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Objective: To provide evidence for the existence of six myofascial meridians proposed by Myers (1997) based on anatomical dissection studies.

Data sources: Relevant articles published between 1900 and December 2014 were searched in MEDLINE (Pubmed), ScienceDirect and Google Scholar.

Study selection: Peer-reviewed human anatomical dissection studies reporting morphological continuity between the muscular constituents of the examined meridians were included. If no study demonstrating a structural connection between two muscles was found, papers on general anatomy of the corresponding body region were targeted.

Data extraction: A continuity between two muscles was only documented if two independent investigators agreed that it was reported clearly. Also, two independent investigators rated methodological quality of included studies by means of a validated assessment tool (QUACS).

Data synthesis: The literature search identified 6589 articles. Of these, 62 papers met the inclusion criteria. The studies reviewed suggest strong evidence for the existence of three myofascial meridians: the superficial back line (all three transitions verified, based on 14 studies), the back functional line (all three transitions verified, 8 studies) and the front functional line (both transitions verified, 6 studies). Moderate to strong evidence is available for parts of the spiral line (five of nine verified transitions, 21 studies) and the lateral line (two of five verified transitions, 10 studies). No evidence exists for the superficial front line (no verified transition, 7 studies).

Conclusions: The present systematic review suggests that most skeletal muscles of the human body are directly linked by connective tissue. Examining the functional relevance of these myofascial chains is the most urgent task of future research. Strain transmission along meridians would both open a new frontier for the understanding of referred pain and provide a rationale for the development of more holistic treatment approaches.

Keywords: continuity, anatomy trains, meridians, fascia

Abbreviations:

QUACS: QUality Appraisal for Cadaveric Studies

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

SBL: superficial back line

SFL: superficial front line

LL: lateral line

SL: spiral line

BFL: back functional line

FFL: front functional line

Treatments of fascial tissues have become increasingly popular in musculoskeletal disorders.[1-5] This might be owing to recent histological findings. The discovery of contractile cells, free nerve endings and mechanoreceptors suggests that fascia in contrast to prior assumptions plays a proprioceptive and mechanically active role.[6-13] Numerous therapists whoaddress fascia orientate themselves to concepts of myofascial chains. Such approaches originate from the assumption that the muscles of the human body do not function as independent units. Instead, they are regarded as part of a tensegrity-like, bodywide network with fascial structures acting as linking components. As fascia can transmit tension[14,15] and in view of its proprioceptive and nociceptive functions, existence of myofascial meridians could be responsive for disorders and pain radiating to remote anatomical structures. Myers[16] defined eleven myofascial meridians connecting distant parts of the body by means of muscles and fascial tissues (Fig. 1). The central rule for the selection of a meridian's components is a direct linear connection between two muscles. For instance, a part of the superficial back line (Tab.1) is suggested to be formed by M. biceps femoris and the erector spinae muscle both being linked by means of the sacrotuberous ligament and the lumbar fascia. Even if the biceps femoris also displayed a structural continuity to the gluteus maximus, this connection would not be considered part of the meridian due to its curved, non-linear course. Though used and referred to in several studies,[17-22] the myofascial meridians are based on anecdotal evidence from practice and have never been verified. Confirming body-wide direct morphological continuity between muscle and fascial tissue would thus yield both an empirical background for such trials and an argument for practitioners to take treatment of complete meridians into consideration. This paper aimed to provide evidence for six of the myofascial meridians based on anatomical dissection studies.

Methods

The present systematic review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[23] Two independent investigators performed a systematic literature research. The targeted myofascial meridians were the superficial back line (SBL), superficial front line (SFL), lateral line (LL), spiral line (SL), back functional line (BFL) and front functional line (FFL; Tab. 1, Fig.1). For each transition of these meridians, peer reviewed anatomical dissection studies (published 1900-2014) reporting myofascial continuity between the involved muscles were searched. Animal studies and case reports were excluded; the same applied to articles in languages other than German and English.

