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Assessment of pain quality reveals distinct differences between nociceptive innervation of low back fascia and muscle in humans

Andreas Schilder*, Walter Magerl, Thomas Klein, Rolf-Detlef Treede

Abstract

Introduction/Objectives: Verbal descriptors are an important pain assessment parameter. The purpose of this study was to explore the ability to discriminate deep muscle pain and overlying fascia pain according to verbal descriptors and compare the pattern with skin stimulation (from previously published data).

Methods: In 16 healthy human subjects, electrical stimulation was chosen to excite a broad spectrum of nociceptive primary afferents innervating the respective tissues. The 24-item Pain Perception Scale (Schmerzempfindungsskala [SES]) was used to determine the induced pain quality.

Results: Overall, affective ($P = 0.69$) and sensory scores ($P = 0.07$) were not significantly different between muscle and fascia. Factor analysis of the sensory descriptors revealed a stable 3-factor solution distinguishing superficial thermal ("heat pain" identified by the items "burning," "scalding," and "hot") from superficial mechanical ("sharp pain" identified by the items "cutting," "tearing," and "stinging") and "deep pain" (identified by the items "beating," "throbbing," and "pounding"). The "deep pain" factor was more pronounced for muscle than fascia ($P < 0.01$), whereas the other 2 factors were more pronounced for fascia (both $P < 0.01$). The patterns of skin and fascia matched precisely in sensory factors and on single-item level.

Conclusion: The differences in sensory descriptor patterns between muscle and fascia may potentially guide treatment towards muscle or fascia in low back pain physiotherapeutic regimes. The similarity of descriptor patterns between fascia and skin, both including the terms "burning" and "stinging," opens the possibility that neuropathic back pain (when the dorsal ramus of the spinal nerve is affected) may be confused with low back pain of fascia origin.

Keywords: Pain quality, Thoracolumbar fascia, Multifidus muscle, Electrical stimulation, Verbal descriptors

1. Introduction

Verbal pain descriptors are important and reliable parameters to characterize both acute and chronic pain and are included in many pain questionnaires (eg, the McGill Pain Questionnaire,[21] DN4 Questionnaire,[7] or "Schmerzempfindungsskala" [SES]; the Pain Perception Scale).[12] Various sets of descriptors were used to distinguish, eg, A-delta-mediated vs C-fiber-mediated pain,[16,28] nociceptive vs neuropathic pain,[7,11] trigeminal neuralgia vs atypical facial pain,[22] and primary vs secondary chronic pain syndromes.[1,31] Verbal descriptors were also used to prime processing of painful stimuli,[10] to examine the sensitivity of patients to words,[6] and to identify neuropathic components of low back pain.[2] We previously confirmed the factorial structure of the SES in a human surrogate model using electrical skin stimulation[13] and used those verbal descriptors to differentiate pain qualities induced by injection of hypertonic saline into muscle, fascia, or subcutaneous tissue.[24] Hypertonic saline activated a subset of chemosensitive nociceptive afferents. The present study explored the ability of verbal descriptors to discriminate the pain qualities induced by a broader spectrum of nerve fibers in muscle and fascia (by electrical stimulation[25]) or skin (data from Ref. 13).

2. Material and methods

2.1. Participants

Sixteen healthy volunteers (8 females and 8 males; 24.2 ± 2.0, mean ± SD) participated in 2 sessions after giving informed consent. The exclusion criteria were any medication, history of

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Department of Neurophysiology, Centre for Biomedicine and Medical Technology (CBTM), Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany

**Corresponding author. Address: Department of Neurophysiology, Centre for Biomedicine and Medical Technology Mannheim (CBTM), Medical Faculty Mannheim, HeidelbergUniversity, Ludolf-Krehl-St, 13-17, 68167 Mannheim, Germany. Tel.: +49 621 383 9926; fax: +49 621 383 9921. E-mail address: Andreas.Schilder@medma.uni-heidelberg.de (A. Schilder).*

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chronic pain, or recent surgeries to the abdomen, legs, or back. The experimental protocol was approved by the local ethics committee (Medical Faculty Mannheim, 2010-274N-MA).

