



A Controlled Comparison between Manual Lymphatic Mapping (MLM) of Plantar Lymph Flow and Standard Physiologic Maps Using Lymph Drainage Therapy (LDT)/Osteopathic Lymphatic Technique (OLT)

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Abstract

Background: Trained practitioners claim to identify the specific direction of superficial or deep lymphatic circulation using a non-invasive technique called Manual Lymphatic Mapping (MLM). MLM is a recent advance in manual therapy, a component of Lymph Drainage Therapy (LDT)/Osteopathic Lymphatic Technique (OLT).

Objective: Assess the potential of trained practitioners to palpate superficial lymphatic flow.

Method: Each practitioner mapped the sole of the foot of a healthy volunteer, a region never previously studied. The results of the mapping were compared between trained and untrained practitioners and physiologic lymph charts

Results: Trained practitioners (n=393) provided significantly more correct mappings (correct answers = 245) than untrained practitioners (n=411, correct answers = 11) ($X^2 = 329.54$, $p < 0.05$), and $OR = 60.20$, $p < 0.05$.

Conclusion: Trained practitioners, but not untrained practitioners, mapped pedal flow by palpation, consistent with standard physiologic lymphatic maps. Flow studies, by imaging in individual subjects mapped by palpation, must further test this finding.

Keywords: Clinical skills; Lymph; Lymph drainage therapy; Lymphatic system; Manual lymphatic mapping; Lymphedema; Manual therapy; Manual lymphatic therapy; Osteopathy

Abbreviations: CDP: Complex Decongestive Physiotherapy; LDT: Lymph Drainage Therapy; MLDT: Manual Lymph Drainage Therapy; MLM: Manual Lymphatic Mapping; MLT: Manual Lymphatic Therapy; MT: Manual Therapy; OLT: Osteopathic Lymphatic Technique

Introduction

The lymphatic system was identified late in history, probably because of the difficulty to see it with the naked eye. Specific manual techniques for the lymphatic system have been used by osteopaths since the end of the 19th century [1,2]. Emil Vodder, PhD in Philosophy and manual therapist, and his wife, developed an innovative approach to manually enhance lymph flow throughout the body. Today, manual therapists, including DOs, PTs, OTs, nurses, and other practitioners use Combined Decongestive Physiotherapy (CDP) for lymphedema. CDP is one of the non-invasive treatments of choice for lymphedema, and is recognized and reimbursed by a growing number of national insurance companies [3-6]. CDP consists of many components, including hands-on, manual lymph drainage therapy (MLDT), skin care, external compressions, etc. The emphasis of MLDT is to create alternative pathways through which lymph can flow [3].

MLM is a gentle, non-invasive method by which trained manual therapists - using only their hands - declare being able to identify the specific direction of the superficial or deep lymphatic circulation on an affected or unaffected area of the body [2,7]. Manual Lymphatic Mapping (MLM) could be used to refine manual lymphatic assessment and treatment, or as an element of the manual component of CDP. MLM is a component of Lymph Drainage Therapy (LDT)/Osteopathic Lymphatic Technique (OLT) — a hands-on modality developed by Bruno Chikly, MD, DO, [2,7] inspired by the traditional work of osteopaths CE Miller (1920), [8, 9] FP Millard [10] and Emil Vodder,

[11]. One of the characteristics of LDT/OLT is to teach manual practitioners to synchronize to the specific rhythm, direction, and depth of the superficial or deep lymphatic-interstitial fluid flow. This study examines the feasibility of manual lymphatic palpation. If confirmed, these techniques could help provide a faster assessment, as well as a specific treatment and protocol for lymphatic pathologies.

Lymphatic intrinsic contractility (Lymphangiomotoricity): The Lymph “Rhythm”

Elements of the lymphatic system include lymph capillaries (or initial lymphatics), with no real valves or proper muscular units, which carry fluid from interstitial spaces (interstitial fluid) to pre-collectors. At the site of fluid entry, we find, in initial lymphatics, oak leaf-shaped endothelial cells with overlapping flaps; the openings are about 2 microns in size [12]. Pre-collectors slowly acquire valves. They convey the fluid to larger vessels called lymph collectors. Human lymph collectors are approximately 100 to 600 microns in diameter, and consist primarily of chains of muscular units called lymphangions, bordered by two-leaflet bicuspid valves.