Relevant publications were identified using MEDLINE (Pubmed; searched with MeSH terms), ScienceDirect and Google Scholar. While search algorithms for Pubmed and ScienceDirect were of more general character (algorithms see Tab.2), a free-text search including concrete names of the supposedly connected muscles was performed in Google Scholar. Here, the first 100 hits for each transition of the corresponding meridian were screened. If the initial literature research using the above described procedure with three databases did not yield any results for a specific transition, dissection studies describing the general anatomy of the corresponding body region were targeted and screened for the myofascial connection. Additionally, the reference lists of all detected studies were checked. Data extraction was carried out by two independent investigators and a continuity was only documented if both agreed that it was reported clearly.

The methodological quality of the enclosed studies was evaluated by means of the QUACS scale (QUality Appraisal for Cadaveric Studies) whose reliability and validity have been demonstrated recently.[24] The scale encompasses a checklist of 13 dichotomous items, each scored with either zero (no/not stated) or one (yes/clearly present) point. The quality score is calculated in percent. Zero to 20 percent indicate poor, 21 to 40 percent fair, 41 to 60 percent moderate, 61-80 percent substantial, and 81 to 100 percent excellent methodological quality. Ratings were done by two independent researchers. In case of disagreement, a third reviewer casted the decisive vote. For each meridians respectively its transitions, evidence was classified as strong (consistent findings among multiple high quality studies), moderate (consistent findings among multiple low quality studies and/or one high quality study), limited (one low quality study), conflicting (inconsistent findings among multiple studies), or not existent (no studies available) according to the recommendations of the Cochrane Collaboration Back Review Group.[25]

Results

The initial literature research yielded 6584 publications. After removing duplicates and papers not pertaining to the research question exclusion criteria were applied. The resulting sample comprised 62 studies (see Fig. 2). The findings for each meridian including detailed information about characteristics of the appendant transitions are displayed in Tab.3, methodological quality of the included studies is shown in Tab.4.

Strong evidence exists for all transitions of the SBL (based on 14 studies), BFL (8 studies) and FFL (6 studies). With regard to the SL (moderate evidence for five of nine transitions, 21 studies) and the LL (moderate to strong evidence for two of five transitions, 10 studies) findings were ambivalent. No evidence from anatomical dissection studies is available for the SFL (no verified transition, 7 studies).

Discussion

The present systematic review provides relevant information for movement therapists and strength and conditioning coaches. It demonstrates that fascia, besides recently discovered features such as pain perception and stiffness regulation connects the skeletal muscles forming a body-wide web of myofascial chains. Extensive structural continuity was clearly verified for three of the six examined meridians (SBL, BFL, FFL). In addition, findings were at least ambivalent with respect to the LL and SL. The fact that we could only confirm half of both lines' transitions does not neglect their existence. Most of the reviewed studies did not specifically search for continuities mentioning them only as a subordinate finding. Since clinicians and anatomists show increasing interest in fascia, it is well possible that future, more focused research will verify the remaining myofascial links.[88] In contrast to the solid evidence for these five meridians, doubts have to be raised about the existence of the SFL. There is no structural connection between the rectus femoris muscle and M. rectus abdominis. Also, M. sternalis, which is suggested to be the cranial continuation of rectus abdominis, exists only in a small percentage of the population.[41-44] Even if present, it does not fuse consistently with the rectus abdominis.[41]

The practical relevance of the present research is twofold. First, the existence of myofascial meridians might help to explain the phenomenon of referred pain which often occurs in nonspecific disorders. For example, myofascial trigger points of the calf have been shown to elicit pain that radiates to the sole of the foot and to the dorsal thigh.[89] As this projection pattern corresponds to the course of the SBL, it might represent the morphological substrate. A second aspect relates to therapy and training of the musculoskeletal system. Direct morphological continuity between adjacent muscles provides the empirical background to extend diagnostic and therapeutic focus beyond one single anatomical structure. Treatment according to myofascial meridians could be effective in reducing low back pain. Several studies have shown that low back pain patients display reduced hamstring flexibility.[90-93] Due to the direct morphological relationship of the hamstrings and the low back region (both are part of the SBL), relieving tension of the posterior thigh muscles could be a conceivable approach to alleviate pain. Overload injuries in competitive sports represent another entity of pathologies which possibly occur due to the presence of myofascial meridians. Recent studies indicate that tightness of the gastrocnemius and the hamstrings are associated with plantar fasciitis.[94-96] As both muscles and the plantar aponeurosis belong to the SBL, they might represent a target of exercise therapy. Finally, groin pain or athletic pubalgia is suggested to be provoked by a tight adductor longus and a weak rectus abdominis[97,98] which according to our results are directly connected in the FFL. The tightening of the adductor may thus develop due to communication with the rectus via the described linkage.

