Original Article

Phlebology

Phlebology
0(0) 1–8

DOI: 10.1177/0268355520984065
journals.sagepub.com/home/phl
SAGE

The effects of water immersion and walking on leg volume, ankle circumference and epifascial thickness in healthy subjects with occupational edema

Giovanni Mosti[1] and Alberto Caggiati[2]

Abstract

Background: Balneotherapy has been considered beneficial in patients with chronic venous disease due to patient-reported positive outcomes on improvement of symptoms and quality of life.

Study aim: Assessing the effects of prolonged water immersion (WI) on leg edema and epifascial thickness and to compare these data with those achieved after continuous walking on ground.

Material and methods: On three consecutive days, 14 otherwise healthy volunteers (9 females, 5 males, mean age 53 ± 10 years) affected by occupational edema (OE), defined as the edema developing during the time period of the working day and disappearing overnight, stayed standing immobile in a swimming pool for 30 minutes (30'), continuously walking again for 30' in the same pool and walking on ground for 30' without interruptions in a randomized sequence. Leg volume, ankle circumference and epifascial thickness of both legs were assessed each day before and after each intervention.

Results: Leg volume showed a median reduction by 4.20% (IQR 5-3.6) ($p = 0.0002$) after 30' of immobile standing immersion and by 6.50% (IQR 7.30-5.61) ($P < 0.0001$) when the patients walked in the pool. Ankle circumference showed a median reduction by 2.89% (IQR 4.23-2.03) ($p = 0.02$) with the subjects staying standing still in water and by 5.98% (IQR 7.47-4.14) ($p = 0.0002$) after 30' walking in the pool. Epifascial thickness showed a median reduction by 24.35% (IQR 35.26-22.5) ($P < 0.0001$) when the volunteers remained standing still and by 32.66% (IQR 36.91-28-84) ($P < 0.0001$), when walking in water. Leg volumetry showed a median reduction by 0.20% (IQR-0.44-0.29) ($p = 0.375$) after walking on ground for 30'. Ankle circumference and epifascial thickness did not show any difference walking on ground compared to baseline situation.

Conclusions: This study showed that 30' of WI, especially when associated with walking, reduced leg volume in otherwise heathy subjects with OE and that walking outside the water did not.

Keywords

Balneotherapy, water immersion, venous rehabilitation, leg volumetry, leg edema, skin thickness

Introduction

Balneotherapy (physical treatments performed during water immersion) is considered beneficial in patients with chronic venous disease (CVD) based on improvement of symptoms and quality of life reported by patients.[1,2] A recent Cochrane review highlighted the need for evidence-based data on the effect of balneotherapy in CVD legs.[3] In their conclusions the Authors recommended to standardize measurements of outcomes such as disease severity score, quality of life, pain, oedema and finally choice of time points during follow-up for future studies. The need to evaluate the objective effects of balneotherapies on vein size, venous hemodynamics and leg volume was not mentioned.

In a study from our group it was demonstrated by underwater Duplex Sonography (uDS), that water

[1]Angiology Department, MD Barbantini Clinic, Lucca, Italy
[2]Anatomy Department, Sapienza University of Rome, Rome, Italy

Corresponding author:
Giovanni Mosti, Clinica MD Barbantini, Via del Calcio n.2, 55100 Lucca, Italy.
Email: giovanni.mosti10@gmail.com

immersion (WI) elicits an immediate reduction of vein caliber accompanied by the increase of blood return and, in legs with venous insufficiency, the reduction of reflux.[4] More recently, underwater Strain Gauge Plethysmography (uSGP) showed a decrease of leg volume immediately after the immersion and a further decrease during a short walking into the pool maybe due to an increased ejection fraction (EF) of the calf muscles.[5]

The aim of this study was to evaluate the effects of a prolonged WI on the leg volume and epifascial thickness in otherwise healthy volunteers with pitting occupational edema (OE), defined as the edema developing during the time period of the working day and disappearing overnight.[6–9] Results obtained after 30' of immobile standing or continuous walking in a standard pool were compared with those achieved after 30' of continuous walking on ground.

Material and methods

Study cohort

Fourteen healthy volunteers (9 females, 5 males, mean age 53 ± 10 years; BMI range 18–25) working mainly in standing/sitting position (3 nurses, 2 physicians, 7 shop assistants, 2 company employees) showing an evening OE were enrolled in this study and both their legs were tested. Before the test all the volunteers did their usual job that, in our country, lasts eight hours during which all the volunteers worked standing or sitting keeping on for the whole shift.