2.2. Experimental protocol

Concentric bipolar needle electrodes (diameter 0.46 mm, stimulation area 0.07 mm^2; CareFusion, San Diego, CA) were positioned under ultrasound guidance (M-Turbo ultrasound system; Sonosite, Munich, Germany) bilaterally into the thoracolumbar fascia, and into the multifidus muscle, 10 mm below the surface of the thoracolumbar fascia at lumbar level (L3/L4). Electrical stimuli (pulse width: 2 ms) were applied by a constant current stimulator (DS7A; Digitimer, Welwyn Garden City, United Kingdom). Individual detection (just noticeable sensation) and pain thresholds were determined. Single stimuli at twice the magnitude of the individual pain threshold and trains of high-frequency stimuli (100 Hz for 1 second) at 10 times the individual electrical detection threshold were used to elicit pain.[14,17,25] For more details, see Ref. 25. The sequence of testing was cross-over balanced for right–left and tissue type. All participants were blinded regarding the stimulated tissue. Pain qualities were inquired for the single electrical pulses first and then high-frequency trains, since the latter introduced pain facilitation.[13,14,17]

2.3. Pain quality

The assessment of pain qualities consisted of a validated list of 14 affective and 10 sensory descriptors in German language (the Pain Perception Scale, "Schmerzempfindungsskala" [SES][12]) rated on a 4-level ordinal scale (0 = no match, 1 = light match, 2 = largely match, and 3 = total match). Because ratings of pain qualities did not differ between single and high-frequency stimulation (see analysis of variance [ANOVA] results), further pattern analysis was performed on data collapsed across both stimulation types.

2.4. Statistics

Statistical analysis used descriptive statistics, T test, and repeated-measures ANOVA (within-subject levels: single vs train stimuli, tissue, and sensory items). Factor analysis of sensory descriptors accepting factors with eigenvalues >1 was used to reduce the complexity of sensory patterns. Subsequent factor rotation using normalized VARIMAX yielded orthogonal factors with maximal factor separation (Statistica 7.3, StatSoft (Europe) GmbH, Hamburg, Germany; see also Ref. 13). *P* values <0.05 indicated statistical significance.

Table 1

Three-way repeated-measures analysis of variance (RM-ANOVA) sensory items.*

Effect*	*df* effect	*df* error	F	*P*
1. Single vs train stimulation	1	15	0.375	0.5494
2. Fascia vs muscle stimulation	1	15	3.763	0.0714
3. Sensory items (10)	9	135	5.536	<<0.0001
1 × 2 interaction	1	15	2.601	0.1276
1 × 3 interaction	9	135	2.275	0.0209
2 × 3 interaction	9	135	8.616	<<0.0001
1 × 2 × 3 interaction	9	135	1.568	0.1309

* Main effect 1: comparison of single electrical stimuli vs high-frequency train stimulation. Main effect 2: comparison of stimulation in the fascia vs stimulation in the muscle. Main effect 3: comparison of the 10 different SES items.

3. Results

All participants experienced pain during electrical single pulse or high-frequency stimulation of muscle or fascia. Ratings of affective items were generally very low and did not differ between muscle and fascia (0.39 vs 0.43, $P = 0.69$). There was no significant stimulation type × tissue interaction (ANOVA: $F_{1,15} = 0.17$, $P = 0.69$), nor stimulation type × tissue × item interaction for the 14 affective SES items (ANOVA: $F_{13,195} = 0.92$, $P = 0.53$).

By contrast, sensory ratings were generally higher but did also not differ significantly in overall magnitude (0.86 vs 0.72, $P = 0.07$). Ratings did not differ between single or 100-Hz train stimulation (stimulation type × tissue × item interaction: $F_{9,135} = 1.57$, $P = 0.13$), but there was a tissue-specific rating pattern (tissue × items interaction: $F_{9,135} = 8.62$, $P < 0.0001$; **Table 1**). Whereas muscle stimulation was more intensely "beating" and "throbbing" (both $P < 0.001$), fascia stimulation was more

