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Role of Fascial Connectivity in Musculoskeletal Dysfunctions: A Narrative Review

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Abstract:

Introduction: Musculoskeletal dysfunctions happen to be the most common reason for referral to physiotherapy and manual therapy services. Therapists may use several articular and/or soft tissue concepts/approaches to evaluate and treat such dysfunctions that may include integration of myofascial system. Despite the research in this area spanning more than three decades, the role played by fascia has not received its duly deserved attention, owing to the lack of definitive research evidence. The concept of 'fascial connectivity' evolved two decades ago from a simple anatomical hypothesis called 'myofascial meridians'. Since then it has been widely researched, as conceptually it makes more sense for functional movements than 'single-muscle' theory. Researchers have been exploring its existence and role in musculoskeletal dysfunctions and clinicians continue to practice based on anecdotal evidence. This narrative review attempts to gather available evidence, in order to support and facilitate further research that can enhance evidence based practice in this field. **Methods:** A search of most major databases was conducted with relevant keywords that yielded 272 articles as of December 2019. Thirty five articles were included for final review with level of evidence ranging from 3b to 2a (as per Center of Evidence Based Medicine's scoring). **Results:** Findings from cadaveric, animal and human studies supports the claim of fascial connectivity to neighboring structures in the course of specific muscle-fascia chains that may have significant clinical implications. Current research (level 2) supports the existence of certain myofascial connections and their potential role in the manifestation of musculoskeletal dysfunctions and their treatment. **Conclusion:** Although these reviews and trials yield positive evidence for the objective reality/existence of fascial connectivity and continuity, several aspects need further exploration and in-depth analysis, which could not be evidenced entirely in this review. Manual and physical therapists may utilize the concept of fascial connectivity as a convincing justification to deal with clinical problems, but need to remain vigilant that functional implications are still being investigated.

Keywords: Fascia; fascial connectivity, myofascial meridians; myofascial chains

Introduction

Musculoskeletal pain and dysfunction are among the main reasons behind visits to physicians and manual therapists; it is also the most frequent cause of long-term chronic pain affecting countless individuals around the world (Woolf & Pfleger 2003). Without appropriate management, chronic pain may impact several aspects of an individual's health, including physical, psychological, and social well-being, while also creating a tremendous economic and workplace burden. As the prevalence of musculoskeletal pain is expected to increase with a sedentary population having longevity (Woolf & Pfleger 2003), it calls for more preponderant effort in the development and evaluation of incipient ways of managing these patients.

Manual therapists, use several different schools of thought in dealing with their patients. Some therapists use articular techniques such as that of Maitland's while others use soft tissue techniques such as muscle energy techniques, myofascial release or myofascial manipulation etc. to name but a few. Several researchers find the role of the fascia of interest and utmost significance in musculoskeletal disorders, owing to its potential to influence muscular activity. Research from the past decade has been able to point towards the part played by fascia in numerous musculoskeletal dysfunctions as the skeletal muscles throughout the body are indirectly linked to each other by fascial tissue forming a network with some specific patterns (Luomala, & Pihlman, 2016; Myers T.W. 2009; Wilke et al., 2016a). These conceptual patterns were later named 'myofascial meridians', as a means to better understand the mapping of the fascial system (Myers T.W. (2009).

Traditionally, researchers studied human movement through a reductionist lens which disintegrates and examines the movements in isolation. The reductionism approach does not identify the complexities intertwined and the diverse dynamics found within complex systems such as human movement. According to Dischiavi et al (2018), human movement may be better understood through holism. This concept can guide someone who is attempting to understand the fascia and its intricate system, in order to appreciate its complexity within an apparently simple design. Fascia can be simply defined as a network of fibrous tissue pervading the entire body, which surrounds, supports, suspends, protects, connects and divides muscular, skeletal and visceral components of an organism (Kumka& Bonar 2012). Apart from lubricating the fibers it also gives nourishment to the whole body (Still 1910). It is said to manage the balance between tension and compression around the organs, joints and muscles, and hence considered as a "tensegrity" or tensional integrity structure (Chen et al., 2016). Depending on its location fascia in general displays marked differences concerning thickness, amount of elastic fibers (Stecco et al., 2009) and adherence and expansions to the surrounding soft tissues including muscles (Stecco et al., 2009). Additionally, the amount of associating fibers is not constant and shows extensive dissimilarity for different transitions (Snow et al., 1995; Stecco et al., 2013)). This holds specific essentialness as the structures connecting the muscular parts of the meridians envelop tendinous, aponeurotic and ligamentous tissue as well as the deep fascia.

It is a known fact that fascia is capable of modifying its tensional situation in response to the stress applied to it (Bordoni, & Simonelli, 2018. Wilke et al., 2017b;) and it is believed that the strain transmission might occur along certain specific pathways as a response to changing muscle activity (Norton-Old et al. 2013; Krause et al., 2016). Through 'mechanotransduction' (conversion of physical forces into intracellular biochemical responses), these forces may be transmitted at a cellular level, altering gene expression of fibroblasts and thereby changing the extracellular matrix composition (Chaitow 2016; Bordoni et al., 2019). Inflammatory mediators may also be secreted by repeated mechanical straining of fibroblasts (Dodd et al., 2006). All of these changes could influence the regular day-to-day functions of force transmission or sliding required for the musculoskeletal system. Such dysfunction could lead to pain or proprioceptive issues, considering the fact that fascia has been shown to be innervated (Tesarz et al., 2011; Schilder et al., 2018).

