

SPATIAL VARIATION IN TISSUE DIELECTRIC CONSTANT (TDC) VALUES ALONG THE LEG OF HEALTHY YOUNG ADULT FEMALES ASSOCIATED WITH COMPRESSION BANDAGING

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Abstract

Introduction:

Compression is an established therapeutic tool utilized for the management of edema of multiple etiologies and in the management of venous leg ulcers.¹⁻³ Assessing compression-related biophysical changes of a localized area, such as around a wound, or in an area outside of an extremity cannot be assessed by local circumferential measurement. Tissue dielectric constant (TDC), which provides a measure of the local tissue water content (LTWC), offers an alternative method to document variation in LTWC of the skin in a specific location.^{4,5} Such localized assessments can provide insight into the effects of a treatment intervention at localized areas such as those associated with compression bandage or compression application. To date such TDC measurements at multiple target sites in combination with compression has not been reported. Aims of the study: 1) Characterize the TDC measurements from multiple areas along the medial aspect of the lower limb in healthy volunteers; 2) Explore the potential utilization of the TDC to assess change in LTWC in a focused area following application of three different compression applications.

Methods:

TDC was used to document LTW content following the application of three different compression conditions: longitudinal elastic stockinette, 2-layer cohesive compression system, and combination of the two. (N=18). Assessments were made at four time points, and four locations. Statistical analysis was performed to analyze comparative changes from baseline and between compression conditions. (Fig. 1)

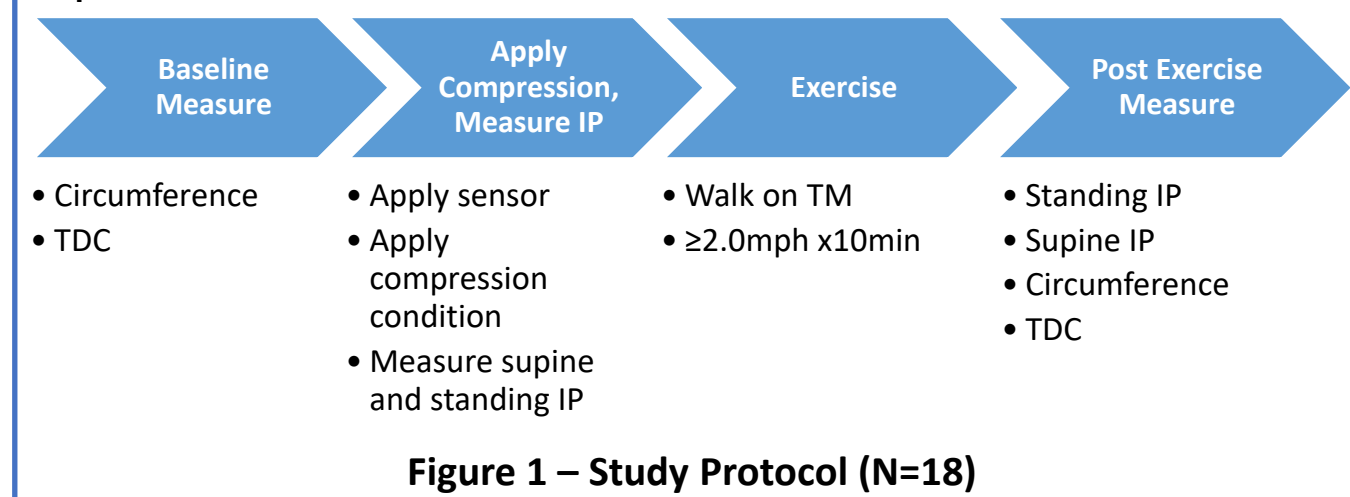
Results:

Variation in LTW content was observed spatially at baseline and remained after the intervention for all compression conditions assessed. There was a statistically significant change from baseline for all the compression conditions. However, no significant differences between the compression applications was observed.

Discussion/Conclusion:

Measuring impact of a compression application, beyond segmental changes in circumferential measurements has the potential to provide insight into the biophysical impact of specific compression textile locally. Spatial variations in LTWC observed in healthy subjects and the demonstrated reliability of the TDC values in these healthy non-edematous conditions provide further support for the utility of such applications of TDC measurements. The extension to patients with lower extremity edema or lymphedema needs to be evaluated.

Methods



IP

Interface pressure (IP, dosage = mmHg) created with the application of a compression textile was measured via TEKscan I-scan® piezoelectric sensor applied to the medial aspect of the right lower extremity. The sensor allowed visualization pressure distribution vertically and horizontally.



