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Validation of a mobile NMR sensor for the determination of skin layers and the local estimation of the T2 relaxation time distribution in the lower arm

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1. Purpose

In microgravity the skin of the head shows an oedema whereas the skin of the legs undergoes dehydration. New techniques for in vivo measurements of changes in thickness and fluid content of different skin layers were helpful for studying the mechanisms behind these phenomena of local fluid volume regulation in the skin. In this study the Profile NMR-MOUSE® (Nuclear Magnetic Resonance Mobile Universal Surface Explorer) was evaluated for its capability of measuring the thickness of different dermal layers. Furthermore the sensitivity was tested for significant detection of changes in structure and in T2* contrast evoked by a physical and a pharmacological intervention.

2. Material and Methods

The Profile-NMR-MOUSE

The instrument uses a permanent single sided magnet with 0.47 Tesla. The 1H NMR signals (20 MHz) were recorded in a planar parallel slice of 50 µm thickness at 5700 µm distance from the magnet surface. Using a CPMG sequence 500 echoes were recorded and integrated to calculate the signal intensity (pulse length 5.5µs, echo time 64.5 µs, aquisition time 21.0 µs, 8 averages). By moving the NMR-MOUSE in equidistant 50 µm steps a profile of the skin structure was recorded within 15 min.

Figure 1: The Proflile-NMR-MOUSE in the setup for examinations of the lower left arm

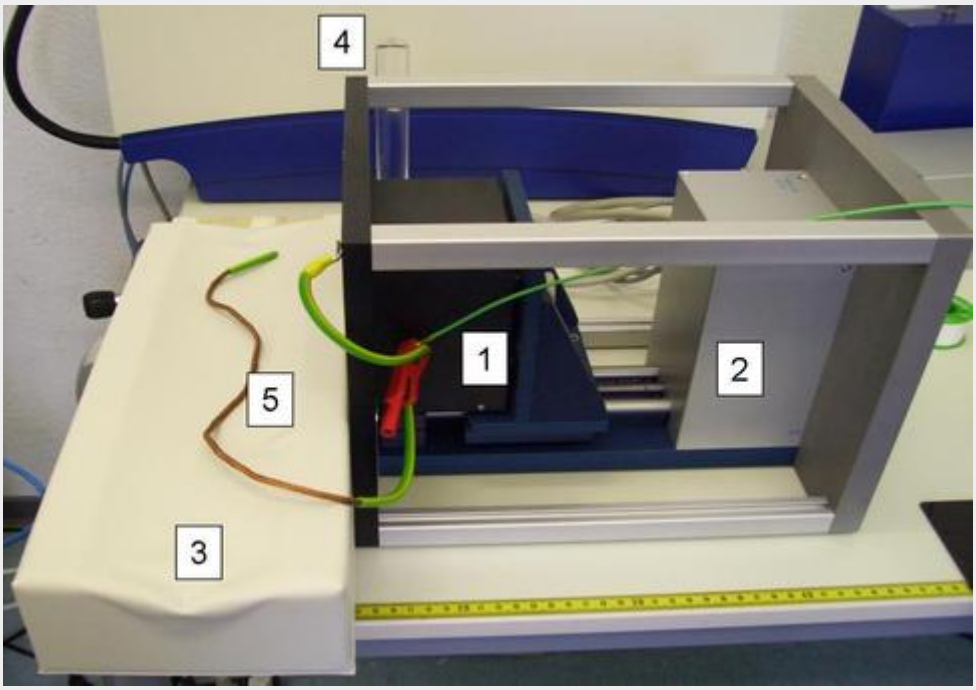

Figure 1: The Profile-NMR-MOUSE in the setup for examinations of the lower left arm. 1) NMR-MOUSE, 2) lift with step motor, 3) cushion, 4) hand grip, 5) grounded RF shield antenna

Skin profiles

For 10 male subjects the skin at the inner side of the left lower arm was examined five times on different days. On each day the skin was examined before and during venous occlusion applied by an air-cuff. Between these two measurements the arm was not moved in the set up.

For comparison the native skin was also measured at the same place for 5 times with a GE instrument using a 10 MHz linear scanner head operating in B mode.