Study Limitations

Although our review yields solid evidence for the existence of myofascial chains, several aspects call for further study. Future research should be dedicated to the presence of the meridians which could not be evidenced entirely in this work. Another issue relates to the function of regional specializations which so far remains unclear. Depending on its localization, fascia in general exhibits substantial differences concerning thickness, amount of elastic fibers,[11] and adherence to the underlying muscle.[8] Also, the number of connecting fibers is not uniform and shows considerable variation for different transistions.[27] This holds particular significance as the structures linking the muscular stations of the meridians encompass tendinous, aponeurotic and ligamentous tissue as well as the deep fascia. Finally, it is of utmost importance to elucidate the functional significance of the myofascial chains as the capability for strain transfer represents the decisive criterion to justify treatment of meridians. Though the available evidence points towards existence of tensile transmission via myofascial pathways, most experimental research was carried out in vitro using cadavers.[14,15,36] Randomized, controlled in-vivo studies are warranted in order to draw more precise assumptions on the significance of myofasical chains for the movement system.

Conclusions

Although the concept of myofascial meridians is widely used in exercise therapy and osteopathic medicine, the scientific basis for the proposed connections is still a matter of debate. The present review provides first systematical evidence based on cadaveric dissection studies. While there is strong evidence for the existence of the SBL, BFL and FFL, it is ambivalent with regard to the SL and LL respectively poor for the SFL. Within its borders, the system of myofascial meridians represents a promising approach to transfer tensegrity principles into practice. Therapists may use the myofascial chains as a conclusive orientation but should be aware that the functional implications remain to be studied.

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Figure captions

Fig.1. The six examined myofascial meridians (from left to right: SL, LL, FFL, BFL, SBL, SFL/ illustration modified based on Myers, 2014).

Fig.2. Flow chart displaying the literature research.

Table captions

Tab.1. Soft tissue components of the included myofascial meridians (modified based on Myers, 2014)

Tab.2. Databases und algorithms for the literature research

Tab.3 Included studies and morphological details for the examined transitions (N= number of studies reporting continuity, n=cumulative number of subjects, N/GA=number of studies on general anatomy, C=finding observed in % of subjects/cumulative calculation in studies stating consistency)

Tab.4 Numbers and quality of included studies reporting myofascial continuity between the constituents of the meridians. Studies on general anatomy are depicted in brackets.

Myofascial Meridian	**Soft tissue components**
Superficial back line	• plantar fascia • achilles tendon/ m. gastrocnemius • Hamstrings (m. biceps femoris, m. semitendinosus, m. semimembranosus) • sacrotuberous ligament • lumbar fascia/erector spinae
Superficial front line	• toe extensors, m. tibialis anterior, anterior crural department • subpatellar tendon • m. rectus femoris/quadriceps • m. rectus abdominis • m. sternalis/sternochondral fascia • m. sternocleidomastoideus
Back functional line	• m.vastus lateralis • m. gluteus maximus • lumbar fascia • m. latissimus dorsi
Front functional line	• m. adductor longus • m. rectus abdominis • m. pectoralis major
Spiral line	• lumbar/erector spinae • sacrotuberous ligament • m. biceps femoris • m. peronaeus longus • m. tibialis anterior • m. tensor fasciae latae, iliotibial tract • m. obliquus abdominis internus • m. obliquus abdominis externus • m. serratus anterior • m. rhomboideus major and minor • m. splenius capitis and cervicis
Lateral line	• m. peroneus longus & brevis, lateral crural compartment • lliotibial tract/glutaeus medius • m. tensor fasciae latae • m. gluteus maximus • m. obliquus abdominis externus & internus • m. intercostalis externus & internus • m. plenius capitis/m. sternocleidomastoid