There are several theories explaining pathophysiological and pathomechanical processes that follow after myofascial tissue trauma or overuse, extending from cellular (viscoelasticity, piezoelectricity, tensegrity etc.) to global level (force transmission, sliding, fluid dynamics, hysteresis, innervation, sensitization etc.); however, a discussion on this is beyond the scope of this review. The ultimate result of the altered myofascial tissue is restricted fascia, resulting in altered lines of force with muscle contraction (Stecco et al., 2013; Meltzer et al., 2010). Muscles of the body don't operate as independent units; instead, they are considered as a part of a tensegrity-like myofascial network that spans throughout the body, with fascia being the linking component (Wilke et al., 2016b). As time goes by, these biomechanical changes could lead to reduced strength, incoordination, (Ercole et al., 2010; Stecco et al., 2013), pain or proprioceptive dysfunction (Tesarz et al., 2011). Thus, it may be argued that the treatment of disorders affecting the musculoskeletal system may need to be focused on this fascial network (Kwong, & Findley 2014). The recent increase in research carried out in this field has made treatment targeting the fascia to be increasingly popular in the management of musculoskeletal disorders (Ajimsha 2018).

Although this concept has strong physiologic and histologic support to justify its use by clinicians, it lacks research based evidence for clinical practice. Therefore, this narrative review will outline the historical development of the fascial connectivity concept, and gather evidence regarding its role in musculoskeletal dysfunctions. The main objective of the review was to investigate how several researchers studied this concept to identify/justify the fascial connectivity, its functioning and clinical effectiveness, all of which can form the basis for future research and clinical practice.

For a better understanding of the basis of this concept of connectivity (eg:- myofascial meridians), one needs to know the circumstances that led to its synthesis. The following section gives this information in brief before we proceed to explain the methodology and key findings of this review.

The Myofascial Meridian Concept

'Myofascial meridian' was a term coined in 1997 by Tom Myers, a prominent anatomist and body-worker. He developed it as a means of expressing to his students the role of the fascial system as it relates to human structure and function. According to this concept, fascia can be viewed as being organized in the body in specific patterns/lines of pull or series of myofascial tissue that disperse strain, facilitate movement, and provide stability throughout the structures of the body (Tozzi 2015). This theory aided practitioners to explore how two or more distant or remote structures in the body influence one another.

In his early years, Tom inspired by his mentor Ida Rolf, developed a game 'anatomy trains' in 1990 to teach his students fascial anatomy at Rolfing institute. The basic idea was to string the muscles together through the fascia, contrary to the then belief of 'single-muscle theory'. Single-muscle theory failed to reason how functional human movement can be performed by a single muscle and provide a holistic perspective. For example, it is highly unlikely that a biceps brachii muscle can perform its function in the most efficient manner in the absence of its antagonists, fixators and synergists. Therefore, this theory failed to answer several important questions relating to functional movement patterns.

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With several years of work in this field, these strings or lines became more apparent to Myers who then started applying this concept on his clients. This later became known as 'myofascial meridians' or 'myofascial chains'. Based on decades of work, research, and practical application on clients, Myers identified 12 specific meridians throughout the body namely,

- Superficial Back Line (SBL)
- Superficial Front Line (SFL)
- Lateral Line (LL)
- Spiral Line (SL)
- Superficial Front Arm Line (SFAL)
- Deep Back Arm Line (DBAL)
- Deep Front Arm Line (DFAL)
- Superficial Back Arm Line (SBAL)
- Back Functional Line (BFL)
- Front Functional Line (FFL)
- Ipsilateral Functional Line (IFL)
- Deep Front Line (DFL)

This review will explore studies that have researched the existence of all or some of this connectivity, appraise the literature, and verify whether they indeed hold true in the causation and/or treatment of musculoskeletal disorders/dysfunctions.

Methods

A search was conducted in MEDLINE, CINAHL, Academic Search Premier (ASP), Cochrane library, and PEDro databases with keywords *'fascial connectivity'* and 'myo*fascial meridians or chains'* for the period till December 2019. Research published in the English language alone was identified, relevant articles were selected after reviewing the abstract, and saved as full text for further review. No grey literature was included. They were then rated with Centre for Evidence-Based Medicine's (CEBM) level of evidence scale and PEDro scale (for experimental studies) to brief their hierarchy of evidence and methodological quality. Two experienced reviewers completed the review process. Any review and rating discrepancies were solved through verbal discussion and a supplementary review by a third reviewer.

Results

Of the 272 studies identified in the original search, thirty-five articles were included for the final review (Figure 1). The key characteristics and findings of the included studies are provided in Table 1.