Described as little “lymphatic hearts”, [13,14] the contractility

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of lymphangions was initially objectively evaluated in humans by Olszewski [15,16]. Lymphangions work much like the body's heart pacemakers, contracting regularly throughout the lymphatic system (Lymphangiomotricity), and moving lymph in peristaltic waves [17,18]. From the tunica media to the tunica externa, these muscular units have extensive autonomic nervous system innervation [19].

The first descriptions of intrinsic contractility in human lymphatics were done by Kinmonth and Taylor in 1956 [20]. They mentioned that these contractions, independent of respiration, have a rhythm of approximately 4-6/min. in humans. Szegvari made another observation in 1963, and made lymphangiographic observation of lymphatic contractions in humans, of about 4-5/min [21]. Since the initial objective quantification of human lymph vessels by Olszewski (1979, 1980, 1982), there have been a few hundred studies on both animals and humans measuring lymphangiomotricity *in vivo* and *in vitro* [16,22].

Most recent studies show that these intrinsic lymph pumps generate lymph flow via the coordinated rapid strong contractions of their smooth muscular units [18]. Numerous researches corroborate these data. Lymphangiomotricity is described as being generated by pacemaker activity, creating rapid synchronized phasic contractions with rhythmic contractility/peristalsis [23,24]. These lymphatic phasic contractions are ideally suited to the propagation of an action potential over large distances [25]. Lymph contractions are furthermore regulated by the autonomic nervous system (ANS), bringing motor coordination, as well as synchronization [26,27]. Vagotomy, for example, will cause lymphatic contraction rhythms and valve movements to "become irregular and inconsistent" [28].

Lymphatic vessels are located initially just under the dermo-epidermic junction, making them potentially relatively easy to palpate [29]. External compression, such as manual pressure, could increase lymph contractility by stimulating external stretch receptors [30].

Anchoring filaments (Fibers of Leak): Continuity from lymphatic vessels to the skin

Lymphatic vessels demonstrate specific anchoring filaments (or fibers of Leak), identified for the first time by Pullinger and Florey in 1935, and evaluated by Leak and Burke in 1970. They are described as fine filaments that insert on the outer leaflet of the lymphatic endothelium, and "extend for long distances into the adjoining connective tissue" [31].

This fibrillar fibers complex, connecting lymph vessels to the surrounding elastic fibers, is in continuity with the "vast elastic network of the dermis" [29]. In contrast, a fibrillar elastic apparatus connecting to the surrounding tissue, especially the dermis, is not present around blood capillaries [32]. As a plausible hypothesis, this continuity of the superficial phasic lymph rhythm/contractile waves all the way to the skin, transmitted by the surrounding elastic fibers, might be perceived by human mechanoreceptors.

Lymphatic vessels diameter change and human mechanoreceptors

Human mechanoreceptors are exquisitely sensitive. In this hypothetical model, one characteristic the practitioner needs to palpate is the effect of the "diameter change" created by lymphatic contraction, and transmitted to the skin by the anchoring filaments ([24] <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3065345/>). To get a quantitative idea of these lymphatic signals we need to identify the diameter change during the lymphatic diastole/systole cycle. According to David Zawieja, the diameter change associated with lymphatic phasic

contractions is on the order of 40-80 microns for a hundred micron diameter lymphatic [17,18]. Human lymphatics are usually 100 to 600 microns in diameter.

According to numerous studies, the threshold of human mechanoreceptors for different mechanical stimulus is astonishingly small, on the order of a micrometer [33-40]. One recent study even determined that human tactile discrimination extends to the nanoscale [41]. Miyaoka et al. studied the discrimination ability of fine textures in human tactile perception using abrasive papers with particle sizes between 1 and 40 μm . They found that difference thresholds of fine-surface textures were between 2.4 and 3.3 μm [33].