Figure 2: Ultrasound image from the skin

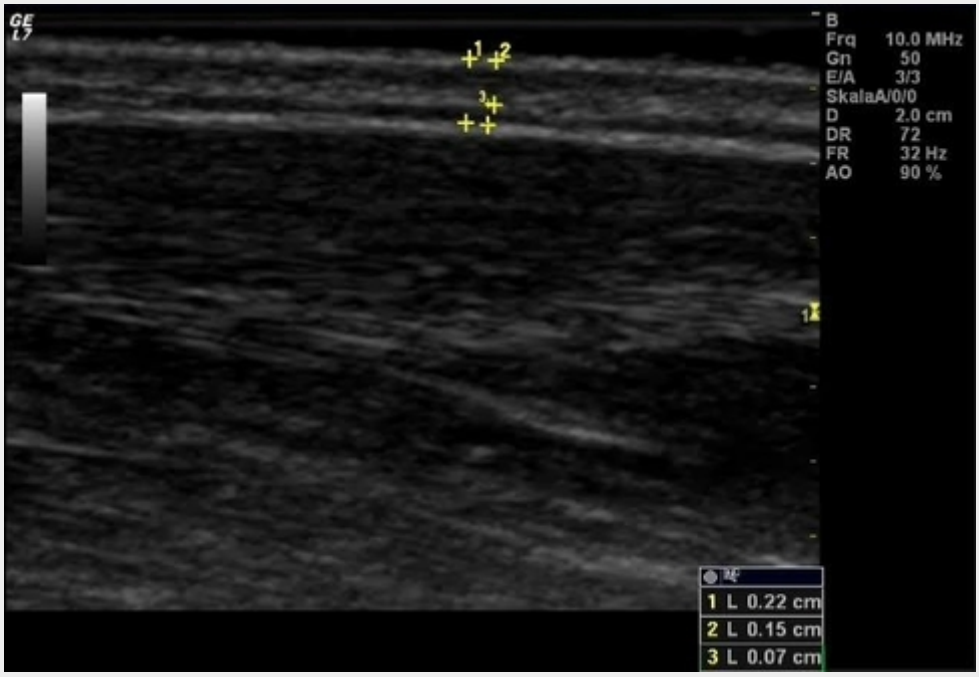

Figure 2: Ultrasound image from the skin. The skin and its two layers are labled with yellow crosses.

T_2*analysis in two dermal layers

In one slice in the dermis and in one in the subcutis the transverse relaxation time T_2* was measured using the same CPMG pulse sequence as for the profiles but signal to noise was improved by increasing the no. of averages to 128. Five male subjects were examined, who were a subgroup of the group examined for skin profiles. Changes in T_2* were provoked by the rheumatic salve Finalgon® which enhances blood volume and flow. Five and 60 minutes after application the measurements were repeated. The acquisition time for each slice was 9 min.

From the 1H spin echo train the short and long T_2* component of the tissue were calculated using an bi-exponential fit.

3. Results

In the NMR-MOUSE profiles two layers were visible: The dermis including the epidermis was characterised by an almost homogeneous signal intensity. The subcutis was characterised by higher and more variable signal intensity. Finally, the muscle fascia was again characterised by lower signal

intensity.