Figure 1: Study flow diagram

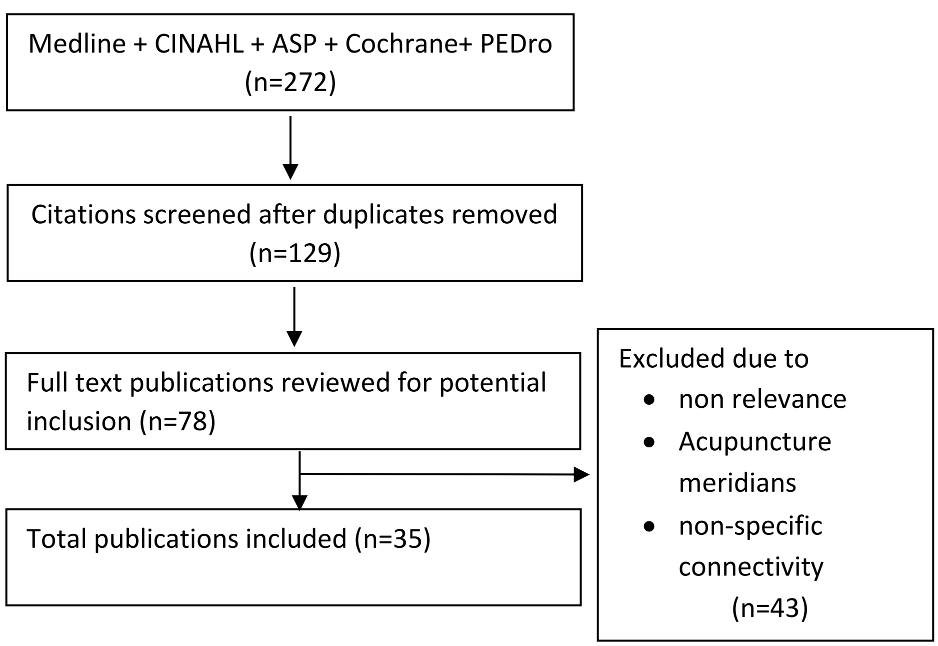

Table 1: key characteristics and findings of the included studies

Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
1	2019	Williams, W and Selkow, N.M	Remote effect of self- MFR	SBL	Asymptomatic college students	self-myofascial release (SMR) of the plantar surface of the foot in addition to the hamstring	hamstring foam rolling, lacrosse ball on the plantar surface of the foot, and a combination of both	sit-and-reach test - hamstring flexibility	Yes
2	2019	Wilke, J. and Krause, F.	review the available literature considering the existence of myofascial chains in the shoulder-arm region	Ventral, Dorsal and Lateral arm chain	anatomical cadaver studies (publication between 1900 and 2019) that reported morphological in-series tissue continuity between muscles of the upper limb and shoulder	Systematic review	systematic review	QUACS scale for quality rating	Yes
3	2019	Wilke et al.	examine the age dependency of nonlocal exercise effects following plantar fascia SMR	SBL	Healthy subjects	plantar foot SMR, performed in standing position	different age groups	sit and reach test - hamstring flexibility	Yes
4	2019	Wang, J	the effects of forearm plank exercise on tone and stiffness in the superficial back line muscle	SBL	Healthy subjects	sling forearm plank exercises and mat forearm plank exercises	two forms of forearm plank exercises	muscle tone and stiffness - upper lumbar muscles, lower lumbar muscles, long head of biceps femoris, and medial part of gastrocnemius	probably
5	2019	Sulowska et al.	evaluate the influence of plantar short foot muscles exercises on the performance of lower extremities	SBL	long-distance runners	plantar short foot muscles exercises	Group 1 with neutral foot and Group 2 with slight and increased pronation based on Foot Posture Index	The knee flexors and extensors torque, work, and power on Isokinetic Dynamometer and Running-Based Anaerobic Sprint Test	probably
6	2019	Song et al.	effects of the myofascial meridians release technique on pain and postural control	SBL	college students with forward head posture		the intervention effects of the Grastone massage and the Rollfing massage	numerical rating scale of pain, distance of forward head displacement and neck disability index.	Yes

Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
7	2019	(Wilhite C et al.) Paloncy et al.	whether the same increase in hamstring mobility within the superficial backline function that is achieved with a clinician-administered suboccipital trigger point release can also be obtained through a patient/self-administered method	SBL	Asymptomatic adults	suboccipital trigger point release	Clinician administered versus patient/self-administered	hamstring mobility - slide ruler box sit-and-reach-test	Yes
8	2019	Fousekis et al.	investigate the effects of Ergon® IASTM applications on the upper or lower part of the SBL on the hamstring's flexibility	SBL	Aymptomatic university students with reduced trunk-hamstring flexibility	Ergon® IASTM Technique applications in the posterior trunk and thigh	3 groups - Upper SBL, Lower SBL and Control	hamstring flexibility - Sit-and-reach test	Yes
9	2019	Devereux et al.	the effects of treating latent myofascial trigger points (MTrPs) in the lower limb kinetic chain with respect to performance during sporting actions	Anterior and Posterior muscle chains	Male athletes with MTrPs	Dry Needling	4 groups - Rectus femoris only; medial Gastrocnemius only; both muscles; control group	squat jumps at 5 incremental loads and were recorded using the My Jump app (iOS) for jump height, power output, optimal force, and optimal velocity	May be
10	2019	Danyschuk, A.	to study the biomechanical properties of myo-fascial kinematic chain of the foot-tibia	Lateral and posterior chain of foot-tibia	children 7-14 years with unfixed and clinically pronounced flat feet	Observational study	2 groups - flat feet and functional disorders of foot	EMG of lateral (long tibia) and dorsal (posterior tibia) of the myo-fascial kinematic chains of the right and left tibia; Video-computer analysis was performed with the help of the system for determining the functional state of the locomotor system;	May be