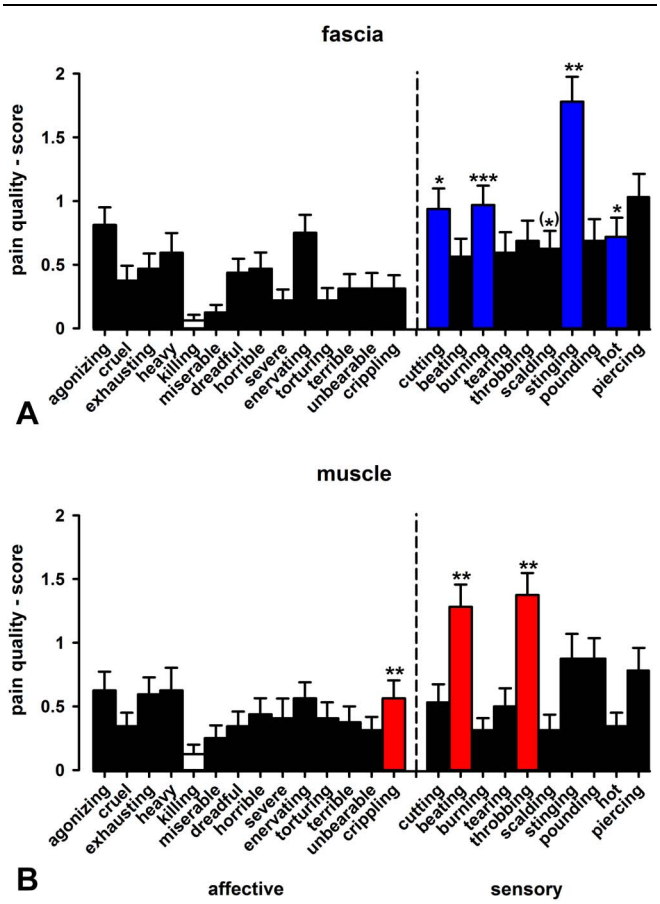

Figure 1. Pain qualities after electrical stimulation of the fascia or muscle (raw data). Affective and sensory pain qualities of the Pain Perception Scale ("Schmerzempfindungsskala" [SES]). Pain was induced by electrical pulses applied to the fascia (A) or the muscle (B). Ratings were given on a 0 to 3 scale (0 = does not apply, 3 = applies exactly; n = 16). Filled bars indicate a significant difference vs "zero" in rating magnitude of the respective descriptor ($P < 0.05$). Ratings that were significantly higher in the fascia than muscle are shown as blue bars; ratings that were significantly higher in the muscle than the fascia are shown as red bars (mean ± SEM). The T test between tissues, *$P = 0.05$, **$P < 0.01$, ***$P < 0.001$, (*)$P = 0.06$. SES original German language pain descriptors in left to right order: Affective labels: "quälend," "grausam," "erschöpfend," "heftig," "mörderisch," "elend," "schauderhaft," "scheußlich," "schwer," "entnervend," "marternd," "furchtbar," "unerträglich," and "lähmend." Sensory labels: "schneidend," "klopfend," "brennend," "reißend," "pochend," "glühend," "stechend," "hämmernd," "heiß," and "durchstoßend."

Table 2

Factor loadings after normalized VARIMAX rotation.*

Single items	Sensory pain factors		
	Heat pain	Sharp mechanical pain	Deep mechanical pain
Cutting	0.247850	**0.702318**	0.016339
Beating	−0.019720	−0.310780	**0.638010**
Burning	**0.834356**	0.257180	−0.126125
Tearing	0.322219	**0.705978**	0.202930
Throbbing	−0.011744	−0.092402	**0.812314**
Scalding	**0.793800**	0.173343	0.080527
Stinging	0.360550	**0.697966**	−0.077912
Pounding	−0.253089	0.110516	**0.723008**
Hot	**0.902405**	0.042582	−0.009679
Piercing	0.165125	*0.519123*	*0.466734*
Variance explained (single factor)	0.278673 (27.9%)	0.249160 (24.9%)	0.239619 (24.0%)
Variance explained (total)		0.767452 (76.7%)	

* The factor analysis was performed in 2 steps. First, separately for every stimulus type and tissue type, the factorial structure was almost identical and applied to any given combination in the same way (data not shown). The analysis was then executed for the complete data set yielding the result shown in the above table.
Relevant item loadings are marked in bold face; item with shared loading ("piercing") is italicized.

intensely "stinging" ($P < 0.01$) and "cutting" ($P < 0.05$), as well as "burning" ($P < 0.001$) and "hot" ($P < 0.05$; **Fig. 1**).

Sensory items were reduced to sensory factors by factor analysis and factor separation maximized by VARIMAX rotation, which revealed 3 orthogonal sensory factors explaining 76.7% of variance (single factor explaining 24%–28% of variance), namely "heat pain" (high-factor loadings on the items "burning," "scalding," and "hot"), superficial sharp pain (high loadings on "cutting," "tearing," and "stinging"), and deep pain (high loadings on "beating," "throbbing," and "pounding"). The item "piercing" exhibited shared loading on both "sharp pain" and "deep pain" factors (**Table 2**). Results of this factor analysis were almost identical to previous analysis for skin electrical stimulation.[13]