Figure 3: Skin profiles

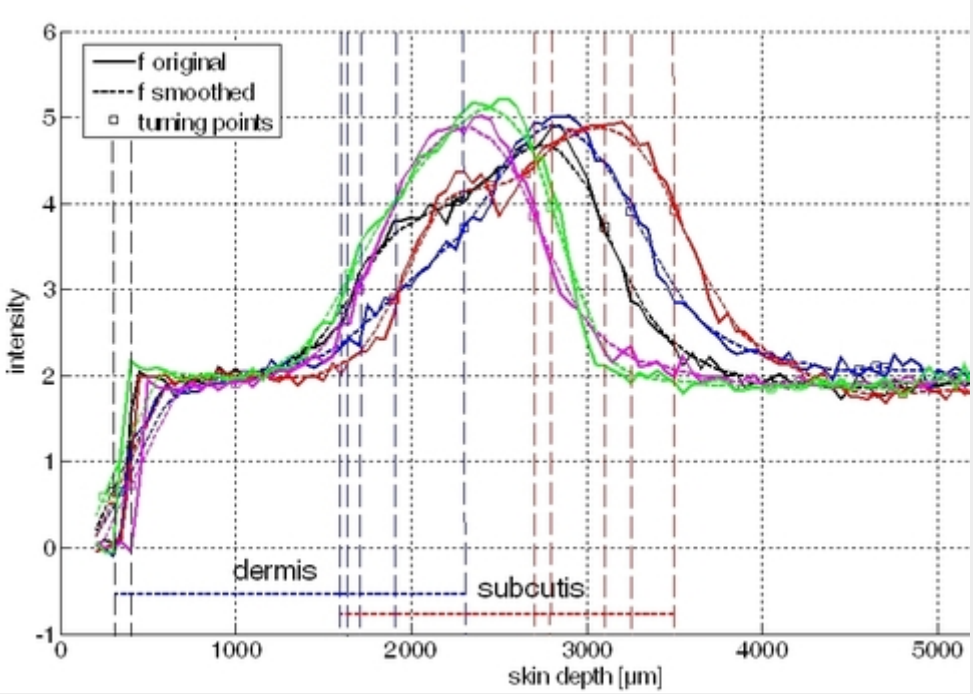

Figure 3: Skin profiles from 5 repetitive examinations on different days of the same skin area. Signal intensity was calculated from the integral of the whole echo train recorded in a slice. The turning points calculated from the smoothed curve function were used as borders for the dermal layers.

Figure 4: Thickness of the skin and its major layers (µm) measured by the NMR-MOUSE and ultrasound

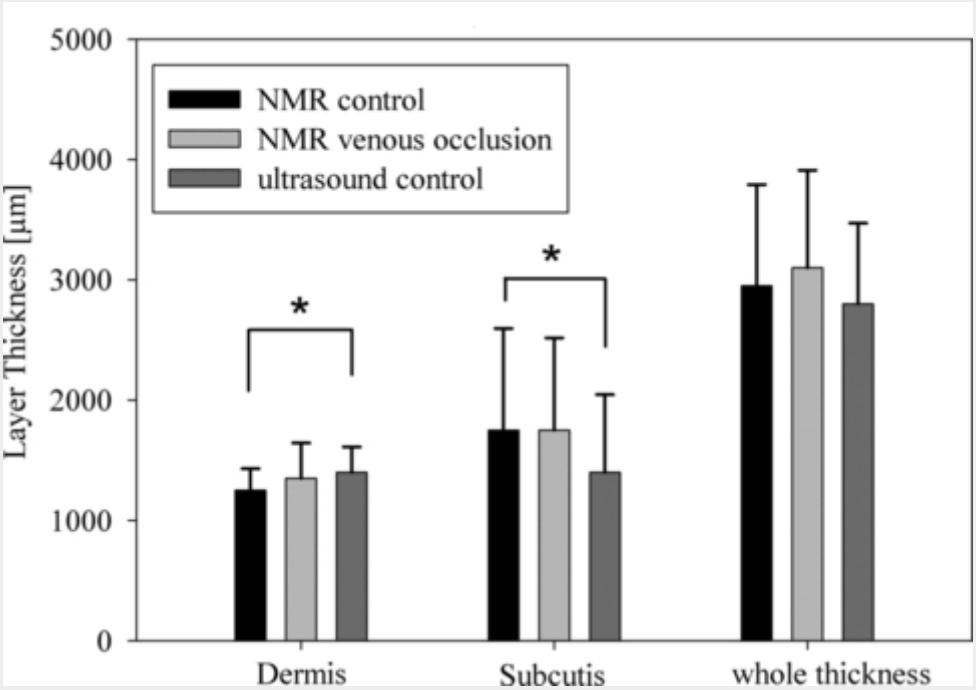

Figure 4: Thickness of the skin and its major layers measured by the NMR-MOUSE and ultrasound (µm, mean±SD, n=10, 5 repetitions each)

In the native state of the skin ultrasound imaging measured bigger values for the dermis and smaller values for the subcutis in comparison with the NMR-MOUSE. Values for the whole skin were not different between the two methods (paired t-test, $p<0.05$). Due to the large variation in skin profiles the visible swelling of the lower arm by venous occlusion manoeuvre could not be demonstrated by significant changes in thickness values determined with the NMR-MOUSE.