Figure 2 – Measurement of Interface Pressure

TDC

Tissue dielectric constant (TDC) is a non-invasive, convenient, reliable and accurate method to assess local tissue water content (LTWC). Using an open-ended coaxial probe, a low power 300MHz signal is transmitted into the skin. Based on the portion of the portion transmitted back, a TDC value is determined.

The TDC value contains both free and bound water in the tissue. It has been used to assess lower limb edema, lymphedema and both post-operative and post-treatment changes. The MoistureMeterD compact (MMDC) was utilized (Delfin Technologies Ltd, Finland).

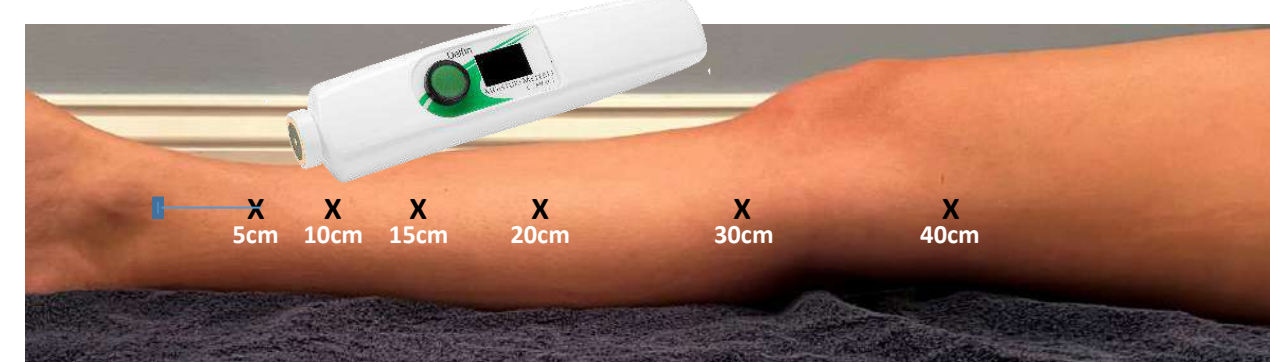


Figure 3 – Measurement of Local Tissue Water Content

Results

Measurement Location	Baseline		Post Intervention	
	Circumference (cm)	95% CI for ICC _(3,1)	Circumference (cm)	95% CI for ICC _(3,1)
5cm	22.7 ± 1.5 (20.7 - 25.2)	0.967 (0.928 - 0.987)	22.8 ± 1.4 (20.6 - 25)	0.938 (0.865 - 0.975)
10cm	26.9 ± 1.9 (23.7 - 30.5)	0.970 (0.934 - 0.988)	26.9 ± 1.9 (23.7 - 30.4)	0.980 (0.955 - 0.992)
15cm	30.8 ± 2.6 (27.2 - 36.3)	0.982 (0.961 - 0.993)	31.6 ± 2.4 (27.0 - 36.4)	0.986 (0.968 - 0.994)
20cm	35.3 ± 2.0 (31.3-39.6)	0.963 (0.919-0.985)	35.2 ± 2.1 (31.2 - 39.4)	0.992 (0.983 - 0.997)
30cm	33.9 ± 2.2 (29.4 - 37.3)	0.991 (0.979 - 0.996)	33.8 ± 2.2 (29.5 - 37.3)	0.994 (0.986 - 0.997)
40cm	37.7 ± 3.0 (33.4 - 43.8)	0.992 (0.983 - 0.997)	37.8 ± 3.1 (33.5 - 44.6)	0.994 (0.988 - 0.998)

Table 1 – Leg Circumferential Measurements. Baseline and post intervention circumferential measurements at six measuring points on the lower limb of healthy women (N=18).

