexion	SCM
LL	Ankle eversion		Ankle eversion	Peroneus
	Neck rotation and flexion		Neck rotation and flexion	SCM
SL(B)		Ankle eversion	Ankle eversion	Peroneus
		Neck extension	Neck extension	Semi-spinalis
SL(F)	Ankle dorsiflexion		Ankle dorsiflexion	Tibialis anterior
	Neck rotation and extension		Neck rotation and extension	Splenius capitis
FL(B)		Shoulder adduction and extension	Shoulder adduction and extension	Latissimus dorsi
		Knee extension	Half squat	Vastus lateralis
FL(F)	Shoulder adduction and flexion		Shoulder adduction and flexion	Pectoralis major
	Hip adduction		Hip adduction	Adductor longus
DFL	Hip adduction		Hip adduction	Adductor magnus
	Neck side bending		Neck side bending	Scalenes

hip joints in an abducted position. Contraction of the muscles of the knee joints, namely the vastus lateralis, was measured while the examiner applied resistance at the angle of maximum contraction. The participant was asked to make a half squat in the supine position. (Table 3) shows the measurement methods used for each myofascial meridian.

4. Electromyography

Telemyo 2400T G2 (USA) was used to obtain EMG images of muscles along myofascial meridians. Surface electrodes (Single Electrodes, Noraxon, USA) were used. The sampling rate was set at 1,000 Hz; and the bandwidth, at 20~350 Hz. The root mean square method was used for EMG signals from each muscle.

For the normalization of EMG data, measurement data were expressed in terms of maximum voluntary isometric contraction (MVCmax) and were compared.

$$\%MVC = \text{Measurement data}/MVCmax$$

5. Statistical analysis

SPSS 22.0 was used to analyze muscle contraction correlations among the muscles along the myofascial meridians using EMG data. The level of statistical significance was set at $p < .05$. Descriptive statistics were used for the general characteristics of the participants. EMG data of terminal muscle contraction in the supine and upright positions were combined, and Pearson correlation coefficients were calculated to analyze muscle contraction correlations.

RESULTS

The muscle contraction correlation results for each myofascial meridian are as follows:

1. Superficial back line

The gastrocnemius, lumbar erector, thoracic erector, and semispinalis were significantly correlated. However, the biceps femoris was not significantly correlated with any of the muscles along the superficial back line (Table 4).

Table 4. Muscle contraction correlation of the superficial back line

	GCM	BF	LE	TE	SS
GCM	1	.041	-.543**	-.463*	-.603**
BF		1	.143	-.040	.027
LE			1	.568**	.828**
TE				1	.756**
SS					1

GCM: Gastrocnemius, BF: Biceps femoris, LE: Lumbar elector, TE: Thoracic elector, SS: Semispinalis
*$p < .05$, **$p < .01$

2. Superficial front line

The tibialis anterior, pectoralis major, and SCM were significantly correlated with all muscles along the superficial front line. The rectus femoris was significantly correlated with the tibialis anterior, pectoralis major, and SCM. The rectus abdomen lower and upper were significantly correlated with all muscles except the rectus femoris (Table 5).

Table 5. Muscle contraction correlation of the superficial front line

	TA	RF	RAL	RAU	PM	SCM
TA	1	.721**	-.377*	-.440*	-.467*	-.813**
RF		1	-.271	-.342	-.451*	-.683**
RAL			1	.844**	.473*	.451*
RAU				1	.526**	.642**
PM					1	.452*
SCM						1

TA: Tibialis anterior, RF: Rectus femoris, RAL: Rectus abdomen lower, RAU: Rectus abdomen upper, PM: Pectoralis major, SCM: Sternocleidomastoid
*$p < .05$, **$p < .01$

3. Lateral line

The peroneus longus was significantly correlated with all the muscles except the external abdominal oblique. The TFL was significantly correlated with all the muscles except the external abdominal oblique. The muscle gluteus medius was significantly correlated with all the muscles except the external abdominal oblique. The external abdominal oblique was not significantly correlated with any muscles along the lateral line. The SCM was significantly correlated with all the muscles except the external abdominal oblique (Table 6).