Figure 5: Short component of T2* (ms) in the dermis and subcutis layer

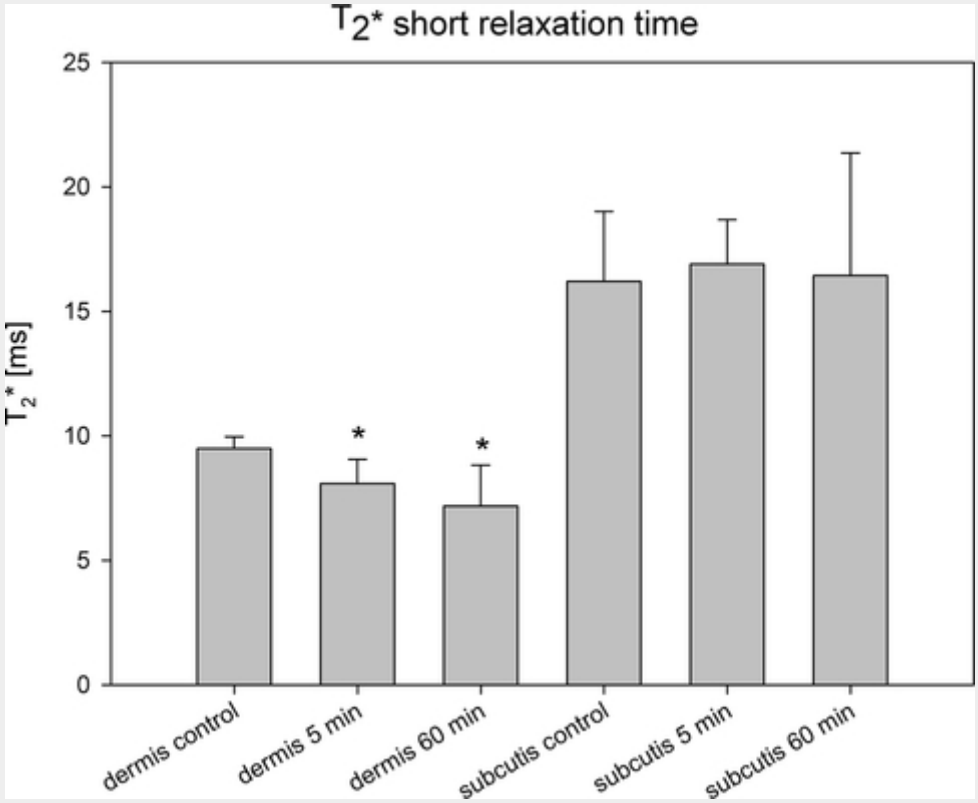

Figure 5: Short component of T2* (ms) in the dermis and subcutis layer before and 5 and 60 min after the application of a rheumatic salve increasing blood volume and flow.