	Baseline Pressure (mmHg)		Post Exercise Pressure (mmHg)	
	Supine	Standing	Supine	Standing
Longitudinal Elastic Stockinette				
Ankle	10.7 ± 4.2 (4 - 23)	13.8 ± 5.2 (5 - 30)	12.5 ± 4.6 (4 - 26)	14.9 ± 5.2 (5 - 30)
Calf	10.7 ± 3.6 (3 - 23)	12.6 ± 4.7 (5 - 31)	11.6 ± 4.8 (5 - 26)	14.6 ± 5.5 (5 - 32)
2-Layer Cohesive Compression System				
Ankle	27.9 ± 8.7 (8 - 58)	31.6 ± 9.9 (9 - 57)	25.4 ± 9.3 (8 - 56)	35.25 ± 11.2 (11 - 68)
Calf	24.7 ± 9.3 (9 - 48)	26.6 ± 10.4 (10 - 55)	17.4 ± 7.8 (6 - 36)	28.8 ± 10.7 (11 - 54)
Combination				
Ankle	37.5 ± 9.8 (9 - 56)	42.6 ± 11.9 (11 - 69)	27.0 ± 8.9 (9 - 55)	40.0 ± 12.9 (12 - 75)
Calf	35.2 ± 11.9 (12 - 66)	38.3 ± 13.4 (13 - 67)	22.4 ± 10.1 (10 - 60)	37 ± 13.8 (14 - 80)

Table 2 – Interface Pressures. Interface pressures measured at ankle and calf immediately after application of each compression condition (Baseline) and post 10 minutes of exercise. Data in the table are presented as mean ± SD and (Range). SD, Standard deviation.

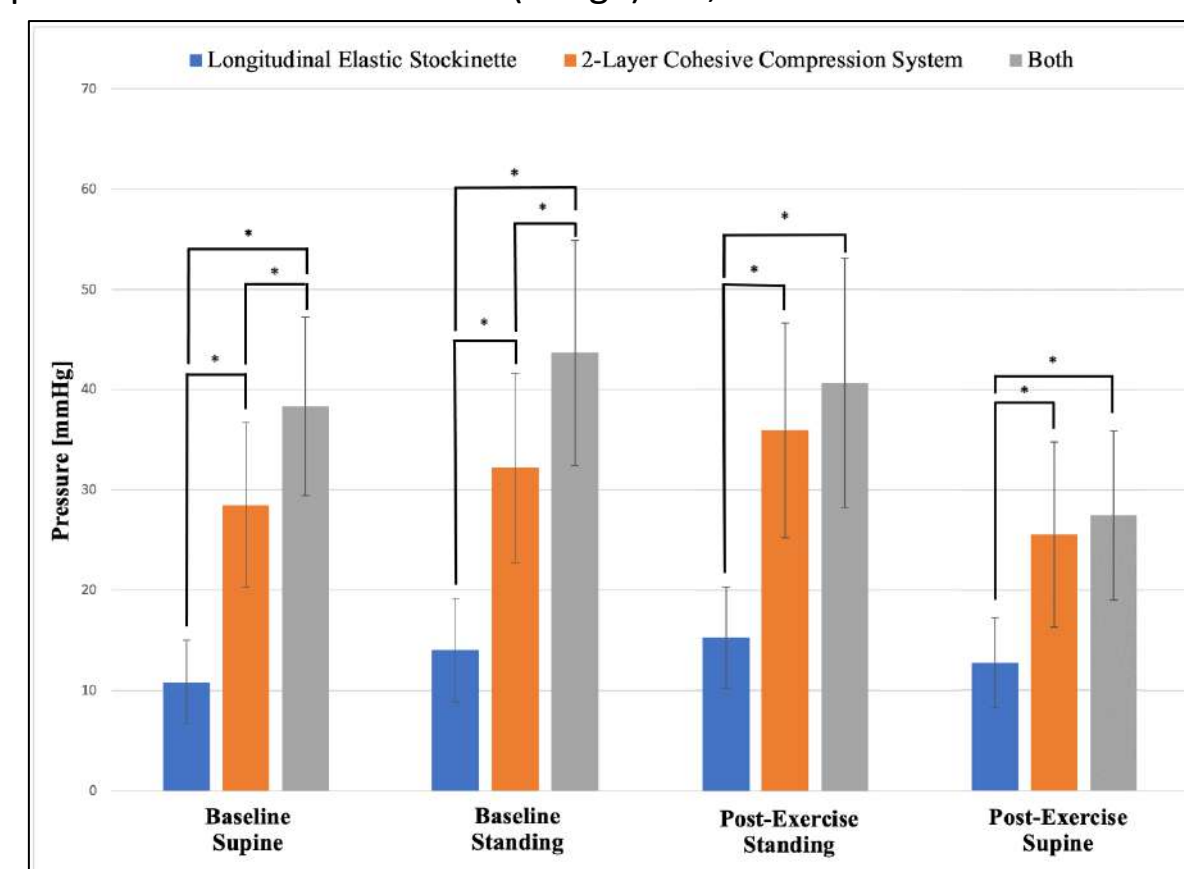


Figure 4 – Interface Pressure Local Averages at Ankle.