Analysis of variance confirmed the different sensory patterns identified by analysis of all single items (**Table 3**). Post hoc tests revealed that mean ratings of the "heat pain" factor (0.55) were lower than the other 2 (0.88 and 0.91; both $P < 0.05$; **Fig. 2**). Moreover, all 3 sensory factors differed significantly between tissues, namely "heat pain" (0.77 vs 0.32, $P < 0.01$) and "sharp pain" (1.09 vs 0.66, $P < 0.01$) rated higher in the fascia, and "deep pain" higher in the muscle (1.12 vs 0.70, $P < 0.01$; **Fig. 2**). Thus, the fascia exhibited a significantly more superficial pain quality pattern, whereas the muscle exhibited a "deep pain" pattern. To compare data from fascia or muscle with previously published data on pain qualities after punctate electrical stimulation of the skin,[13] we normalized all rating data to the mean and SD of the

Table 3

Three-way repeated-measures analysis of variance (RM-ANOVA) sensory factors.*

Effect	*df* effect	*df* error	F	*P*
1. Single vs train stimulation	1	15	0.225	0.6424
2. Fascia vs muscle stimulation	1	15	4.455	0.0520
3. Sensory factors (3)	2	30	4.081	0.0271
1 × 2 interaction	1	15	2.458	0.1378
1 × 3 interaction	2	30	3.804	0.0337
2 × 3 interaction	2	30	10.855	0.0003
1 × 2 × 3 interaction	2	30	1.877	0.1705

* Main factor 1: comparison of single electrical stimuli vs high-frequency train stimulation. Main factor 2: comparison of stimulation in the fascia vs stimulation in the muscle. Main factor 3: comparison of the 3 different sensory factors (heat, sharp mechanical, and deep mechanical).

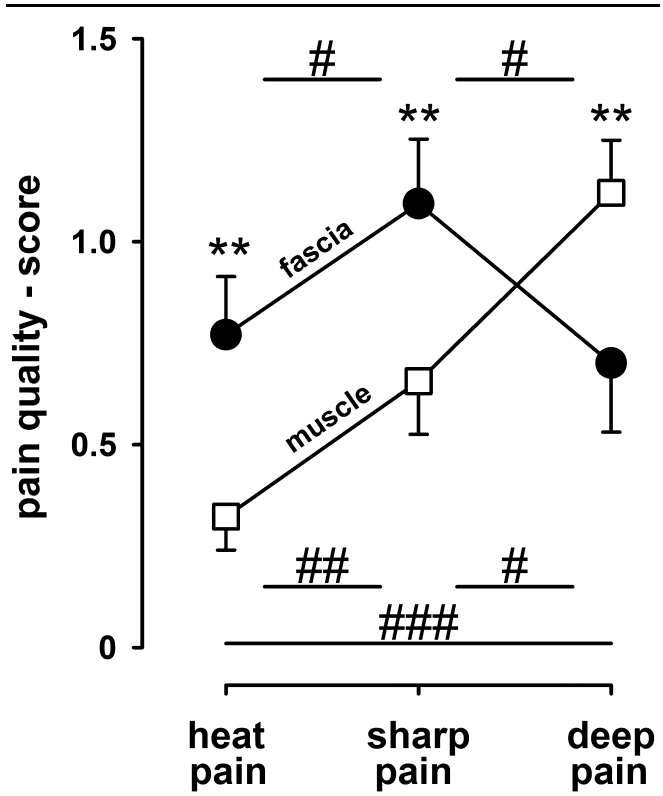

Figure 2. Pain qualities after electrical stimulation of the fascia or muscle collapsed to a 3-factor model. Sensory pain factors (mean scores of a 0–3 scale) broken down into superficial pain (heat and sharp mechanical) or deep pain based on factor analysis. Superficial pain factors were significantly higher after fascia stimulation than muscle, but the "deep pain" factor significantly lower. "Sharp pain" was significantly higher than "heat pain" or "deep pain" in the fascia, whereas deep pain in the muscle was significantly higher than "heat" or "sharp mechanical pain" (mean ± SEM). The T test between tissues, $^{**}P < 0.01$, significances for between-tissue comparisons survived Bonferroni correction ($P = 0.05/3 = 0.017$) in any case; the T test within tissues, $\#P = 0.05$, $\#\#P < 0.01$, and $\#\#\#P < 0.001$.