Inclusion criteria were: age from 18 to 65 years, OE in the absence of venous and lymphatic disorder as assessed by clinical examination, clinical history, and Duplex scanning.

Pregnancy or breast-feeding, venous or lymphatic disorder, absence of OE, presence of systemic diseases or use of drugs possibly causing leg edema were considered exclusion criteria.

Study protocol

All the volunteers were tested at the same hour in the late afternoon (6 pm) after their working shift performed from the morning to the time test, at the end of Summer 2019 in the Dalia swimming pool (Pietrasanta, Lucca, Italy). Air temperature was 26–28°C and the humidity average rate 70%. The volunteers were trained to walk in circle in the pool and to walk along a well-established path on ground with a fixed pace. After the training the volunteers were asked:

- to stay standing still for 30 minutes in the pool (water depth 110 cm, water temperature 30°C) without any standing support.
- to continuously walk, again for 30', in the same pool at a constant water depth of 110 cm.
- to walk on ground for 30' without interruptions.

The three tests were performed in three consecutive days, in a randomized sequence (list randomizer www.random.org) to minimize all the possible variables. Leg volume, ankle circumference and epifascial thickness measured at ankle level were assessed every day before and after the tests in order to get daily data for every single test. All the measurements were taken by the same doctor in a not blinded setting.

Measuring systems

Leg volume was measured by water displacement volumetry (WDV).[10] The right leg was always measured before the left one. The spout of the WDV container was at 38 cm from the bottom. The water discarded after leg immersion was weighted by an electronic scale.

Ankle circumference was measured by tape 5 cm above the medial malleolus and an indelible mark was placed in order to repeat measurements in a consistent site. At the same level the thickness of the epifascial layer was measured by Duplex Ultrasound (S9, Sonoscape Shenzen, China), with a 7.5–12 MHz probe according to the "no touch technique": a great amount of gel was used to ensure ultrasound transmission avoiding any contact between the probe and the skin.[11] Epifascial thickness was measured as the distance between the epidermal echoes and the muscular fascia (so to include both cutaneous and subcutaneous layers) by a line crossing the great saphenous vein lumen to obtain reproducible measurements (Figure 1).

Ethics

All the volunteers gave their informed consent before enrollment. The study was performed according to the principles of the World Medical Association Declaration of Helsinki. Ethical committee approval is not required by the Italian authorities for observational studies. In addition, all the procedures were noninvasive, without any drug or medical device, of short duration and performed by healthy subjects under continuous medical surveillance.

Statistical analysis

Median values and interquartile ranges are given as data are not normally distributed. For data comparisons the Friedmann test with multiple comparison was used. Paired Wilcoxon tests were performed to compare two sets of data. The difference between right and left leg and between male and females was not analyzed since the number of subjects was too small

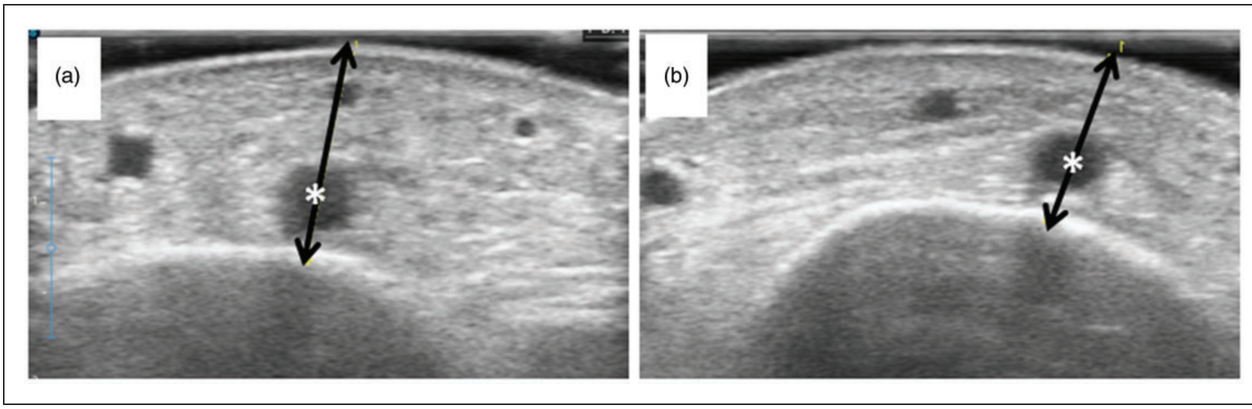
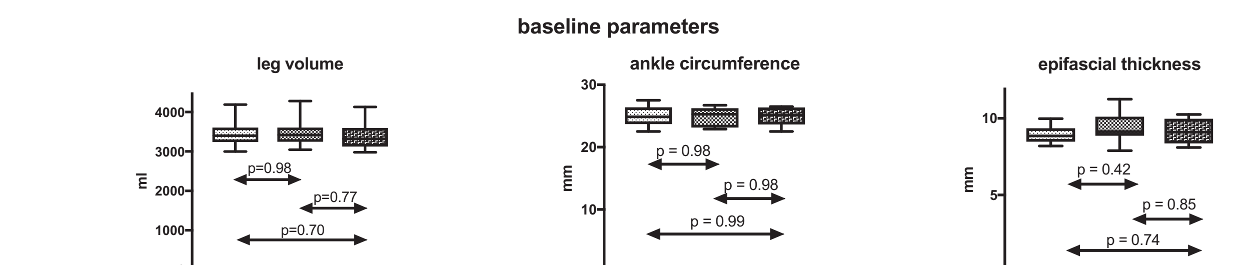