Location	Cumulative Average	Session 1	Session 2	Session 3	95% CI for ICC _(3,1)
10cm	43.5 ± 3.4	43.9 ± 3.8 (39.2 – 51.9)	43.5 ± 3.1 (38.2 – 51.4)	43.5 ± 3.8 (34.3 – 52.1)	0.730 (0.409 - 0.893)
20cm	43.9 ± 2.9	44.2 ± 3.9 (38.4 – 52.1)	44.1 ± 2.9 (39.3 – 51.4)	44.2 ± 4.5 (34.3 – 52.2)	.836 (0.636 - 0.934)
30cm	43.6 ± 2.7	42.4 ± 2.9 (34.3 – 45.9)	42.6 ± 2.5 (38.2 – 46.2)	42.7 ± 3.7 (34.3 – 51.3)	.848 (0.664 - 0.939)
40cm	40.5 ± 2.8	40.9 ± 3.1 (34.2 – 46.2)	41.4 ± 2.7 (38.1 – 46.0)	40.8 ± 3.6 (34.3 – 46.0)	.880 (.738 - .951)

Table 3 – Baseline Tissue Dielectric Constant Values. Cumulative average and detailed TDC values expressed as percentage water for each treatment session, at four locations on the medial aspect of the right lower leg of healthy women (N=18). Test-Retest Reliability of TDC (%) is presented as 95% CI for ICC. TDC, Tissue Dielectric Constant; ICC, intraclass correlation coefficient; CI, confidence interval.

Location	Longitudinal Elastic Stockinette		2-Layer Cohesive Compression System		Combination Application	
	Baseline	Post Exercise	Baseline	Post Exercise	Baseline	Post Exercise
10cm	44 ± 3.8 (39.2 - 51.9)	44.6 ± 4.1 p = 0.102	43.5 ± 3.1 (38.2 - 51.4)	42.9 ± 2.8 p = 0.408	43.5 ± 3.8 (34.3 - 52.1)	43.1 ± 4.2 p = 0.256
20cm	44.2 ± 4.0 (38.4 - 52.1)	44.1 ± 3.4 p = 0.811	44.1 ± 3.0 (39.3 - 51.4)	44.0 ± 2.4 p = 0.828	44.2 ± 4.5 (34.3 - 52.2)	43.8 ± 4.7 p = 0.538
30cm	42.4 ± 3.0 (34.3 - 45.9)	43.2 ± 3.0 p = 0.022	42.6 ± 2.5 (38.2 - 46.2)	43.5 ± 2.3 p = 0.026	42.7 ± 3.7 (34.3 - 51.3)	44.2 ± 4.2 p = 0.029
40cm	40.9 ± 3.1 (34.2 - 46.1)	40.5 ± 3.2 p = 0.223	41.4 ± 2.7 (38.1 - 46.0)	40.8 ± 2.5 p = 0.062	40.8 ± 3.6 (34.3 - 51.3)	40.3 ± 3.9 p = 0.049

Table 4 – Effect of intervention on tissue dielectric constant. Tissue dielectric constant expressed as percent water measured on the medial aspect of the right lower limb of healthy women (N=18). Data is presented as mean ± SD and (range) for each test condition. Cumulative average calculated from measurements made immediately after compression removal, and again at 2- and 5-minutes. Wilcoxon Sign Ranks test for the post exercise change with significance level (p) is denoted. SD, standard deviation.

Discussion

- TDC is a quantifiable measure of LTWC.
- Research has shown that there are variations in TDC values among anatomical sites on the lower leg and among clinical devices.
- Variations in TDC values explained by differences in tissue composition at each of the assessed location and the device utilized.
- Utilization of a single measurement to be representative of a larger segmental area can obscure or minimize the effect of a focal treatment.
- TDC documented difference in LTWC not captured by circumferential measurements.

Conclusion

- There is potential for the use of TDC, as a measure of LTWC, as a modality to assess compression related change in lower extremity.
- The absence of significant change in TDC values in these healthy non-edematous conditions provides further support for the utility of such applications of TDC measurements.
- Additional study of patients with lower extremity edema and lymphedema is needed to evaluate.

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2-Layer Cohesive Compression System assessed was CoFlex® TLC (Milliken Healthcare Products, Spartanburg, SC, USA)
Longitudinal Elastic Stockinette assessed was EdemaWear® (Compression Dynamics, Omaha, NE, USA)