Figure 6: Long component of T2* (ms) in the dermis and subcutis layer

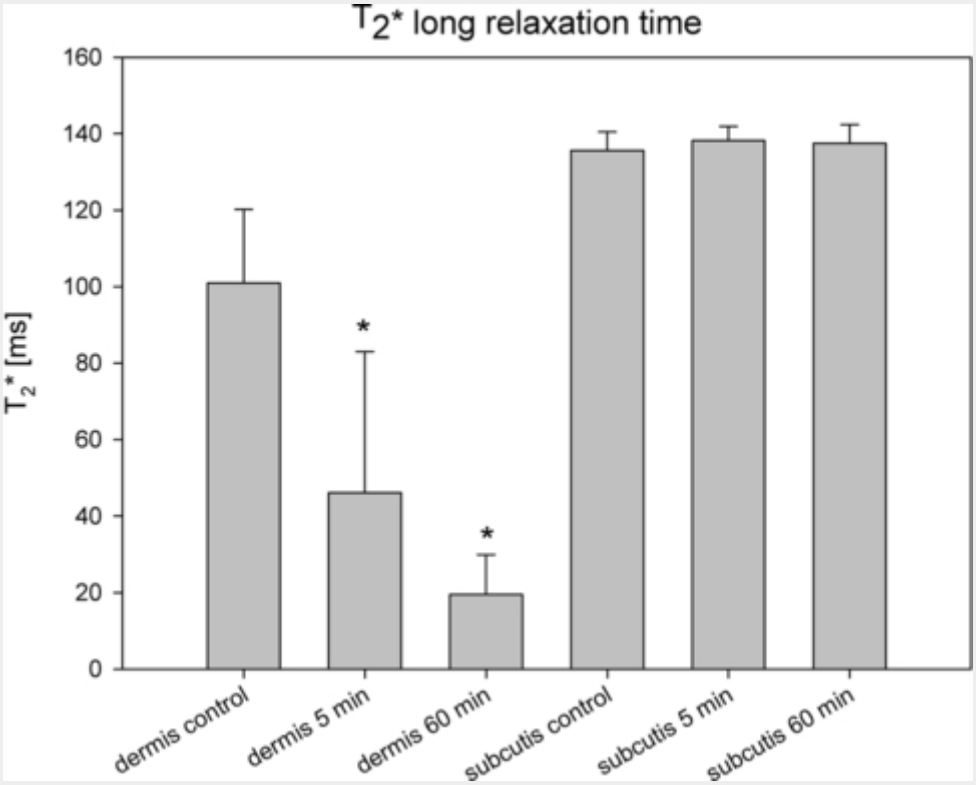

Figure 6: Long component of T2* (ms) in the dermis and subcutis layer before and 5 and 60 min after the application of a rheumatic salve increasing blood volume and flow.

In the dermis but not in the subcutis the increase in blood volume and flow due to the rheumatic salve caused a significant decrease of both T_2* components (ms, $P<0.05$ repeated measure ANOVA). The sensitive slice was placed deep enough in the dermis to avoid the detection solvent diffusion from the surface into the skin. The solvent had caused an increase in T_2*.

4. Conclusion

Measurements of the skin structure by means of a Profile NMR-MOUSE® suffered from poor reproducibility and long acquisition time. The NMR-MOUSE detects signals from plain slices of about 1 cm^2 which was therefore not geometrically adequate for an analysis of skin structure. Ultrasound measurements visualise that in the skin of lower arm layers of dermis and subcutis were not plain and not constant in thickness. Only minor deviation in the analysed area of the skin, that are not avoidable in clinical trials, can therefore result in largely different profiles recorded with the NMR-MOUSE.

The analysis of T_2* values was reproducibly capable to demonstrate a significant reduction in both, the short and long component of T_2* induced by increased blood volume and flow in the dermis layer of the skin as a pharmacological reaction on a rheumatic salve.

5. Mediafiles

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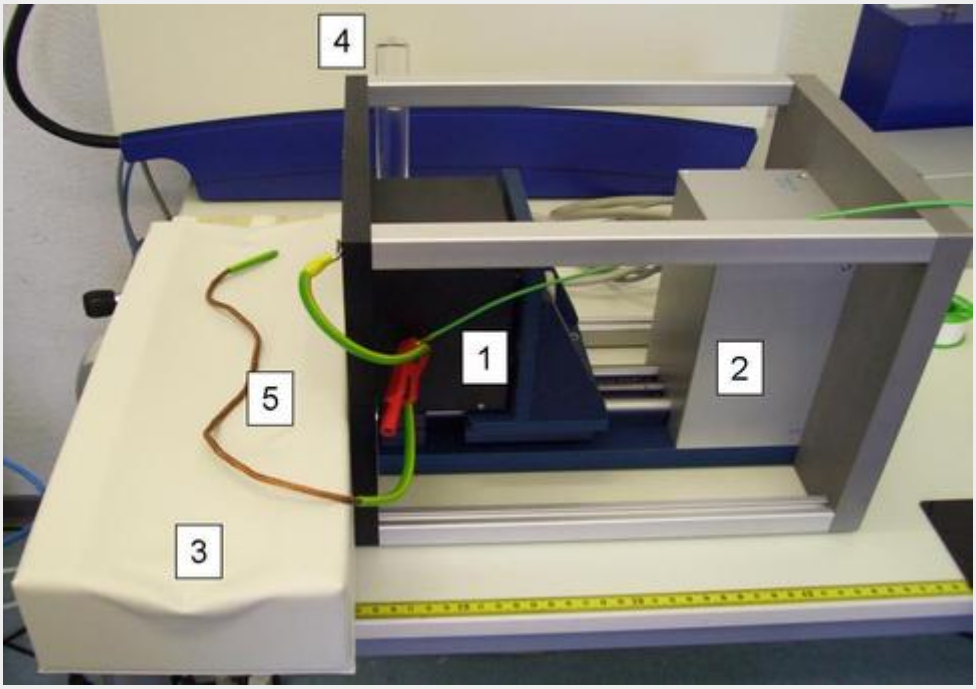