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Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
11	2019	Chakhuttray et al.	to test immediate effect of the rubber hammer on fl exibility on thesuperfi cial back line	SBL	Healthy subjects	applying rubber hammer on subjects in prone	2 groups - Expeerimental (rubber hammer) and control	Sit and reach test, straight leg raising (SLR) test, and Modifi ed Schober 'stest were performed to detect change of body fl exibility	Yes
12	2019	Burk et al.	To determine if remote myofascial techniques can effectively increase the range of motion at a distant body segment	SBL	RCTs on human subjects	MFR or static stretching to Caudal / Cephalad muscles of SBL	remote interventions to local treatment or sham or inactive controls	Multiple measures including Cervical spine ROM and Sit-and-reach distance; PEDro scale for study quality	Yes
13	2019	Borg et al.	whether myofascial treatment, using a device generating deep pulsating vibrations, can provide increased ROM and well-being of patients with frozen shoulder (FS)	-	Subjects with primary FS	soft and deep massage treatment usung devices providing mechanical vibrations at a variable frequency between 400 to 1200 pulsations per minute in a sine wave	none	Shoulder ROM and Quality of sleep	probably
14	2018	Vulfsons et al.	To examine muscle activations along the superficial back line in LBP patients	SBL	Chronic Low back pain	muscle activation during conditions 1-3: passive movement, active movement and active movement against maximum isometric resistance of the right gastrocnemius muscle; and conditions 4-5 neck extension without and with isometric resistance from the prone position	Chronic low baack pain versus healthy controls	sEMG measurement of muscle activation of gastrocnemius, hamstrings, erector spine, and upper trapezius	Yes
15	2018	Tijs et al	to assess whether myofascial loads exerted by neighboring muscles result in length changes of Soleus (SO) muscle fascicles	SBL	animal study	the effects of proximal muscle-tendon unnit length changes of two-joint gastrocnemius (GA) and plantaris (PL) muscles on the fascicle length of the one-joint SO muscle	measurement in 2 conditions: within (1) an intact muscle compartment and (2) a disrupted compartment	sonomicrometry	Yes

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Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
16	2018	Raţă et al.	track the effects of stretching on the electromyographic activity of muscle chains	Anterior and Posterior muscle chains	Subject with Haglund's disease	static stretching positions	Single case study	visual examination and surface electromyography (maximum volumetric isometric contraction)	Yes
17	2018	Marizeiro et al.	immediate effects of diaphragmatic myofascial release	Posterior chain muscle	sedentary women	diaphragmatic myofascial release techniques	Experimental group and Control (placebo) group	chest wall mobility using cirtometry; flexibility, lumbar spine range of motion, and respiratory muscle strength	Yes
18	2018	Joshi et al.	effect of Static Stretching (SS) of hamstrings with remote Myofascial Release (MFR) and a combination on hamstring flexibility.	SBL	asymptomatic adults	Static Stretching (SS) of hamstrings with remote Myofascial Release (MFR) (bilateral plantar fascia and suboccipital region) and a combination of SS and remote MFR on hamstring flexibility.	3 groups - SS, MFR and Combination; therapist administered versus patient administered	Knee Extension Angle, and Sit and Reach Test	Yes
19	2018	Do et al.	investigate the immediate effect of applying self-myofascial release (SMR) to the plantar fascia using a foam roller on hamstring and lumbar spine flexibility	SBL	Healthy subjects	the SMR group rolled the surface of the foot from the heel to the metatarsal head using a foam roller for 5 minutes. The sham group received passive mobilization of the ankle joint in the supine position	2 groups - SMR and sham group	Toe Touch test, and passive straight leg raise (PSLR) test	Yes
20	2017	Wilke et al.	whether remote exercise is as effective as local stretching	Posterior chain muscle	Healthy subjects	Stretching of Lower limb and cervical spine	3 groups: remote stretching of the lower limb (LLS), local stretching of the cervical spine (CSS) or inactive control (CON)	maximal cervical ROM	Yes

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Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
21	2017	Eid et al.	study the acute effects of Ergon® IASTM Therapy (EIT)3 application on the upper part and lower of the SBL on hamstrings flexibility.	SBL	Healthy subjects	myofascial EIT treatment of the upper part and lower part of the SBL	three groups:myofascial EIT treatment of the upper part of SBL; lower part of the SBL; or served as control group	a) the Sit and Reach (SR) test, b) the passive straight leg raise (SLR) test and c) the Fingertip-to-Floor (FTF) Test	yes
22	2016	Wilke et al.	potential remote effects of lower limb stretching on cervical range of motion	SBL	Healthy subjects	static stretching for the gastrocnemius and the hamstrings	2 groups: Static stretching versus inactive controls	maximal cervical ROM in flexion/extension	Yes
23	2016	Wilke et al.	the impact of lower limb exercises on musculo-mechanical properties of the neighboring lumbar erector spinae and hypothesizes that strain can be transmitted from the lower extremity to the trunk.	SBL	Healthy subjects	(1) stretching of the gastrocnemius and the hamstrings, (2) activation exercises of the gastrocnemius and the hamstrings at 20% of the individual maximum strength (3) inactive, seated control condition	3 groups: (1) stretching (2) activation exercises (3) inactive, seated control condition	myotonometry	probably
24	2016	Wilke et al.	To provide evidence for the existence of 6 myofascial meridians proposed by Myers based on anatomic dissection studies	the superficial back line, the back functional line, front functional line, the spiral line, the lateral line, and the superficial front line	Systematic review: Peer-reviewed human anatomic dissection studies reporting morphologic continuity between the muscular constituents of the examined meridians	systematic review	systematic review	systematic review	Yes; for all except SFL
25	2016	Krause et al.	to provide a systematic overview on tensile transmission along myofascial chains	SBL, BFL, FFL	based on anatomical dissection studies and in-vivo experiments	systematic review	systematic review	systematic review	Yes