Figure 1. Sonographic measurement of skin thickness at the ankle, that was measured by crossing the great saphenous vein (*) lumen. (a) Before immersion (11.86 mm). (b) After 30' standing still into the pool (10.06 mm). Skin thickness reduction was 19.6%.



	1st day	2nd day	3rd day
Minimum	2998	3046	2980
25% Percentile	3243	3247	3116
Median	3404	3424	3370
75% Percentile	3608	3608	3651
Maximum	4191	4282	4130
Lower 95% CI of mean	3339	3346	3247
Upper 95% CI of mean	3614	3634	3563

	1st day	2nd day	3rd day
Minimum	22,5	22,9	22,5
25% Percentile	23,7	23,2	23,6
Median	24,9	25,3	25,2
75% Percentile	26,4	26,3	26,4
Maximum	27,5	26,7	26,5
Lower 95% CI of mean	23,9	23,8	23,9
Upper 95% CI of mean	26,2	26,0	26,0

	1st day	2nd day	3rd day
Minimum	8,2	7,9	8,1
25% Percentile	8,5	8,9	8,4
Median	8,9	9,1	9,1
75% Percentile	9,4	10,1	10,0
Maximum	10,0	11,3	10,3
Lower 95% CI of mean	8,5	8,7	8,6
Upper 95% CI of mean	9,4	10,1	9,7

Figure 2. Baseline values of leg volume, ankle circumference and epifascial thickness in the three different days of the tests. Data are reported as medians and interquartile range (IQR).

to make a meaningful comparison. Differences with a $P<.05$ were considered statistically significant. Statistical evaluations and the graphs were generated by Graph Pad Prism, version 7, software (Graph Pad, San Diego, Ca, USA).

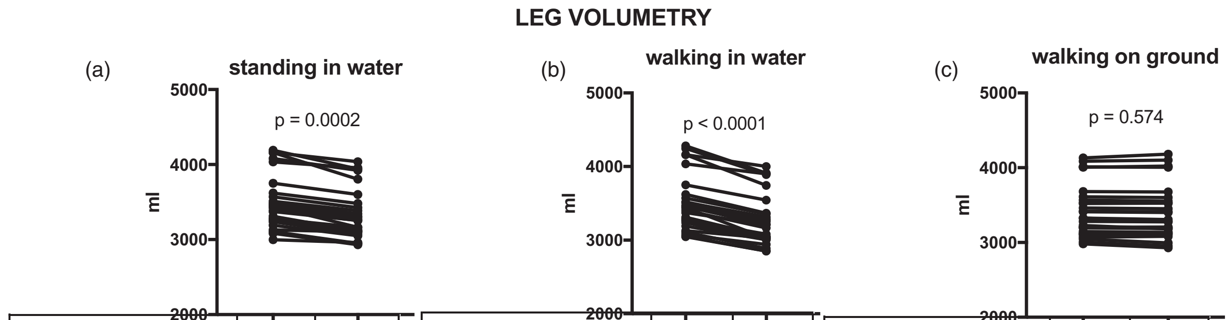
Results

Baseline measurements

Leg volume, ankle circumference and epifascial thickness showed only minor, not significant changes in the three consecutive test days (Figure 2).