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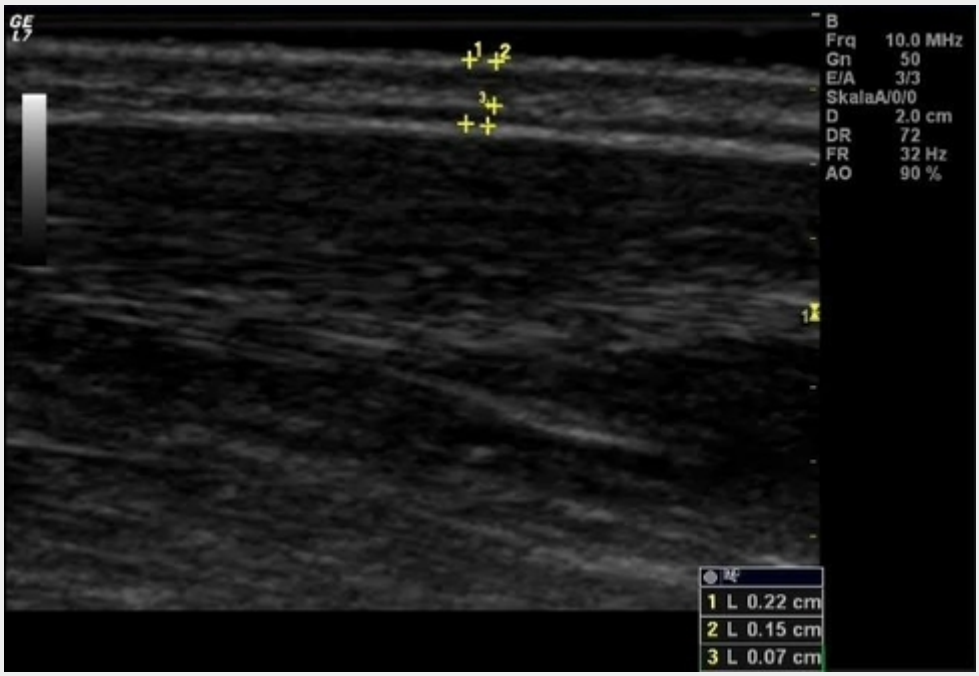

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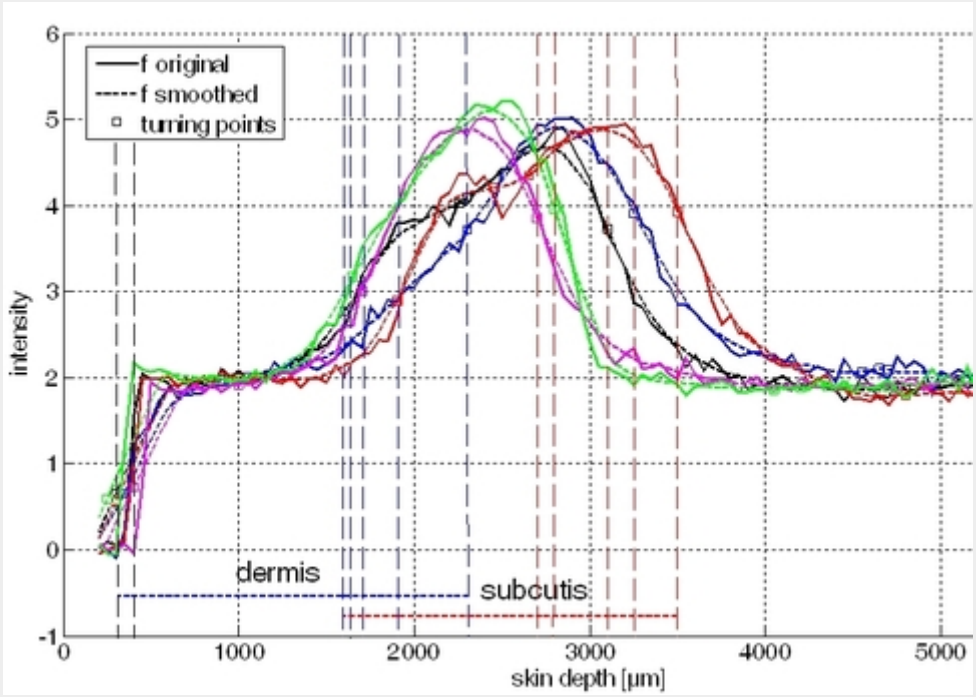