For Johansson and Vallbo, the Pacinian corpuscles, and rapidly adapting Meissner's corpuscles, had the lowest thresholds of all human mechanoreceptors, with medians of 9.2 and 13.8 micrometers [34]. Mountcastle determined that Pacinian corpuscles are "capable of sensing vibrations, associated with slip and texture, which can be less than a micrometer in amplitude" [35]. Lamotte and Srinivasan found a threshold of 6 micrometers for a dot diameter of 50 microns, and about 1 micron for dots with diameters of 500 microns or greater. The Meissner corpuscles "had dot heights thresholds as low as 2 micrometers, which was the mean detection thresholds for humans" [36]. Johansson and Lamotte, and later Simonetti, all did different experiments to confirm that the mean detection threshold of human mechanoreceptors was within a few microns [37-38]. From these data we can conclude that phasic and coordinated lymphatic contractions are transmitted to the surrounding dermal layer by an elastic apparatus, a signal that human mechanoreceptors could potentially perceive. Nevertheless, this would not make the lymphatic flow readily "palpable". As with many other professional manual approaches, without previous specific training it may understandably seem impossible to assess these components of the lymph circulation, and discriminate between different skin "signals".

Materials and Methods: MLM Reliability Study

Objective

Assess the potential of a population of "trained practitioners" to palpate lymphatic flow.

Method

Population size: in total, eight hundred and four practitioners, enrolled in LDT/OLT courses, were included in the study.

Control Group (untrained group): Population size: 393 (352 females/41 males). Ages were not collected.

Students enrolled in first-day LDT/OLT level 1 seminars (an introductory lymph class), without any prior training in MLM.

Experimental Group (trained group): Population size: 411 (365 females/46 males). Ages were not collected.

Students enrolled in LDT/OLT level 2 seminars.

Sampling: The "untrained" group was comprised of manual therapists' students who randomly registered in an introductory lymph class (LDT level 1). These attendees declared no previous training in lymph flow palpation. They were given forms, and chose freely whether to fill in the forms (or not). These forms were completed during approximately a 15 min break (convenient sampling).

Similarly, for the “trained group”, testing was performed after their first 3 days of training in manual mapping technique (MLM), (practitioners did not yet have extended practice of their mapping skills.). There was no interaction between practitioners during their answer time.

No student was in both groups, so there was no overlap.

For both populations, the students consented both to attend the course, and to carry out the exercises. For both populations, the type of superficial non-invasive touch for this research was also a routine part of the LDT/OLT seminar.

Exclusion criteria: Before starting, each practitioner was asked to complete and sign a questionnaire that included two exclusionary questions:

1. “I have been trained to assess the lymph flow by palpation: Yes ___ No ___”
2. “I have seen a complete lymph chart of the sole of the foot (with watersheds). Yes ___ No ___”


Practitioners in the control group were excluded if they had previous training in palpation of lymph flow.

All candidates who had previously seen a lymph chart of the sole of the foot were excluded. Trained practitioners were to “blindly” palpate the sole of the foot, and the results were compared to known maps of the area.

All participants were healthy volunteers. Attendees with clinical lympho-vascular pathologies were excluded (Figure 1).

LDT Class Type: _____
 Location: _____
 Date: _____
 Name: _____
 Signature: _____

I have been trained to assess the lymph flow by palpation. Yes ___ No ___
 I have seen a complete lymph chart of the sole of the foot (with watersheds). Yes ___ No ___



Sole of the Right Foot

Figure 1: Questionnaire / Form.

Medical examination

The lower leg and foot of the participants in the class were checked only for evident clinical lymphatic pathologies by a physician, or a certified lymphedema therapist. Attendees were only checked for basic pathological clinical signs, such as clinical lymphedema, redness, pathological appearance of the skin, fibrosis, as well as any subjective self-reported signs, such as pain, tenderness, etc., and a medical history of lymphedema. Common benign vein disorders were discarded.