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Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
26	2015	Grieve, R.	to investigate the immediate effect of a single application of SMR on the plantar aspect of the feet, on hamstring and lumbar spine flexibility	Posterior chain muscle	Healthy subjects	Self-myofascial release (SMR) of the plantar surface of the foot	2 groups: Self myofascial release and control	sit-and-reach test	Yes
27	2014	Weisman et al.	To map the association of muscle activations along the superficial back line (SBL) using separate conditions of active range of motion with and without resistance and passive range of motion	SBL	Healthy subjects	passive movement, active movement and active movement against maximum isometric resistance (IR) of the right gastrocnemius; and neck extension without and with isometric resistance from prone position.	underwent five test conditions. Conditions 1–3 involved passive movement, active movement and active movement against maximum isometric resistance (IR) of the right gastrocnemius and conditions 4 and 5 involved neck extension without and with isometric resistance from prone position.	surface electromyography	Yes
28	2013	Hyong et al.	to examine the immediate effects of passive hamstring stretching exercises on cervical spine range of motion and balance	Posterior chain muscle	Healthy subjects	The experimental group were administered hamstring stretching with ankle dorsiflexion for 30 seconds three times, whereas the control group received the same treatment without ankle dorsiflexion	2 groups: experimental and control	cervical range of motion goniometer, and balance using TETRAX Portable Multiple System	Yes
29	2013	Bolívar et al.	to determine whether tightness of the posterior muscles of the lower extremity was associated with plantar fasciitis.	Posterior chain muscle	Subjects with plantar fascitis	Observational study	2 groups: experimental and control	Tightness of Hamstring and calf muscles were evaluated through the straight leg elevation test, popliteal angle test, and ankle dorsiflexion	Yes
30	2011	Labovitz et al.	to determine if hamstring tightness was an increased risk in plantar fasciitis	Posterior chain muscle	Subjects with plantar fascitis	Observational study	2 groups: experimental and control	Body mass index (BMI), the presence of plantar fasciitis, equinus, and calcaneal spurs were assessed. The popliteal angle was measured.	Yes

Sl.No.	Year	Author(s)	Objective	Myofascial chain tested / Identified	Population	Intervention	Comparison	Outcome measure	Does the result support existence of Myofascial connectivity?
31	2010	Bezuidenhout, J.	to determine the effect of chiropractic spinal manipulative therapy compared to that of fascial treatment on SBL fascial line restrictions	SBL	asymptomatic subjects	Chiropractic SMT and Direct MFR technique	2 groups: Chiropractic SMT and Direct MFR technique to the restricted SBL	Bunkie test and ROM test to determine level of endurance and fascial line restrictions respectively	Yes
32	2001	Halbertsma et al.	To investigate the extensibility and stiffness of the hamstrings in patients with nonspecific low back pain (LBP)	Posterior chain muscle	LBP subjects	Straight leg raising, pulling force, and activity of hamstring and back muscles were recorded	3 groups: LBP subjects, and healthy controls - flexible and stiff group.	The lift force, leg excursion, pelvic-femoral angle, first sensation of pain, and the electromyogram of the hamstrings and back muscles measured in an experimental straight-leg raising set-up	probably
33	2001	Feldman et al.	to determine the incidence of low back pain in a cohort of adolescents and to ascertain risk factors	unclear	adolescents	evaluated during 1995–1996 at three separate times, 6 months apart	-	low back pain occurrence	May be
34	1996	Tafazzoli, F. and Lamontagne, M	to measure and compare the passive elastic moment, the stiffness and the damping coefficient of the hip joint, as functions of the hip and knee joint angles in men with and without low-back pain	unclear	LBP subjects	The passive elastic moment was measured using an isokinetic device in the passive mode	2 groups: LBP and healthy controls	Isokinetic device	May be
35	1992	Hultman et al.	Test if difference exists in the Anthropometry, Spinal Canal Width, and Flexibility of the Spine and Hamstring Muscles of subjects with LBP	unclear	LBP subjects	Observational study	3 groups: Healthy, recurrent LBP and Chronic LBP	anthropometry, spinal canal width, spinal sagittal configuration and flexibility, and the flexibility of the hamstrings musculature with straight leg raising (SLR)	May be

Discussion

Fascial connectivity and musculoskeletal dysfunctions

Direct morphologic coherence between neighboring muscles provides a factual basis to broaden the diagnostic and therapeutic focus beyond a single anatomic structure (Leonard, 2013). For instance, in patients with low back pain, treatment directed towards neighboring or remote myofascial structures via specific fascial connectivity could prove to be effective in reducing pain (Grieve et al., 2015). Several studies support the observation that patients with low back pain most often present with reduced hamstring flexibility (Tafazzoli, & Lamontagne., 1996; Halbertsma et al., 2001). It has been shown that relieving the tension of the posterior thigh muscles could be a conceivable approach to alleviate low back pain (Feldman et al., 2001; Hultman et al., 1992). As per the myofascial meridian concept, both these regions form a part of the SBL (Superficial back line), a fascial connectivity that extends from head to toe through the posterior aspect of the body. Overload disorders in contact sports are another pathological entity that can occur due to the existence of myofascial meridians (Myers 2014; Wilke et al., 2016a).

Similar to previously mentioned research exploring direct morphologic coherence, Labovitz et al. (2011) and Bolivar et al. (2013) studied the indirect link between remote myofascial structures. They pointed out that poor extensibility of gastrocnemius and hamstrings muscles may be associated with plantar fasciitis (PF). Since gastrocnemius, hamstring and plantar aponeurosis belong to the SBL, they might represent a focus for therapy when one or the other structure is affected by trauma or overuse. This aspect was studied by Labovitz et al., (2011) in a prospective cohort study (CEBM grade 2b) with an aim to find out if hamstring tightness was an increased risk in PF. They found out that patients with hamstring tightness were about 8.7 times more likely to experience PF in the corresponding foot compared with patients without hamstring tightness. In a case-control analysis (CEBM grade 3b), Bolivar et al. had tested essentially the same hypothesis with 100 participants in 2013, and concluded that the tightness of the posterior muscles of the lower limb was significantly correlating with the incidence of PF. Both these studies suggest that assessment of PF should include evaluation of hamstring tightness and triceps surae muscles and incorporate a stretching protocol for the same as one of the treatments. Since both studies were in a non-randomized format, caution is needed in interpreting their findings and their generalizability. It also necessitates high-quality confirmation studies to establish these findings.