Database	Search algorithm
Pubmed	(("cadaver"[Mesh]) AND ("anatomy"[Mesh])) AND ("Fascia"[Mesh]) OR ((myofascial OR aponeurotic OR fascial) AND (continuity OR decussation OR interdigitation OR expansion OR extension))
Science Direct	cadaver AND (fascia OR myofascial OR aponeurotic OR fascial) AND (continuity OR decussation OR interdigitation OR expansion OR extension)
Google Scholar	(dissection) AND ("obliquus internus" AND "obliquus externus") AND (continuity OR expansion OR extension OR fuses OR merges OR blends)

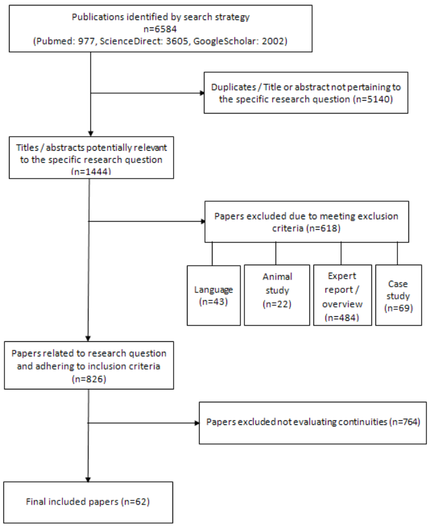
	Transition	N (n)	C	NA (n)	Description
Superficial back line	Plantar fascia – gastrocnemius	4 (72)	25/72	-	While Kamel and Sakla[26] and Stecco et al.[9] report continuity in all examined cases, state Snow et al.[27] and Kim et al.[28] that the link diminishes with increasing age.
	Gastrocnemius – Hamstrings	5 (57)	51/52	-	Four studies[29-32] report the semitendinosus to be linked to gastrocnemius, whereas one[33] found a link between semimembranosus and gastrocnemius
	Hamstrings – lumbar fascia/ erector spinae	5 (73)	BF:50 /63	-	Martin et al.[34] report fusion of all Hamstrings and erector spinae via sacrotuberous ligament (SL). Sato et al.,[35] van Wingerden et al.,[36] and Woodley et al.[37] state that biceps femoris blends with the SL in all cases, Vleeming et al.[38] report continuity for 50 %.
Superficial front line	Toe extensors/tibialis anterior – rectus femoris	-	-	2 (27)	No studies confirming continuity were found. Two studies[39,40] on general anatomy did not yield indications for a morphological link.
	Rectus femoris – rectus abdominis	-	-	-	This transition is only mechanical, thus no literature research was performed for this transition.
	Rectus abdominis – sternalis	-	-	5 (496)	No studies confirming continuity were found. Five studies[41-45] on general anatomy did not yield indications for a morphological link.
	Sternalis – sternocleidomastoideus	-	-	5 (496)	No studies confirming continuity were found. Five studies[41-45] on general anatomy did not yield indications for a morphological link.
Back functional line	Latissimus – Lumbar fascia	3 (60)	40/40	-	All three studies[46-48] reported the latissimus to fuse with the lumbar fascia at the superficial lamina of the posterior layer.
	Lumbar fascia – Gluteus maximus	5 (68)	58/58	-	Similar to the latissimus, all studies[47-51] reported the gluteus maximus to fuse with the lumbar fascia at the superficial lamina of the posterior layer.