Leg volume. Compared to the baseline value of 3404 ml (IQR 3243–3608 ml), the leg volume significantly decreased to 3255 ml (IQR 3102–3467 ml), with a median difference by 149 ml (–4.20%) after 30 minutes of immobile standing immersion ($p = 0.0002$). Leg volume decreased even more from 3424 ml (IQR 3247–3608 ml) to 3188 ml (IQR 3027–3364 ml) with a median difference by 236 ml (–6.50%), when the patients walked in the pool ($p < 0.0001$). The difference between leg volume reduction after immobile immersion and after walking in water was statistically significant ($p < 0.0001$). After walking on ground for 30' leg volumetry showed a very small and not significant reduction from 3370 ml (IQR 3116–3651 ml) to 3355 ml (IQR 3125–3646 ml) with a difference by 15 ml (–0.20%) after walking (Figure 3).

Ankle circumference. Compared to baseline value of 24.85 cm (IQR 23.68–26.38 cm), the ankle circumference significantly decreased to 24.10 cm (IQR 22.9–25.85),



(a) standing in water

	pre	post
Minimum	2998	2930
25% Percentile	3243	3102
Median	3404	3255
75% Percentile	3608	3467
Maximum	4191	4039
Lower 95% CI of mean	3339	3196
Upper 95% CI of mean	3614	3454

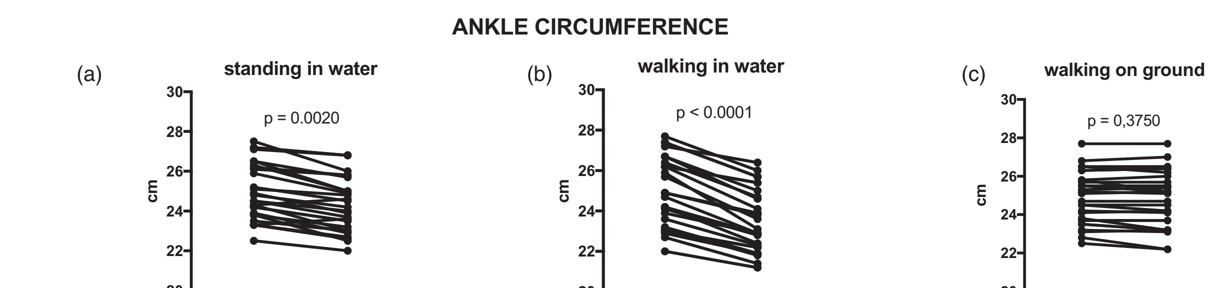
(b) walking in water

	pre	post
Minimum	3046	2850
25% Percentile	3247	3027
Median	3424	3188
75% Percentile	3608	3364
Maximum	4282	4002
Lower 95% CI of mean	3346	3127
Upper 95% CI of mean	3634	3392

(c) walking on ground

	pre	post
Minimum	2980	2929
25% Percentile	3116	3125
Median	3370	3355
75% Percentile	3651	3646
Maximum	4130	4180
Lower 95% CI of mean	3166	3153
Upper 95% CI of mean	3705	3716

Figure 3. Leg volumetry before and after: (a) standing in water, (b) walking in water, (c) walking on ground. Data are reported as medians and interquartile range (IQR).



(a) standing in water

	pre	post
Minimum	22,5	22
25% Percentile	23,7	22,9
Median	24,9	24,1
75% Percentile	26,4	25,9
Maximum	27,5	26,8
Lower 95% CI of mea	23,9	23,1
Upper 95% CI of mea	26,2	25,4

(b) walking in water

	pre	post
Minimum	22,9	21,9
25% Percentile	23,2	22,1
Median	25,3	23,0
75% Percentile	26,3	24,8
Maximum	26,7	25,4
Lower 95% CI of mea	23,8	22,5
Upper 95% CI of mea	26,0	24,3

(c) walking on ground

	pre	post
Minimum	22,5	22,2
25% Percentile	23,6	23,2
Median	25,2	25,2
75% Percentile	26,4	26,3
Maximum	26,5	26,5
Lower 95% CI of mea	23,9	23,7
Upper 95% CI of mea	26,0	25,9

Figure 4. Ankle circumference before and after: (a) standing in water, (b) walking in water, (c) walking on ground. Data are reported as medians and interquartile range (IQR).

with a median difference by 0.75 cm (–2.89%) with the subjects staying standing still in water ($p = 0.02$). Ankle circumference decreased even more after 30' walking in the pool from 25.30 cm (IQR 23.15–26.26 cm) to 23 cm (IQR 22.13–24.78 cm) with a median difference by 2.3 cm (–5.98%) ($p = 0.0002$). Again, the reduction of ankle circumference after walking was significantly greater than that after standing still ($p = 0.003$). Walking for 30' on ground did not change the ankle circumference that measured 25.2 cm (IQR 23.63–26.35) before walking and 25.2 cm (IQR 23.2–26.25) after walking (Figure 4).

