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Quantitative Measurement of Lymphedema Using Tissue Dielectric Constant and Bioimpedance Analysis

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Introduction

In the clinical diagnosis of lymphedema, various methods such as arm circumference or volume measurements, perometer, and bioimpedance analysis (BIA) are utilized. Tissue dielectric constant (TDC) is emerging as a tool for evaluating lymphedema by measuring skin moisture content within seconds using a portable device that makes direct contact with the skin. TDC allows for measurements on any body part, including the trunk and breast, providing quick results within seconds. This study aims to quantitatively assess the efficacy of lymphedema therapy in healthy individuals using TDC and BIA, evaluating the utility of these measurement methods.

Methods

A total of 31 healthy participants, including 12 males and 19 females in their twenties, underwent treatment for lymphedema, including pumping and clearing the terminus, manual lymphatic drainage (MLD), and low-level laser therapy (LLLT) (Figure 1). TDC measurements were conducted using a Lymphscanner (Delfin Technologies, Kuopio, Finland) before treatment, after MLD, and after LLLT. A handheld probe contacted 9 sites on both dominant and non-dominant arms for approximately 10 seconds each, generating results displayed as a percentage of water content (PWC) on the device. Additionally, BIA was performed using an InBody S10 device (InBody, Seoul, Republic of Korea). BIA data comprised segmental water, extracellular water (ECW)/total body water (TBW), impedance at 1 kHz and 5 kHz, and expected impedance measured at 0 Hz (R0) of each arm. Pre- and post-treatment TDC and BIA data underwent analysis through paired t-tests.

Results

In the dominant arm, statistically significant changes in PWC% after MLD were solely observed in the breast and trunk regions, with no notable differences across the remaining 7 sites (Table 1). Post-LLLT assessment revealed no significant changes in any of the 9 sites. Among BIA data, only impedance at 5kHz and R0 exhibited statistically significant differences in pre- and post-treatment (Table 2). Interlimb comparison shows significant changes only in PWC after MLD in the trunk and breast.

Table 1. Pre, post-treatment percentage of water content (PWC)

Location	PWC% in dominant side							*P* value	
	pre	Post-MLD			Post-LLLT				
	mean±SD	mean±SD	Difference mean±SD	*P value*	mean±SD	Difference mean±SD	*P* value	Post-MLD	Post-LLLT
Ventral forearm	41.17±4.76	41.97±5.43	-0.80±3.79	0.252	41.94±6.27	-0.03±3.25	0.956	0.038	0.797
Medial upper arm	33.85±5.82	33.45±4.95	-0.40±2.07	0.293	33.49±5.35	0.04±5.29	0.894	0.179	0.123
Ventral upper arm	37.53±6.37	37.29±5.66	-0.24±2.14	0.544	33.72±6.19	0.43±6.54	0.279	0.911	00.557
Shoulder	43.35±5.30	42.96±5.02	-0.40±2.78	0.432	44.23±5.53	1.27±2.43	0.008*	0.119	0.026
Hand	39.98±5.87	40.08±5.00	0.10±4.13	0.897	40.31±5.78	0.24±0.89	0.685	0.310*	0.420
Dorsal forearm	43.95±6.29	44.18±6.63	0.24±3.13	0.677	44.12±6.41	-0.06±3.67	0.847	1.000	0.951
Dorsal upper arm	37.49±4.07	38.14±4.63	0.65±3.15	0.314	37.59±4.34	-0.55±3.31	0.357	0.282	00.852
Trunk	42.40±5.71	38.39±4.53	-4.01±4.73	<0.001*	40.92±5.23	2.54±3.00	<0.001*	0.010*	0.063
Breast	46.44±3.47	44.41±3.22	-2.03±2.80	<0.001*	45.11±3.70	0.70±2.00	0.159	<0.001*	<0.001*

Mean ± SD, *= p<0.05, PWC, percentage of water content; LLLT, low level laser therapy

Table 2. Pre,post-treatment bioimpedance analysis (BIA)

	Dominant side				Non-dominant side		*P*-value
	Pre-treatment mean±SD	Post-treatment mean±SD	difference mean±SD	p-value	Pre-treatment mean±SD	Post-treatment mean±SD	
Segmental Water	1.92±0.62	1.93±0.62	0.01±0.07	0.596	1.91±0.63	1.89±0.61	0.042*
ECW/TBW	0.38±0.00	0.38±0.00	0.00±0.00	0.344	0.38±0.00	0.38±0.61	0.187
Impedance(1Hz)	397.21±59.42	401.58±59.42	4.37±59.53	0.082	396.71±59.56	406.00±3.61	0.155
Impedance(5kHz)	387.38±56.48	392.78±56.48	5.40±56.69	0.015*	388.90±56.34	397.95±4.61	0.242
R0	407.23±58.14	414.28±58.14	7.05±58.13	0.021*	40.8.97±58.35	419.31±0.61	0.394

Mean ± SD, *= p<0.05, ECW, extracellular water; TBQ, total body water

Conclusion

Through TDC, we quantitatively measure tissue water content in specific sites and evaluated significant therapeutic impacts of lymphedema treatment. The ability to measure moisture content swiftly and effortlessly in various areas, including the trunk and breast, represents a pivotal advantage of TDC. Further research, including the integration of TDC with methods like BIA, will expand our understanding of lymphedema and its treatment outcomes.