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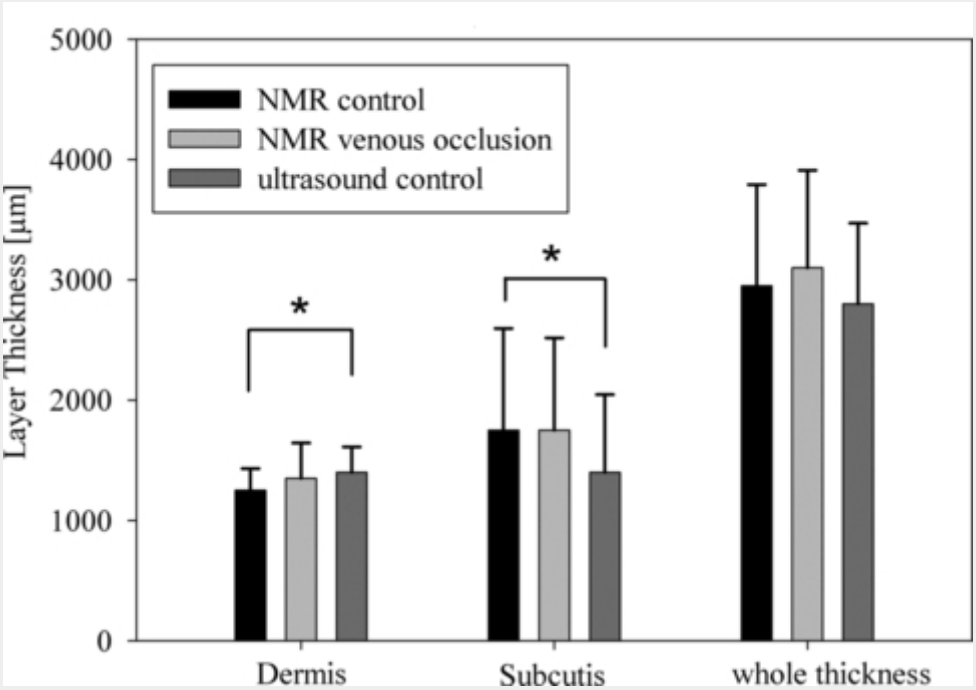