Epifascial thickness. Compared to the baseline value out of the water of 8.86 mm (IQR 8.47–9.36 cm), the epifascial thickness decreased to 6.7 mm (IQR 6.16–6.85 mm) with a difference by 2.16 mm (–24.35%) ($p < 0.01$) when the volunteers remained standing still and from 9.13 cm (IQR 8.87–10.2 mm) to 6.68 (IQR 6.13–7.28) with a difference by 2.45 mm (–32.66%) ($p < 0.0003$) after walking. The reduction of epifascial thickness after walking was significantly greater than that after immobile standing ($p = 0.009$). Walking on ground for 30' did not produce a significant variation of epifascial thickness that remained basically unchanged: mm 9.09 (IQR 8.37–9.97 mm) and mm 9.05 (IQR 8.25–9.22 mm) pre- and post-walking on ground respectively (Figure 5).

Minor differences between baseline measurements are due the fact that leg volume, epifascial thickness and ankle circumference were evaluated in the evening of the three different days.

Discussion

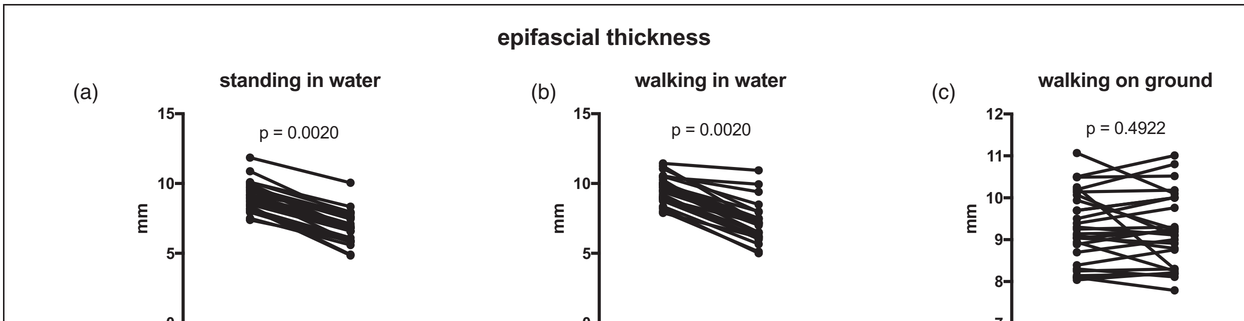
Objective hemodynamic and morphologic parameters regarding beneficial effects of balneotherapy in patients with CVD, were poorly evaluated in the past[12–14] and most of these studies are not fully accepted because of pitfalls in methodology.[3] Very few studies have objectively demonstrated the effects of the immersion into a pool on the venous system. Only recently were the immediate effects of WI on the leg veins and calf volume investigated.[4,5]

In this study we assessed the effects of prolonged WI on OE that consists in leg edema occurring in the evening due to daytime activities (even in the absence of venous disease)[6–9] and is "*the result of a physiologic phenomenon. It is caused by extravasation of fluid from the venules because of a steadily increased venous pressure in the dependent regions of the body, owing to gravity*".[6]

OE disappears overnight to reappear at the end of the following working day as proved by the baseline assessment of the three examined parameters showing a minor daily variability without any statistically significant difference (Figure 2). This is why we could perform the three tests on three consecutive days without waiting for a longer time as already shown in previous studies on occupational edema.[6] In addition, the consistency of the daily baseline value of the three parameters excluded the possible influence of previous tests on the subsequent result. Regardless, in order to avoid any possible training effect and to minimize the possible variables, the sequence of the tests was randomized.

In our study we demonstrated that WI is effective in reducing OE both by standing still or by continuously walking.