In 2015, Grieve et al., investigated the immediate effect of a single application of Self Myofascial Release (SMR) on the plantar aspect of the foot on hamstring and lumbar spine flexibility. A pilot single-blind RCT was conducted (CEBM 2b; PEDro 4/10) with 24 healthy volunteers. They noted a significant increase in the hamstring and lumbar spine flexibility when compared to the control group, with a large effect size. He suggested that flexibility interventions based on myofascial chains, especially the SBL, cause force transmission to occur along the myofascial chain resulting in non-local effects. A result from an in vivo study by Tijs et al (2018) is worth mentioning here as this study specifically tested myofascial force transmission and fascicle length change during myofascial loading by studying the mechanical interaction properties between Soleus and its synergists. This animal study assessed whether myofascial loads exerted by the neighboring muscles result in length changes of Soleus fascicles and found that myofascial force transmission can occur between a prime mover (soleus) and synergistic muscles via connective tissue networks without substantial length changes of the fascicles.

In 2016, Krause et al., conducted a systematic review on intermuscular force transmission along the myofascial chains based on cadaveric studies and in-vivo experiments. This systematic analysis concluded that the tension / force between at least some of the neighboring myofascial structures under investigation can be transferred. Even though the study is concluding positively, the authors quoted that the current results' implication to in-vivo conditions could be limited and suggested that such experiments be done on fresh cadavers, as fixation, as well as freezing and thawing, could alter its biomechanical properties. Furthermore, future research on the in-vivo nature of adjacent structures will explore further the practical significance of the suggested intermuscular myofascial associations for prescription exercise, injury prevention and rehabilitation.

In the same year, Wilke et al., (2016b) evaluated the remote effects of lower limb stretching on cervical range of motion (ROM) based on the myofascial meridians and found that lower extremity stretching induced improvements of cervical range of motion and indicated the existence of strain transfer along the course of myofascial meridians. This was a pilot study with a matched-pair comparison (CEBM scale: 3b). These findings need to be verified by randomised, controlled trials with adequate sample size. The authors also pointed towards the limitations of the outcome measure used as it could not identify whether an increase in flexibility was attained in flexion, pointing towards a measurement bias. Wilke et al, has another conference abstract in 2016c, a randomized, cross-over trial with 13 asymptomatic subjects (PEDro=Unknown (abstract); CEBM scale:2b) The aim was to find out the impact of lower limb exercises on the lumbar erector spinae properties. They found a slight impact of stretching on the elasticity of the lumbar erector spinae. Again, this finding needs to be tested with high-quality trials to have more conclusive evidence in order to prove the myofascial continuity. A recently published single blinded RCT (Joshi et al., 2018) (PEDro: 7/10; CEBM 2b) conducted a study on 58 asymptomatic participants with tight hamstrings and reported that remote myofascial release (MFR) either in the sub occipital region or the plantar fascia has an effect on hamstring flexibility equivalent to the static stretching of hamstring, supporting their hypothesis of myofascial tensegrity. The study has major methodological imperfections influencing its reliability, yet it is recommendable as initial supportive literature for myofascial connectivity.

Wilke et al., (2017a) conducted a medium quality (PEDro : 6/10, CEBM: 2b) randomized controlled study on sixty-three healthy participants to compare the effectiveness of remote stretching based on myofascial chains with local exercise on cervical range of motion (ROM). The participants were assigned randomly to one of the three groups: remote lower limb stretching (LLS), local cervical spine stretching (CSS), or inactive control (CON). Pre (M1), immediate post (M2), and average cervical ROM five minutes after intervention (M3) were measured. Both LLS and CSS increased cervical ROM in all movement planes and at all measurements ($P < .05$) compared with the control group. No statistical differences were noticed between LLS and CSS ($P > .05$). The study concluded that lower limb stretching based on myofascial chains causes comparable acute changes to local exercise in cervical ROMs. Methodological flaws and inadequate power hinders the study's generalizability. The authors have given a caution in the interpretation section as "attained effects do not seem to be direction-specific, further research is warranted in order to provide evidence-based recommendations".

Wilke et al., (2019a) conducted a regression experimental study (CEBM= 3), which examined the age-dependency of the remote exercises on myofascial force transmission. The authors examined the result of age on these myofascial force transmissions in 168 healthy individuals between 13 and 87 years by using a pre-post regression analysis process. The results suggested that age and baseline flexibility predicted changes in hamstring extensibility and recommended further high quality trials.

Recent research by Song et al., (2019) studied the effects of myofascial meridians release technique using either the Grastone massage or the Rolfing massage techniques for improving pain and postural control of those with forward head posture (PEDro =4/10; CEBM= 2b;). The study was conducted among 30 college students randomly allocated to either of the two groups and intervention was provided for six weeks. SBL was chosen as the meridian for the application of the above techniques. All measured outcomes of numeric pain rating, neck disability index and forward head posture improved in both groups with the group receiving Grastone massage based myofascial meridians release showing superior results. However, factors that may have affected the outcomes of the study include the subjects also receiving physiotherapy in the form of pain relieving electrotherapeutic and mechanical modalities, and studying subjects who could conduct their daily living activities without any difficulty. Hence the confidence with which the results can be relied upon or generalized is fairly limited. Another researcher, Sulowska et al., in this same year studied the influence of short plantar foot muscle exercises on lower extremity muscle strength and power among 47 long distance runners (PEDro= 5/10; CEBM= 2b). Participants were grouped based on the foot posture index and trained for 6 weeks with specific intrinsic foot muscle exercises besides their regular running training. The outcome measures they used were highly objective, which included torque, work and strength of knee flexors and extensors on the Isokinetic Dynamometer and Running-Based Anaerobic Sprint Test (RAST). This research did not have any major limitations besides the heterogeneity of subjects due to variation in their running distance. The results reported were very interesting, whereby, both strength and power of proximal segments of the kinetic chain increased after the exercises for plantar short foot muscles, which are part of the SBL as per the anatomy trains concept. These findings are again indicative of the fact that myofascial continuity and its role in energy transfer is a reality, and that this energy transfer takes place along specific lines that may be likened to myofascial meridians.