Table 6. Muscle contraction correlation of the lateral line

	PL	TFL	Gm	EO	SCM
PL	1	.708**	.454*	-.135	-.713**
TFL		1	.421*	-.033	-.585**
Gm			1	-.237	-.399*
EO				1	.157
SCM					1

PL: Peroneus longus, TFL: Tensor fascia lata, Gm: Gluteus medius, EO: External oblique, SCM: Sternocleidomastoid
*$p < .05$, **$p < .01$

4. Spiral line [back]

The peroneus longus, lumbar erector, thoracic erector, and semispinalis were significantly correlated with all the muscles along the spiral back line except the biceps femoris. The biceps femoris was not significantly correlated with any muscles along the spiral back line (Table 7).

Table 7. Muscle contraction correlation of the spiral line (back)

	PL	BF	LE	TE	SS
PL	1	.217	-.603**	-.414*	-.612**
BF		1	-.036	-.132	-.031
LE			1	.736**	.779**
TE				1	.777**
SS					1

PL: Peroneus longus, BF: Biceps femoris, LE: Lumbar elector, TE: Thoracic elector, SS: Semispinalis
*p < .05, **p < .01

5. Spiral line [front]

The tibialis anterior significantly correlated with the TFL, rhomboids, and splenius capitis. The TFL significantly correlated with the tibialis anterior only. The internal abdominal oblique did not significantly correlate with any muscles. The external abdominal oblique significantly correlated with the serratus anterior only. The serratus anterior significantly correlated with the external abdominal oblique, and the rhomboids significantly correlated with the tibialis anterior and splenius capitis. The splenius capitis significantly correlated with the tibialis anterior and rhomboids (Table 8).

6. Functional line [back]

The latissimus dorsi significantly correlated with the thoracic erector and vastus lateralis. The thoracic erector significantly correlated with the vastus lateralis. The lumbar erector and gluteus maximus significantly correlated with each another. The vastus lateralis significantly correlated with the latissimus dorsi and thoracic erector (Table 9).

Table 9. Muscle contraction correlation of the functional line (back)

	(Rt.)LD	(Rt.)TE	(Lt.)LE	(Lt.)GM	(Lt.)VL
(Rt.)LD	1	.621**	-.231	-.062	-.669**
(Rt.)TE		1	.373	.264	-.397*
(Lt.)LE			1	.687**	.127
(Lt.)GM				1	.076
(Lt.)VL					1

LD: Latissimus dorsi, TE: Thoracic elector, LE: Lumbar elector, GM: Gluteus maximus, VL: Vastus lateralis
*p < .05, **p < .01

7. Functional line [front]

The pectoralis major significantly correlated with all the muscles along the functional front line. The rectus abdomen upper significantly correlated with the pectoralis major and rectus abdomen lower. The rectus abdomen lower significantly correlated with all the muscles except the adductor longus. The adductor longus significantly correlated with the pectoralis major only (Table 10).

8. Deep front line

The tibialis posterior significantly correlated with the adductor magnus and scalenes. The adductor magnus significantly correlated with the tibialis posterior and iliopsoas. The iliopsoas significantly correlated with the adductor magnus and scalenes. The scalenes significantly correlated with the tibialis posterior and iliopsoas (Table 11).