	Gluteus maximus – vastus lateralis	2 (46)	42/46	-	While Stern[52] states continuity in all examined cases, Stecco et al.[49] observed a fusion of both structures in two of six specimen.
Front functional line	Pectoralis major – rectus abdominis	3 (51)	51/51	-	Three studies[53-55] observed fusion of the pectoralis major fascia and the contralateral rectus abdominis in each specimen.
	Rectus abdominis – adductor longus	3 (37)	37/37	-	According to three studies[15,56,57] a clear continuity of adductor longus to the contralateral rectus sheath was visible in all examined cases.
Spiral line	Splenius capitis – rhomboideus minor	-	-	2 (19)	Though no study reporting direct continuity was found, Johnson et al.[58] indicate a decussation of fibers, Mercer and Bogduk[59] report collinear orientation of fibers suggesting a possible fusion of both muscles
	Rhomboids – serratus anterior	3 (69)	4/4	-	The fusion of rhomboideus major and serratus anterior is stated in three studies.[60-62] A morphological connection of rhomboideus minor is reported only by two papers.[61.63]
	Serratus anterior – external abdominal oblique	3 (68)	40/40	-	The authors of three studies[62,64,65] describe intersections or interdigitations of both muscles at the lateral arch of the 5th to the 10th rib.
	External – internal abdominal oblique	5 (417)	245/245	-	According to five studies,[66-70] the external abdominal oblique sends aponeurotic extensions to the contralateral internal oblique.
	Internal abdominal oblique – tensor fasciae latae	-	-	2 (40)	No studies confirming continuity were found. Also, studies on general anatomy did not yield any indications for a morphological link.[71,72]
	tensor fasciae latae – tibialis anterior	-	-	3 (90)	No studies confirming continuity were found. Also, studies on general anatomy did not yield any indications for a morphological link.[73-75]
	Tibialis anterior – peroneus longus	-	-	3 (132)	No studies confirming continuity were found. Also, studies on general anatomy[76-78] did not yield any indications for a morphological link.

	Peroneus longus – biceps femoris	3 (44)	23/23	-	El Gharbawy[79,80] in two studies observed biceps femoris to send aponeurotic fibers to the lateral surface of peroneus longus, Marshall et al.[81] describe the middle expansion of the biceps femoris blending with peroneus fascia
	Biceps femoris – erector spinae	5 (73)	50/63	-	As stated for the superficial backline, evidence is conflicting. While Sato et al.[35] report continuity in all cases, Vleeming et al.[38] found both structures to fuse only in half of examined specimen.
Lateral line	Peroneals – iliotibial tract	-	-	2 (47)	No studies confirming continuity were found. Also, studies on general anatomy did not indicate a morphological link though Vieira et al.[73] state that the iliotibial tract extends to the crural fascia
	Iliotibial tract – gluteus maximus/tensor fasciae latae	5 (61)	-		Five studies[8,49,50,82,83] found a consistent connection of gluteus maximus respectively the tensor fascia latae to the iliotibial tract.
	Gluteus maximus/Tensor fasciae latae – abdominal obliques	1 (29)	-		One study[84] reported the external oblique to fuse with fascia lata whose caudal continuation is tensor fasciae latae.[85] No study stated a link of gluteus maximus to the lateral abdominals.
	Abdominal obliques – intercostals	-	-	2 (80)	No studies confirming continuity were found. Two studies[86,87] on general anatomy did not yield indications for a morphological link.
	Intercostals – splenius capitis/sternocleidomastoideus	-	-	2 (80)	No studies confirming continuity were found. Two studies[86,87] on general anatomy did not yield indications for a morphological link.

	Total	Excellent	Substantial	Moderate	Fair	Poor
Superficial back line	14	1	4	7	2	-
Superficial front line	0 (7)	-	(7)	-	-	-
Back functional line	8	1	3	4	-	-
Front functional line	7	3	3	-	1	-
Spiral line	13 (8)	-	2 (3)	10 (5)	1	-
Lateral line	6 (4)	-	6	1 (3)	-	(1)

1


Publications identified by search strategy
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(Pubmed: 977, ScienceDirect: 3605, GoogleScholar: 2002)
Duplicates / Title or abstract not pertaining to the specific research question (n=5140)
Titles / abstracts potentially relevant to the specific research question (n=1444)
Papers excluded due to meeting exclusion criteria (n=618)
Language (n=43)
Animal study (n=22)
Expert report / overview (n=484)
Case study (n=69)
Papers related to research question and adhering to inclusion criteria (n=826)
Papers excluded not evaluating continuities (n=764)
Final included papers (n=62)