Fousekis et al., (2019) in a randomized controlled trial (PEDro= 7/10; CEBM=2b) studied the effects of local vs. remote application of the 'instrumental assisted soft tissue mobilization (IASTM)' treatment on the superficial back line by evaluating the hamstring flexibility. Sixty university students were randomly divided into three sub-groups and received a single 15-minute treatment with IATSM Technique in a) the upper and b) the lower part of SBL or c) served as control. The participants received one session per week for four weeks with a simultaneous pre-and post-therapy assessment. The authors found that hamstring flexibility, as measured by the passive SLR test, improved significantly in both the treatment groups when compared to the control group. There was no significant difference between local or remote application of IATSM treatment. IASTM treatment of either the upper or lower part of the superficial back line may lead to a significant increase in hamstrings flexibility and the authors are attributing this to the myofascial continuity. In a similar medium quality (CEBM 2b; Pedro 5/10) study, Fousekis et al., (2019) found that application of IATSM technique of either the upper or lower part of the SBL will lead to a substantial increase in flexibility in the hamstring regardless of the site of application. An abstract of RCT published by Eid et al., (2017) also describes that IASTM of the trunk and lower extremities improved the hamstring flexibility. As mentioned earlier, a majority of these results need to be interpreted with utmost care because of the methodological imperfections and reliability issues.

A high quality RCT (PEDro= 8/10; CEBM= 2b) by Marizeiro et al., (2018) found that application of Myofascial release in the diaphragmatic region in sedentary women improved not only the chest wall mobility but superficial back line muscle and lumbar spine flexibility also. It is appraisable that more and more studies are adding to the literature of myofascial connectivity even though only very few are connecting this to the myofascial meridians as defined here. A re-search on December 2019 identified six more articles reporting interventions related to Superficial back line (Do et al., 2018; Williams and Selkow., 2019; Wang., 2019; Paloncy et al., 2019; Chakhuttray et al., 2019; Bezuidenhout., 2010) and few more studies mentioning the myofascial connectivity (Devereux et al., 2019; Danyschuk., 2019; Borg et al., 2019; Zhang., 2019). The myofascial connectivity is often a secondary finding in many studies and the introduction of all these findings is beyond the scope of this narrative review.

A recent meta-analysis by Burk et al (2019) (CEBM= 2a) analyzed the remote effect of myofascial interventions with range of motion as the dependent variable. They found eight randomized controlled trials of lower methodological quality (PEDro score 2-7), comprising 354 participants focusing on SBL. Pooled results for ROM showed trends in favor of remote interventions at immediate follow-ups, but with small effect size. The study concluded that remote exercise may increase ROM at distant body segments, but cautioned on result generalizability due to the methodological concerns.

Electromyography and myofascial meridians

Weisman and colleagues (2014) attempted to map the association of muscle activation along the SBL using separate conditions of active ROM with and without resistance, and passive ROM (CEBM 3b). They studied 20 healthy adult males undergoing five test conditions, with surface EMG electrodes placed along the specific points of the SBL. The findings revealed a strong correlation between muscle activations in the test condition and muscle activations along the adjacent SBL. The study indicated a need for a complete evaluation of the SBL in patients suffering from myofascial pain anywhere along it.

Recently, another researcher, Vulfsons et al., (2018) analyzed the surface electromyographic changes along the 'superficial backline' of chronic nonspecific low back pain patients in a case control study (CEBM 3b) with 20 low back pain patients and 17 age matched controls. The study found a significant difference in activation of the muscles belonging to the superficial back line between the groups. The results of both the studies should be interpreted with caution due to the study design used and the bias it can generate. Moreover, surface EMG has inherent limitations as opposed to intra-muscular EMG recording, which can be an important factor that may have influenced their findings.

Raţă et al in 2018 published a case study on morpho-functional implications of myofascial stretching applied to muscle chains. The authors investigated the influence of static stretching at a 24-year-old athlete with Haglund's disease on the electromyographic function of muscle chains. They found that a two month stretching program of 60 minutes, two sessions per week resulted in a rebalancing of the maximum volumetric isometric contraction across various myofascial connections and recommended the static stretching as an effective treatment method for shortened muscle chains. A single case study with surface EMG findings is not a definitive answer but opens a window for further research along these lines

Do Myofascial Meridians really exist?