Immobile standing for 30' in a 110 cm deep pool resulted in a significant reduction of the leg volume, ankle circumference and epifascial thickness. Leg volume reduction occurring after static immersion is due to the leg compression by water Hydrostatic Pressure (wHP). According to the Stevin's law,[15] a 110 cm column of water exerts, at bottom of the pool, a wHP of 81 mmHg decreasing by 0.73 mmHg per centimeter upwards. Therefore, we can assume that in standing position, wHP ranges approximately between



(a)

	pre	post
Minimum	8,2	4,9
25% Percentile	8,5	6,2
Median	8,9	6,7
75% Percentile	9,4	6,8
Maximum	10,0	7,1
Lower 95% CI of mea	8,5	5,8
Upper 95% CI of mea	9,4	7,0

(b)

	pre	post
Minimum	7,9	6,0
25% Percentile	8,9	6,1
Median	9,1	6,5
75% Percentile	10,1	7,3
Maximum	11,3	9,9
Lower 95% CI of mean	8,7	6,1
Upper 95% CI of mean	10,1	7,8

(c)

	pre	post
Minimum	8,1	7,8
25% Percentile	8,4	8,3
Median	9,1	9,1
75% Percentile	10,0	9,2
Maximum	10,0	10,0
Lower 95% CI of mea	8,6	8,4
Upper 95% CI of mea	9,7	9,3

Figure 5. Epifascial thickness before and after: (a) standing, (b) walking in water, (c) walking on ground. Data are reported as medians and interquartile range (IQR).

65–70 mm Hg at gaiter level and between 55–60 mm Hg at the mid-calf. This strong pressure could explain the great leg volume reduction in our case series that is significantly higher[6,16] or similar[17,18] compared to other studies evaluating the effects of graduated compression stockings. Unfortunately, in these other studies[16–18] different protocols and measuring systems make detailed comparison with our results challenging.

The reduction of the calf volume occurring immediately after immersion shown by uSGP[5] is related to the reduction of intravascular volume by narrowing the deep and superficial veins, as demonstrated by uDS.[4] Prolonging the immersion, the wHP causes a further leg volume decrease mainly due to the reduction of the epifascial layer thickness. The reduction of the fluid content of the epifascial layer may be explained by the reduction of venular fluid filtration and by the improvement of the peripheral lymphatic drainage due to wHP. The squeezing effect of wHP on leg tissue most likely forces the interstitial fluid into the lymphatic vessels as venous reabsorption has been excluded by the new knowledge on tissue fluid exchange.[19] On the contrary, it has been shown that compression increases the tension on the anchoring filaments of the initial lymphatics by increasing the tissue pressure. Initial lymphatics will be opened and lymphatic flow will be pushed towards the lymph collectors by their valves. Rhythmic autonomous contractions of the collectors provide the main force of further lymph drainage.[20] Also leg bioimpedance demonstrated that the reduction in volume of the leg is due to a reduction of the extracellular water both after walking with compression garments,[17] or after great saphenous vein catheter foam.[21]

Comparing in-water immobile standing and exercising, the latter resulted in a significantly greater reduction of the leg volume (236 ml vs 150 ml as an average), ankle circumference and epifascial thickness. A mutual enhancement of the effects of wHP and muscle pumping on venous hemodynamics and lymphatic reabsorption may explain these outcomes. It was actually shown that muscle contraction acts as an extrinsic pump on lymphatic flow so increasing interstitial fluid reabsorption.[22,23]

WDV did not show any significant reduction of the leg volume and ankle circumference in the same subjects after walking on ground for 30' at precisely the same time of the day and in the same atmospheric conditions. Even if this observation is in conflict with the common belief that walking facilitates peripheral drainage, it was already described by other authors by using different measuring systems: impedance plethysmography,[24] strain gauge plethysmography,[25] and "truncated cone formula".[17] These studies could be theoretically criticized because strain gauge plethysmography measures only segmental volume variations of the calf, whereas the "truncated cone measurement" excludes the foot volume. However, our data obtained by WDV, that is considered the gold standard for leg volume measurement,[10] confirm that leg volume does not decrease by walking in patients with OE. Volume reduction only occurs when walking is associated with stockings wearing.[8,17,26]

Our findings are in agreement with previous studies reporting a WI-related reduction of leg edema.[27–30] In all these studies the volume reduction was demonstrated utilizing more complex protocols which sometimes[28,30] required longer WI time, and multiple exercises that required assistant personnel for some patients, especially the older ones. Furthermore, in one of these studies, the effects of WI were evaluated in pregnant women in whom the edema is related to fluid and salt retention in addition to dependency and activity restrictions. In a more recent study in patients with chronic leg edema, the effects of a long series of exercises performed in a rehabilitation pool were not compared with those of similar activities when performed on-ground.[30]

It is noteworthy to consider that, despite of more complex protocols, it is our impression that it can be challenging to standardize walking, to check the correct execution of bodyweight exercises, to assess the reproducibility of the exercises, and to objectively quantify the real extent of underwater muscular activities.