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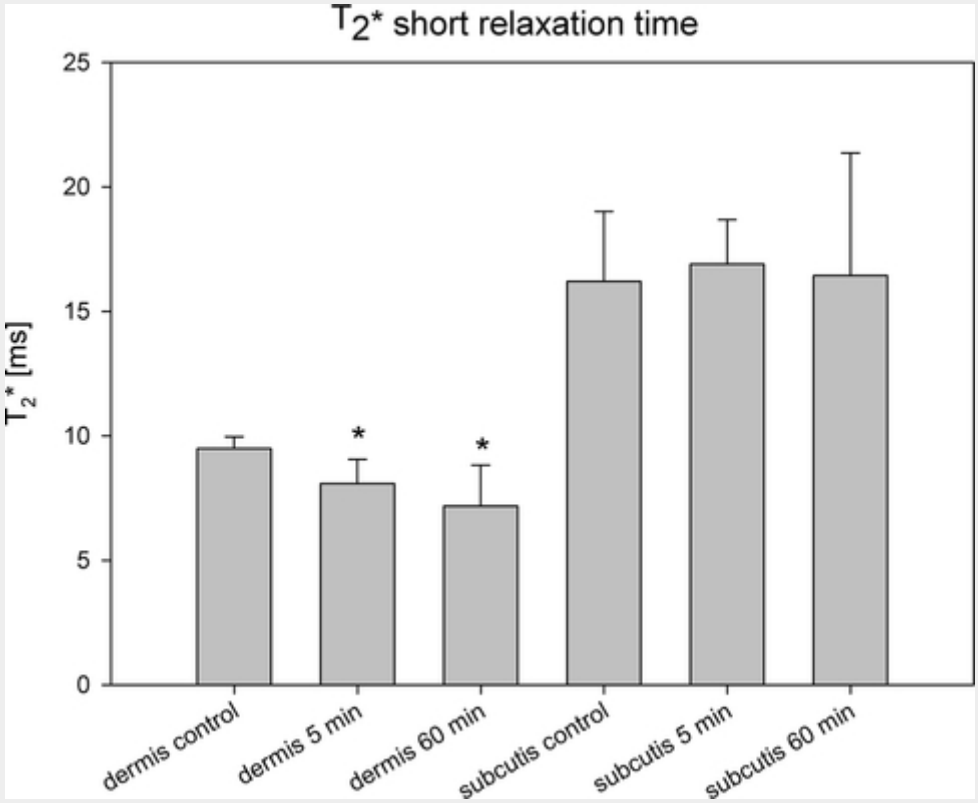

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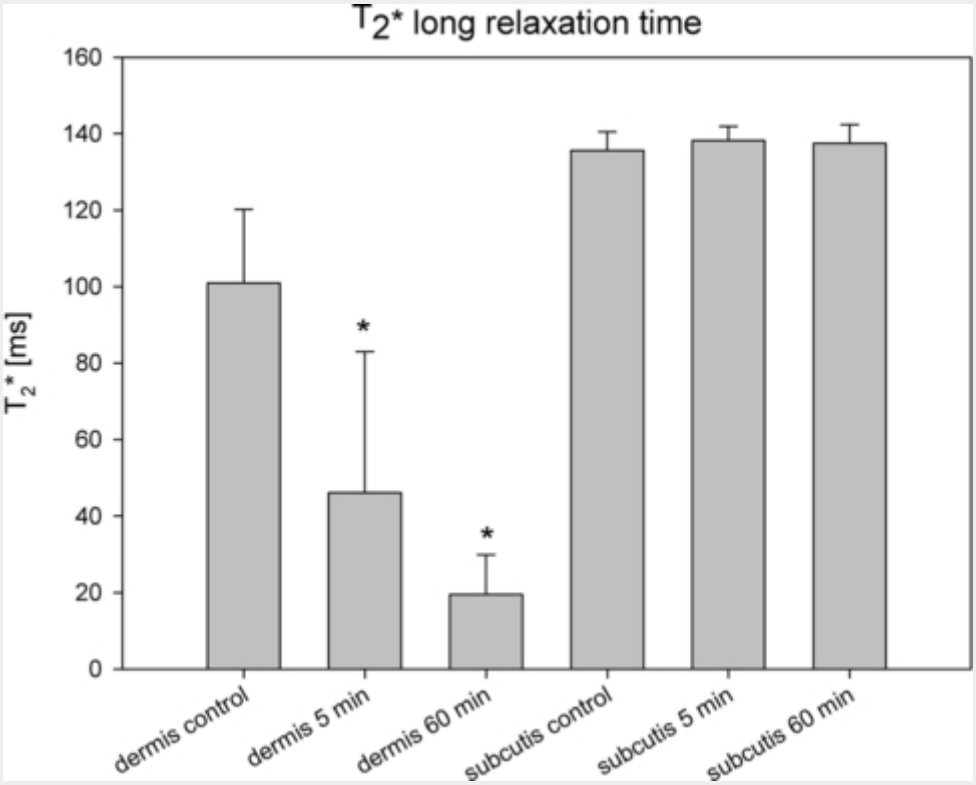

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