The concept of myofascial meridians or myofascial chains has been explored in numerous studies (Hyong & Kang 2013; Weisman et al., 2014; Grieve 2015). Wilke et al. (2016a) were the first to conduct a methodologically high quality systematic review of anatomy dissection studies adhering to PRISMA guidelines, exploring the existence of meridians. Their search for published literature spanned more than a century, from 1900to 2014. The methodological quality of the included studies was evaluated by using QUACS scale (Quality Appraisal for Cadaveric Studies) by two independent evaluators. Proof of each meridian and its transitions has been graded as solid, moderate, minimal, conflicting or non-existent (Wilke et al., 2016a). A change was deemed a myofascial link between two muscles. For example, the gastrocnemius and hamstring muscles are regarded as a transition of the SBL. They discovered evidence for the existence of three myofascial chains proposed by Myers (Myers 2009 & 2014). The results provided strong evidence for myofascial transitions in three of the six examined myofascial meridians: SBL, BFL and FFL. In the SBL, 3 myofascial transitions (plantar fascia-gastrocnemius, gastrocnemius-hamstrings, and hamstrings-lumbar fascia/erector spine) were verified in fifteen studies. In the BFL, three myofascial transitions were verified in 8 studies (latissimus-lumbar fascia, lumbar fascia-gluteus maximus, and gluteus maximus-vastus lateralis). Six studies supported two myofascial transitions (pectoralis major-rectus abdominis and rectus abdominis-adductor longus) for the FFL with a 'strong evidence' grade. There was only moderate evidence supporting the meridians and transitions of the spiral line and the lateral line. There was no evidence for the meridians and transitions of the SFL, which was based on seven studies (Wilke et al., 2016a). The practical pertinence of the findings of this systematic review reconnects us to the existence of myofascial meridians as suggested by Myers (2014) or as believed by the manual therapists. This will facilitate and justify the idea of how lines of pull and compensations in one structure or part of the body impact other distant/remote structures or parts. These findings may lead to the development of more suitable intervention strategies by manual and movement therapists for their patients.

Wilke and Krause have done another systematic review with peer-reviewed anatomical dissection studies in 2019(b) in order to find evidence of structural continuity between the trunk and upper extremity skeletal muscles. Thirteen studies, which were evaluated with QUACS scale for the methodological quality, were included in this review. The analysis revealed the presence of three myofascial connectivity between the trunk and the upper extremity: the ventral arm chain, the lateral arm chain, and the dorsal arm chain with clear proof of direct serial tissue connectivity from neck and shoulder area to forearm. The study concluded with the recommendation for further research to establish the mechanical relevance of the identified myofascial chains before any definitive conclusion.

The majority of the reviewed studies did not explicitly look for the finding of fascial connectivity but mentioned them as a subordinate finding. The systematic reviews by Wilke et al, Krause et al and Burk et al succeeded in tracing the presence of myofascial continuity with a higher level of evidence, but with methodological issues that need to be mentioned. Future research will resolve those limitations and rectify them. Overall, the findings from these systematic reviews can be considered as a starting point for further high-quality studies in the search for the existence of strain transmissions across tissues connected by myofascial meridians.

Pitfalls in myofascial meridian research

As pointed out by Krause et al., (2016), factors that are having an effect on the applicability of these findings should be mentioned and if possible managed in the upcoming studies. Factors like (i) heterogeneity in methods of force application, (ii) variation in the measured outcomes and methods between studies and examined body regions and (iii) factors related to the use of cadaver specimen for biomechanical testing (Krause et al., 2016) should be managed in future studies. These limitations are also applicable to research findings presented by other authors and need critical review for meaningful interpretation of the study results. Consideration of anatomical differences in continuity, as well as histological variations in the connecting structures is also important when interpreting performance. This is an issue that several researchers have failed to address. While considering the experimental studies, to have high quality evidence, appraise and organise the studies with good quality designs, randomization and double-blinding first (Ajimsha & Shenoy 2019). One should understand that a systematic review is not necessarily superior to a well-conducted RCT, and not all RCTs are necessarily superior to observational studies of good methodological quality (Ajimsha & Shenoy 2019). Authors should use their critical appraisal skills to interpret any research evidence before applying them to clinical practice.

Directions for future research

Future studies should include RCTs of in-vitro studies as most of the current experimental research was done using cadavers (Nortonold., et al 2013; Barker et al., 2004). It will be valuable to direct additional research on the other proposed myofascial meridians. This will help to substantiate their existence with sufficient evidence and begin to explore the existence of other lines. A clinician may use the myofascial meridians as a conclusive orientation, but they should be aware that the functional implications are yet to be studied (Wilke et al., 2016a). Currently, an increasing number of clinicians and anatomists show continued interest and enthusiasm on the subject of myofascia, hence the possibility of further research focused on the existence of myofascial links remains very high (van der Wal 2009). The objective reality of myofascial meridians might serve as a breakthrough in explaining several phenomena that lack a clear understanding of their etiology or pathophysiology even today. One such example is referred pain, which frequently occurs in nonspecific disorders and is almost often difficult to explain. Another example is that of myofascial trigger points of the calf that provokes radiating pain to the sole of the foot and the dorsal thigh (Travell & Simons 1992).

Limitations

In spite of our best efforts to perform this review, it has several limitations that are inherent to any narrative review. Although every effort was made to minimize selection and evaluation bias, we accept the fact that this study lacks a reproducible search strategy and the methodological rigor of a systematic review.

Conclusion

Albeit these reviews and trials yield positive evidence for the existence of fascial connectivity and continuity, several aspects need further clarification and in-depth analysis. We need high quality randomized controlled in-vivo trials and biomechanical studies to ascertain the above findings as most of the current studies are either in non-randomized format or with inadequate methodological quality that prevents the generalizability of the results. Future research should focus on determining the presence of the meridians and force transmissions in a more objective and reliable way which could not be evidenced entirely in the work cited in this review. Definitely, it is of utmost significance to explain the functional importance of the myofascial chains as the ability for strain transition represents the decisive criterion to legitimize the treatment of meridians. Another issue is related to the function of regional specializations or myofascial expansions which so far stay indistinct. Manual and physical therapists may utilize the concept of fascial connectivity/meridians as a convincing justification but should be vigilant that functional implications remain to be investigated.

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The authors report no declarations of interest.

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