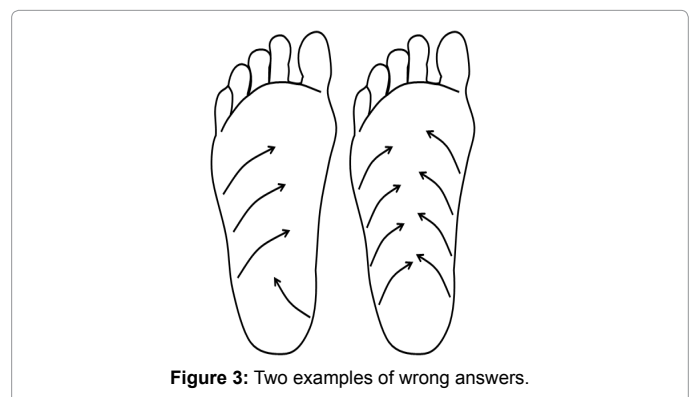
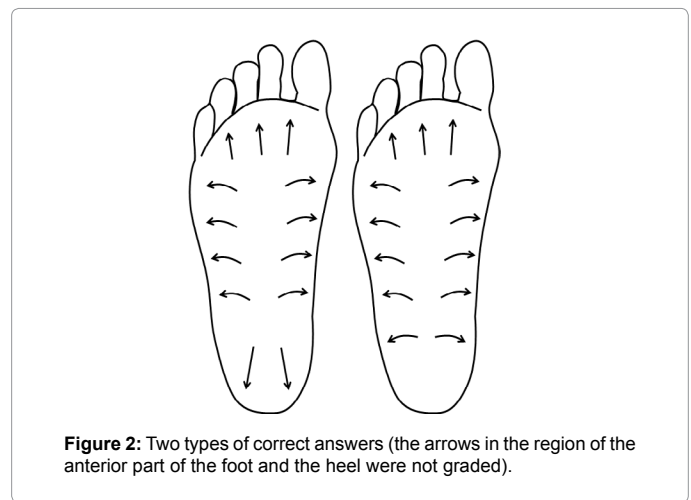
No clinical lymphatic pathologies were found in these populations. No attendee was eliminated for medical reasons.

Choice of the area to test

The sole of the foot is one of the most difficult areas for palpating lymph flow, because it has a thick epidermic layer. However, this area was the most appropriate and honest choice. Clear pictures of lymph vessels in the sole of the foot, with watershed and lymphotomes/lymph territories, are rare in North American anatomy and manual therapy books. Depictions of the lymphotome of other regions, such as the legs, arms, back, and trunk are common (Figures 2 and 3).

The MLM palpation

Trained practitioners declared perceiving some lymph “signals” converging toward specific lymphatic terminal regions (i.e. axilla, inguinals, etc.) using a slow rhythm of about 3 seconds in and 3 seconds out (approximately 0.1 Hertz), and a gentle pressure of about few 1/2 to 1 ounce/cm² (measured on a scale).



Data processing and grading

Each practitioner was asked to write on a form, provided to them in class, what they considered, through touch, to be the directions of lymphatic-interstitial flow in the sole of the right foot of a healthy volunteer. The lymphatic anatomy of this specific region of the body was never previously known to them. The participants were told not to draw arrows on the anterior part of the foot (the ball of the feet), or the heel, during the examination.

These areas were not graded because: 1) the direction of the arrows changes in these areas, and 2) the heel and the ball of the foot can be the two areas with the thickest epidermis in the feet. The forms were evaluated based on the anatomical criteria of Sappey, Casley Smith, Foldi, and Moreau-Dahyot [42-46]. The sole of the foot has two main territories, the lateral half of the sole of the foot drains laterally, and the medial half drains medially. A “correct” answer was clearly seeing two territories with arrows going laterally and medially on the whole selected area. The grading was conservative; if there was any doubt, it was graded as wrong.

Results and Statistical Analysis

Eight hundred and four practitioners were included in the study (trained: 393; untrained: 411). The number of correct and incorrect answers is shown in Table 1.

	Experimental Group	Control Group	Total
Participants	393	411	804
Correct Answers	245	11	256
Incorrect Answers	148	400	548

Table 1: Number of correct and incorrect answers per group.

The chi-square analysis comparing the answers between the experimental group and the control group were significant: $X^2 = 329.54$, $p < 0.05$.

The practitioners in the experimental group were 60 times more likely to provide a correct response than those in the control group OR = 60.20, $p < 0.05$ (95% CI: 31.02 < OR < 119.87).

Discussion

In the present study, a total of 393 newly “trained” manual practitioners that declare having been trained to feel lymphatic flow were tested against an untrained group. Specific arrows were drawn by the 245 practitioners that had correct answers, matching the known general pattern of the superficial lymphatic circulation of the foot. What phenomena could account for these consistent observations?

a) In all probability these arrows does not seem as random as the p -value < 0.05.

b) Arteries or veins

There is no known easily palpable slow arterial pulse in this area. Furthermore, there is no similar artery or vein mapping on the sole of the foot. Arteries and veins do not have this general influence (a fibrillary apparatus/anchoring filaments) all the way to the surrounding skin, and they have a relatively fast rhythm. All these characteristics make it theoretically possible to easily differentiate lymph from blood vessels.

c) Fascia

There is no obvious rhythm ever described in these structures, which can be mechanically felt at a distance on the skin. If it happens

that the contractions of the myofibroblasts are phasic and strong enough to be palpated, once more, there is; no known similar fascia mapping described on the sole of the foot [47].