Our protocol, based on simple walking in water, does not require a rehabilitative pool nor the assistance of dedicated personnel and can be feasible independently by everybody, even by patients with neuromuscular or osteoarticular impairment.

Finally, it is important to observe that our results were achieved with water height of 110 cm to exert a strong pressure on the leg tissues. Possible differences related to patient height are negligible because, in these conditions, the wHP at the bottom of the pool is higher than 70 mm Hg and able to counteract the intravenous pressure in the standard population.

One weakness of this study regards the epifascial thickness measurement. In practice, measuring exactly the epifascial thickness at precisely the same point of the leg and at the same angle can be sometimes difficult. It is true that the reduction of epifascial thickness was consistent in all the measurements and systematically correlates with leg volume reduction. Another weakness is that we have not enrolled patients with CVD or lymphedema, but just included healthy volunteers with OE. However, OE is due to venous stasis and lymphatic impairment and is treated by compression stockings like CVD.[6,31] Accordingly, we believe that OE represents an optimal model for a basic study on the effects of WI in CVD patients in which edema can be related to different pathophysiologic mechanisms (obstruction, incompetence, inflammation, etc). Further and larger studies are necessary to draw conclusions about the amount and duration of clinical effects of a complete balneotherapy treatment and to compare the effect of balneotherapy with other modalities of mechanical treatment of leg edema.

Conclusions

This study proved that a prolonged WI is effective in reducing leg edema and that underwater walking enhances this phenomenon. This is possibly due to the combined effects of wHP and muscle pumping on venous hemodynamics and lymphatic drainage. An in-progress study includes that patients with CVD will evaluate the possible implication of underwater walking in the treatment and rehabilitation of venous diseases.[32]

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical approval

Not requested in Italy for observational studies not involving drugs od devices as in our study.

Guarantor

GM.

Contributorship

Both authors contributed in preparing the protocol, performing the study and writing the manuscript. GM was involved in performing the statistical analysis.

ORCID iD

Giovanni Mosti https://orcid.org/0000-0001-7639-8463

References

1. Carpentier PH, Blaise S, Satger B, et al. A multicenter randomized controlled trial evaluating balneotherapy in patients with advanced chronic venous insufficiency. *J Vasc Surg* 2014; 59: 447–454.
2. Forestier RJ, Briancon G, Francon A, et al. Balneohydro-therapy in the treatment of chronic venous insufficiency. *Vasa* 2014; 43: 365–371.
3. de Moraes Silva MA, Nakano LC, Cisneros LL, et al. Balneotherapy for chronic venous insufficiency. *Cochrane Database Syst Rev* 2019; 8: CD013085.
4. Caggiati A, Lattimer C, Kalodiki E, et al.; Underwater Compression Group. Underwater sonography of leg veins. *EJVES Short Rep* 2018; 41: 13–15.
5. Mosti G, Bergamo G, Oberto S, et al. The feasibility of underwater computerized strain gauge plethysmography and the effects of hydrostatic pressure on the leg venous hemodynamics. *EJVES Vasc Forum* 2020; 47: 60–62.
6. Partsch H, Winiger J and Lun B. Compression stockings reduce occupational leg swelling. *Dermatol Surg* 2004; 30: 737–743.
7. Mosti G and Partsch H. Occupational leg oedema is more reduced by antigraduated than by graduated stockings. *Eur J Vasc Endovasc Surg* 2013 May; 45: 523–527.
8. Quilici Belczak CE, Pereira de Godoy JM, Seidel AC, et al. Comparison of 15–20 mmHg versus 20–30 mmHg compression stockings in reducing occupational oedema in standing and seated healthy individuals. *Int J Vasc Med* 2018; 2018: 2053985.
9. Shibasaki S, Kishino T, Yokoyama T, et al. Sonographic detection of physiological lower leg oedema in the late afternoon in healthy young women. *Clin Physiol Funct Imaging* 2020; 40: 381–384.
10. Rabe E, Carpentier P and Maggioli A. Understanding lower leg volume measurements used in clinical studies focused on venous leg edema. *Int Angiol* 2018; 37: 437–443.
11. Caggiati A. Ultrasonography of skin changes in legs with chronic venous disease. *Eur J Vasc Endovasc Surg* 2016; 52: 534–554.
12. Ernst E, Saradeth T and Resch KL. A single blind randomized, controlled trial of hydrotherapy for varicose veins. *Vasa* 1991; 20: 147–155.
13. Mancini S Jr, Piccinetti A, Nappi G, et al. Clinical, functional and quality of life changes after balneokinesis with sulphurous water in patients with varicose veins. *Vasa* 2003; 32: 26–30.
14. Hartmann B, Drews B, Kayser T, et al. Venous function in patients with venous disease and healthy controls before and after a bathing procedure and subsequent cold stimulus. *J Japanese Assoc Phys Med Balneol Climatol* 1995; 58: 134–134.
15. Bettini A. *A course in classical phisics-2. Fluids and thermodynamics*. Berlin: Springer p.8.
16. Wou J, Williams KJ and Davies AH. Compression stockings versus neuromuscular electrical stimulation devices in the management of occupational leg swelling. *Int J Angiol* 2015; 25: 104–109.
17. Gianesini S, Raffetto JD, Mosti G, et al. Volume control of the lower limb with graduated compression during different muscle pump activation conditions and the relation to limb circumference variation. *J Vasc Surg Venous Lymphat Disord* 2020; 8: 814–820.
18. Gianesini S, Mosti G, Sibilla MG, et al. Lower limb volume in healthy individuals after walking with compression stockings. *J Vasc Surg Venous Lymphat Disord* 2019; 7: 557–561.
19. Levick JR and Michel CC. Microvascular fluid exchange and the revised starling principle. *Cardiovasc Res* 2010; 87: 198–210.