Table 8. Muscle contraction correlation of the spiral line (front)

	(Rt.)TA	(Rt.)TFL	(Rt.)IO	(Lt.)EO	(Lt.)SA	(Lt.)RH	(Rt.)SC
(Rt.)TA	1	.465*	-.052	.008	-.174	-.403*	-.801**
(Rt.)TFL		1	.244	-.149	-.229	-.094	-.362
(Rt.)IO			1	.135	.067	-.056	-.055
(Lt.)EO				1	.760**	-.069	.187
(Lt.)SA					1	-.113	.300
(Lt.)RH						1	.428*
(Rt.)SC							1

TA: Tibialis anterior, TFL: Tensor fascia lata, IO: Internal oblique, EO: External oblique, SA: Serratus anterior, RH: Rhomboides, SC: Spenius capitis
*p < .05, **p < .01

Table 10. Muscle contraction correlation of the functional line (back)

	(Rt.)PM	(Rt.)RAU	(Lt.)RAL	(Lt.)AL
(Rt.)PM	1	.521**	.447*	-.452*
(Rt.)RAU		1	.690**	-.191
(Lt.)RAL			1	-.056
(Lt.)AL				1

PM: Pectoralis major, RAU: Rectus abdomen upper, RAL: Rectus abdomen lower, AL: Adductor longus
$^*p < .05$, $^{**}p < .01$

Table 11. Muscle contraction correlation of the deep front line

	TP	AM	IS	SC
TP	1	.654**	.354	-.586**
AM		1	.425*	-.345
IS			1	-.384*
SC				1

TP: Tibialis posterior, AM: Adductor magnus, IS: Iliopsoas, SC: Scalenes
$^*p < .05$, $^{**}p < .01$

DISCUSSION

Myofascial continuity refers to the connections between ligaments, tendons, and muscles, or the connections between myofascial structures, and is based on the study of anatomy. Myers (2009) explained that tension and movements are transferred through myofascial continuity and referred to direct myofascial connections as "fascial connections" and the transfer of tension from tendons or a force while the body is in a specific position or performing a certain function as "mechanical connection".

In this study, positive correlations were observed for the myofascial connections on the superficial back line, superficial front line, and spiral back line, and negative correlations were observed for the mechanical connections on the same myofascial meridians. On the superficial and spiral back lines, the biceps femoris and lumbar erector connect to one another via the sacrotuberosity Ligaments. On the superficial front line, the rectus femoris mechanically connects to the rectus abdomen without any anatomical connections upon the extension of the trunk. On the lateral line, the gluteus medius, external oblique, and SCM functionally connect to one another upon the lateroflexion of the trunk. Positive and negative correlations are observed among the muscles along these myofascial meridians before and after these connection points, respectively.

Myofascial continuity was observed before the spiral front line and functional line during the trunk rotation exercise. The two myofascial meridians that seemed functionally connected to one another were no significantly correlated, as all exercises were performed without tilting the trunk.

Although no correlation was found between all the muscles along the myofascial meridians, some muscles showed strong positive correlations. They were the lumbar erector-thoracic erector-semispinalis on the superficial back line, tibialis anterior-rectus femoris on the superficial front line, and peroneus longus-TFL on the lateral line. This result suggests strong myofascial connections between the corresponding muscles that cause them to contract together. On the other hand, some muscles strongly negatively correlated, and they were the tibialis anterior-SCM on the superficial front line, the peroneus longus-SCM on the lateral line, and the tibialis anterior-splenius capitis on the spiral front line. These muscles appear to contract when muscles on one end of a myofascial meridian contract to increase contraction efficiency.

In this study, the muscles along the myofascial meridians were found to be partially connected in the supine and upright positions. Our results suggest the possibility for changes in muscle contraction depending on the posture and trunk position.

CONCLUSION

In this study involving 7 male university students, muscle contraction correlations among terminal muscles along 8 myofascial meridians that vertically connect the body were analyzed in the supine and upright positions. As a result, positive correlations were observed for the myofascial connections, and negative correlations were observed for the mechanical connections between the muscles along the myofascial meridians. Based on these results, muscles that show significant contract correlations with one another may be expected to be used as an effective clinical marker in muscle strengthening or relaxation therapy, and rehabilitative training. In this study, the intrinsic functional position of the myofascial meridians was not considered; therefore, results regarding the overall correlation of the myofascial meridians may not be precise. These limitations must be accounted for in future studies.

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