In manual therapy practice, “fascia pulls” are usually felt as straight lines (collagen fibers). “Fascia pull” will often dramatically switch with the change in regional tension, but not lymphatic vessel directions. This makes it quite easy to differentiate “fascia pull” from lymphatics rhythm, as a practitioner would just need to change position (tension) of the area to differentiate fascia from lymph.

d) There is no obvious nerve, bone, periosteum, tendon, or ligament rhythm ever described in these structures that can be mechanically felt at a distance on the skin, and again, there are no similar nervous mappings described on the sole of the foot.

e) Cerebrospinal fluid (CSF)

For CSF movement, no longitudinal peripheral CSF component has yet been demonstrated to show similar lymphatic rhythm characteristics. The controversial possibility of peripheral CSF circulation was mentioned in older literature [48].

f) Interstitial fluid-lymph

Lymphatic vessels, absorbing surrounding interstitial fluid, possess a physiological rhythm similar to the one used by these practitioners. The directions found on the forms follow what can be expected to be found in human feet, in physiological conditions, according to lymphatic anatomical charts. It is reasonable to consider the possibility that, with training, selective attention/palpation may allow discernment of the specific characteristics of lymph flow, just as a listener can determine the sound of a single instrument in a symphony. The interstitial-lymphatic system seems a plausible hypothesis for the arrows described by the trained practitioners that had a correct answer.

As seen in the introduction, palpation of lymph flow could be theoretically possible, if a practitioner could potentially train his/her mechanoreceptors to learn how to differentiate the specific “signals” sent by the lymphatic smooth muscle contractions all the way to the skin layer from other surrounding structures, such as blood vessels or fascia.

The physiological characteristics of lymphangiogenicity make it “theoretically” possible to differentiate lymph from blood vessels, or other structures, while training and selective attention/palpation may allow discernment of lymph flow.

During a concert someone can train him/herself to follow a specific instrument in an orchestra, and bring all the other instruments “into the background” of their consciousness, especially if this instrument has a specific sound, or a specific rhythm. It is reasonable to consider the possibility that, with training, selective attention/palpation may allow discernment of lymph flow, just as a listener can select the sound of a single instrument in a symphony. However, this would not make the lymphatic flow easily “palpable”. This type of training, as with many other professional manual techniques, would require time and dedicated effort. Without previous specific training, it is understandable that it may seem impossible to assess these components of the lymph circulation.

There are several limitations to this study. First, the hands-on assessment of lymphatic flow and the grading are relatively subjective processes. Extensive descriptions of the practitioners (e.g. age) were not collected, but in the relatively large sample of the untrained group, for

example, we don't know if additional information would have made a difference in their initial lymphatic examination of the foot. Numerous subjects from this group commented that, without training, they had absolutely no idea how to palpate or identify the superficial lymphatic flow. Further, lymphatic anatomical variations remain possible. In this study it was assumed that all the healthy volunteers' feet were non-pathological, and that the anatomy followed "standard" lymphatic charts. However, there are some possible anatomical variations in healthy individuals. Some practitioner findings, while matching expected patterns of lymphatic maps, may not have matched a specific subject's subclinical pathologic flow. As an indispensable follow up study, fluorescent micro lymphangiography, or novel ultrasound, needs to be used to confirm these results. Lympho scintigraphy is recognized as a golden standard for lymphatic imaging, unfortunately, with this specific procedure, it would be challenging to properly see superficial lymph flow in this area.

Potential clinical applications of manual lymphatic mapping

If these data are confirmed, Manual Lymphatic Mapping (MLM) has potential for developing and adjusting treatment plans in accord with sequentially observed lymph pathways.

For example, in cases of post mastectomy upper-extremity lymphedema, lymph flow has some 20 alternate pathways to choose between for rerouting to an unaffected lymph territory [7].

It may be difficult for a manual practitioner to "guess", or assume, which pathway will be taken by the lymph flow. Working on each and every possible lymph reroute is very time-consuming, and may not be the most efficient way to help the functional lymph pathways.