20. Moffatt C, Partsch H, Schuren J, et al. *International lymphoedema framework position document*. pp.15–16. Deborah Glover, Editor. Imprimerie Reboul, Saint-Étienne, France. June 2012
21. Cavezzi A, Mosti G, Colucci R, et al. Compression with 23 mmHg or 35 mmHg stockings after saphenous catheterfoam sclerotherapy and phlebectomy of varicose veins: a randomized controlled study. *Phlebology* 2019; 34: 98–106.
22. Moore JE Jr and Bertram CD. Lymphatic system flows. *Annu Rev Fluid Mech* 2018; 50: 459–482.
23. Olszewski W. Contractility patterns of human leg lymphatics in various stages of obstructive lymphedema. *Ann N Y Acad Sci* 2008; 1131: 110–118.
24. Stick C, Stöfen P and Witzleb E. On physiological edema in man's lower extremity. *Eur J Appl Physiol Occup Physiol* 1985; 54: 442–449.
25. Stick C, Hiedl U and Witzleb E. Volume changes in the lower leg during quiet standing and cycling exercise at different ambient temperatures. *Eur J Appl Physiol Occup Physiol* 1993; 66: 427–433.
26. Quilici Belczak CE, Pereira De Godoy JM, Quilici Belzack S, et al. Compression stockings have a synergistic effect with walking in the late afternoon to reduce edema of the lower limbs. *Int Angiol* 2012; 31: 490–493.
27. Irion JM and Irion GL. Water immersion to reduce peripheral edema in pregnancy. *J Women's Health Phys Ther* 2011; 35: 46–49.
28. Hartmann S and Huch R. Response of pregnancy leg edema to a single immersion exercise session. *Acta Obstet Gynecol Scand* 2005; 84: 1150–1153.
29. Kent T, Gregor J, Deardorff L, et al. Edema of pregnancy: a comparison of water aerobics and static immersion. *Obstet Gynecol* 1999; 94: 726–729.
30. Gianesini S, Tessari M, Bacciglieri P, et al. A specifically designed aquatic exercise protocol to reduce chronic lower limb edema. *Phlebology* 2017; 32: 594–600.
31. Amsler F and Blattler W. Compression therapy for occupational leg symptoms and chronic venous disorders e: a meta-analysis of randomised controlled trials. *Eur J Vasc Endovasc Surg* 2008; 35: 366–372.
32. Caggiati A, De Maeseneer M, Cavezzi A, et al. Rehabilitation of patients with venous diseases of the lower limbs: State of the art. *Phlebology* 2018; 33: 663–671.