The princess and the pea - Comparison of different stiffness assessment tools on a multi-layered phantom tissue model

Katja Bartsch[1], Andreas Brandl[2], Philippe Pouletaut[3], Phillip Rossman[4], Mashhour Chakouch[3], Patrick Weber[5], Sabine Bensamoun[3], Robert Schleip[6, 2]

[1] Department of Sport Science and Sports, Friedrich-Alexander University Erlangen-Nürnberg, 91058 Erlangen, Germany, Phone +49 1601505849, Email katja.kb.bartsch@fau.de
[2] DIPLOMA Hochschule, Bad Sooden-Allendorf, Germany
[3] Université de technologie de Compiègne-UTC, CNRS UMR 7338, Biomechanics and Bioengineering, Compiègne, France
[4] Department of Radiology, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA
[5]Department Movement and Health Promotion, German Sport University Cologne, Cologne, Germany
[6] Conservative and Rehabilitative Orthopedics, Department of Sport and Health Sciences, Technical University of Munich, Germany

BACKGROUND Changes in the mechanical properties (i.e. tissue stiffness) of soft tissues have been linked to musculoskeletal disorders, leading to a rising demand in suitable diagnostic methods. However, little data exists to provide evidence-based recommendations for current stiffness assessment tools (SAT), requiring further research investigating their measurement properties [1]. The study aimed to compare different SAT' reliability and validity on a multi-layered phantom tissue model (MPTM).
METHODS A polyurethane MPTM was used to provide findings on concurrent validity. The MPTM simulated the four layers of the thoracolumbar fascia: cutis (CUT), subcutaneous connective tissue (SCT), fascia profunda (FPR), and erector spinae (ERS). To mimic stiffness alterations, 10 phantoms with varying stiffness parameters (specified in Shore OOO) were produced for each tissue layer. Evaluated assessment technologies included indentometry (Durometer, Tissue Compliance Meter, IndentoPro) [2], myotonometry (Myoton Pro®) [3], ultrasound imaging (ultrasound with attached transducer) [4], ultrasound elastography and magnetic resonance elastography [5]. The artificial relative stiffness changes in the MPTM were measured blindly by two different examiners, and the concurrent validity of the SAT was established using correlation coefficients and linear regression analysis. Between the two examiners, the inter-rater reliability of the assessment tools was determined. It can be noted that both elastography techniques were not able to measure stiffness and the polyurethane MPTM should be further developed.
RESULTS A total of 1840 measurements was conducted. Except for elastrography, all SAT found significant correlations for stiffness changes in all layers of the MPTM aside from the FPR layer, ranging from 0.70 to 0.98 (all $p < 0.01$). The inter-rater reliability ranged from good to excellent for these methods ($ICC_{(2,2)} = 0.75$~0.98). Measurement by elastography was not reliably feasible with MPTM.
CONCLUSION Indentometry and myotonometry technologies detected stiffness changes in three of the four MPTM layers (Table 1). With ultrasound imaging, only layers thicker than 3 mm could be measured. No method could detect stiffness changes in the thin (1 mm) layer simulating FPR.

Property / Measurement	Detection of stiffness changes in layers (layer thickness indicated below)				Inter rater reliability
	CUT (3mm)	SCT (6mm)	FPR (1mm)	ERS (10mm)	
Durometer	✓✓✓	✓✓			✓✓
Tissue Compliance Meter	✓	✓✓✓		✓✓✓	✓✓
IndentoPro	✓✓✓	✓✓✓		✓✓✓	✓✓✓
MyotonPro®	✓✓✓	✓✓✓		✓✓✓	✓✓✓
Ultrasound imaging		✓✓✓		✓✓✓	✓✓
Ultrasound and MR elastographies					

Table 1. Correlation of stiffness measurements and inter-rater reliability. Blank denotes "not applicable". ✓ denotes moderate correlation (> 0.4). ✓✓ denotes strong correlation (> 0.7). ✓✓✓ denotes very strong correlation (> 0.9).

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