MLM could be used

1. At the beginning of a manual therapy session/assessment phase. MLM could help make an initial assessment of the areas of fluid stagnation and fibrotic tissue.
2. During the session to allow the therapist to determine whether the most appropriate work area has been selected, and if the

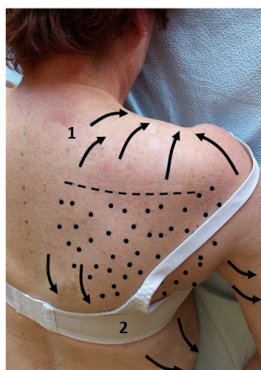


Figure 4: Pre-treatment: typical Manual Lymphatic Mapping (MLM) assessment of a lymphedema patient. This patient initially presents a zone of fluid stagnation (the dotted area), and two spontaneous reroutes to evacuate her upper extremity lymphedema:

1. Toward the ipsilateral clavicle, an unsatisfactory/inefficient reroute to evacuate a whole upper extremity
2. An incomplete/inefficient reroute toward the ipsilateral inguinal (the flow does not reach the inguinal nodes area)

The MLM was done by a dermographic pen during the session, but for clarity, arrows and dots have been replaced by digital lines.

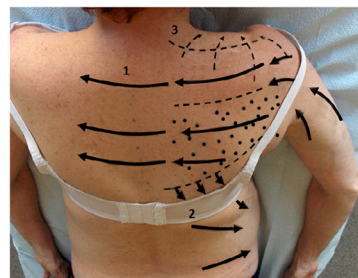


Figure 5: Post-treatment: MLM assessment of the same lymphedema patient. After Manual Lymph Drainage Therapy (MLDT) this patient now presents two efficient reroutes to evacuate her upper extremity lymphedema:

1. Toward the contralateral axilla (a very large and effective reroute, crossing midline)
2. Toward the ipsilateral inguinal (a very effective reroute)

It should be noted that the initial spontaneous reroute toward the ipsilateral clavicle disappeared spontaneously during the treatment with the newly created alternate routes of lymph and interstitial fluid.

lymph flow has been efficiently and non-invasively rerouted by the hands-on manoeuvres (Figures 4 and 5).

3. At the end of the session: mapping can be used to verify the results of the technique and could help select a physical treatment protocol for external compression, such as bandages, garments, Tribute™ or JoVi Pak™, sleeves, Kinesio Taping™, self-drainage, etc.
4. For preventive application such as subclinical lymphedema, latent phase, or lymphedema "stage 0" (see below).

Lastly, MLM may play a role in preventing lymphedema at the subclinical stage (latent phase or lymphedema stage 0, ISL classification) [3].

Stage-0 lymphedema could be defined as a patient with abnormal/non-efficient lymph reroutes, but no clinical edema. A number of abnormalities can be found in subclinical lymphedema, including hyper pressure in the lymphatic microcirculation, measured by fluorescence microlymphography and dermal backflow [49-51].

A promising application of MLM could be in the evaluation of areas of stagnation and functional alternate pathways in latent phases of lymphedema (Stage-0 lymphedema); in other words, before the lymphedema is clinically visible. At this stage, evacuation toward the most efficient alternate lymphatic pathway(s), without the utilization of bandaging, may help save significant time and money for patients, therapists, and insurance companies. More studies are needed to confirm this application of MLM.

Conclusion

This prospective study evaluates the potential of trained LDT/OLT practitioners to palpate superficial lymphatic flow with MLM. It shows that trained practitioners are able to provide maps of the soles of the feet of healthy volunteers. These pathways correlate with known physiologic lymphatic maps of the area, and no other known structures. These data only suggest, at this point, that these arrows may represent lymph-interstitial flow. More studies, such as a direct comparison of MLM with lymph flow imaging studies, are necessary to confirm MLM as an efficient tool in the management, and pre- and post-operative

functional assessment, of lymphatic pathologies, including finding the most accurate alternate pathways in lymphedema. If confirmed, Manual Lymphatic Mapping could offer manual therapists a fast and beneficial management tool for lymphatic pathologies, including subclinical and clinical lymphedema.

Disclosure Statement

Jörgen Quaghebeur, MSc, DO, PhD, EFO, and Walter Witryol, MD, have no direct or indirect financial interests.

Dr. Bruno Chikly, MD, DO, has no direct financial interest, but he is the developer of the Lymph Drainage Therapy (LDT)/Osteopathic Lymphatic Technique (OLT).

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