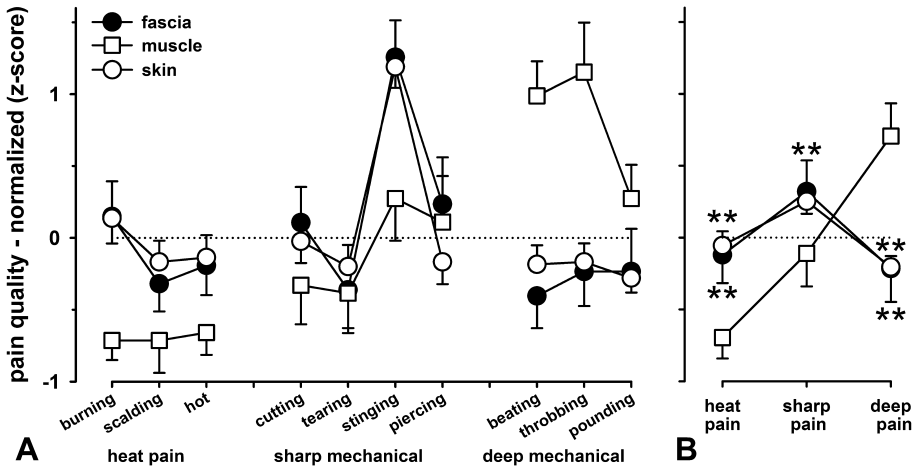

Figure 3. Pain qualities after electrical stimulation of the fascia or muscle compared with skin stimulation. (A) Sensory descriptors were ordered according to a 3-factor model independently determined for muscle/fascia stimulation (Table 2) and skin stimulation (data from Ref. 13). The pattern for skin stimulation closely matched the pattern of fascia stimulation, whereas the pattern for muscle stimulation differed from both. (B) Magnitude of sensory factors for fascia, skin, and muscle shows that the fascia and muscle were significantly different in all factors. Moreover, the skin pattern matched precisely with the fascia. Data normalized to grand mean and SD of the respective tissue. The T test between the muscle and fascia or skin, significances for between-tissue comparisons survived Bonferroni correction ($P = 0.05/5 = 0.01$) in any case; $^{**}P < 0.01$.

respective tissues, which revealed that the ratings for cutaneous stimuli fully matched the pattern after fascia stimulation in every single pain quality item (**Fig. 3A**) and in the 3 sensory factors extracted from the questionnaire (**Fig. 3B**).

4. Discussion

Electrical stimulation probably excited all A fibers, but not all C fibers,[20,23,29] innervating either muscle or fascia of the low back in healthy volunteers and revealed significant differences in sensory but not affective pain descriptor patterns between the 2 deep tissues. Fascia pain replicated the same sensory descriptor patterns of "heat pain" and "sharp pain" previously also found for epicutaneous electrical skin stimulation in a different cohort,[13] whereas classic "deep pain" descriptors dominated the muscle pain descriptor pattern similar to pain qualities after painful injections in various different muscles.[30] Hypertonic saline injections also yielded similar pain descriptor patterns for fascia and skin that were significantly different from muscle.[24]

The most frequently chosen descriptors for saline and electrical stimulation of both fascia and skin were "burning," traditionally attributed to C-fiber-mediated second pain and "stinging," traditionally attributed to A-delta-mediated first pain.[16,27,28,32] This notion was only partly supported by more recent experimental data: although selective C-fiber stimulation was frequently reported as "burning,"[8,9] selective A-delta-fiber stimulation was characterized as both "pricking"/"stinging" and "burning".[4,19] Pathophysiologically, "burning" pain quality is also considered as a prototypical descriptor for neuropathic pain.[5]

The SES scale is widely used in Germany, is validated for clinical pain syndromes,[12,31] and is sensitive to change in clinical and experimental trials.[13,15,24] Patients with neuropathic chronic back pain reported higher sensory and affective SES scores than nonneuropathic.[26] Nonspecific electrical stimulation used in this study may be conceived as a surrogate model of ongoing spontaneous input related to ongoing pain[18]; accordingly, the experimental findings from electrically evoked pain are relevant for clinical spontaneous pain.

A previous study using electrical skin stimuli[13] reproduced the factorial structure of the SES questionnaire, as it was initially proposed.[12] The factor analysis of electrically evoked muscle and fascia pain performed in this study again yielded the same 3 sensory factors. However, although both muscle and fascia are deep soft tissues of the low back, the "deep pain" quality pattern was only identified in muscle, whereas the fascia pain pattern matched the cutaneous pattern of superficial "sharp pain" or "heat pain."[13]

5. Conclusions

Electrical stimulation of different soft tissues in the lower back revealed distinct pain quality patterns for muscle vs fascia and skin. The differences in sensory descriptor patterns between muscle and low back pain may be exploited in physiotherapy and differentially guide treatment towards the respective source of soft tissue; the "deep pain" qualities point towards muscle as the appropriate target, whereas "heat pain" or "sharp pain" qualities point towards fascia. Further studies in patients suffering from nonspecific back pain have to verify whether different pain qualities are valid identifiers of different deep tissues as sources of pain. The descriptor patterns of fascia and skin, however, may potentially lead to misinterpretation of fascia-related pain in the lower back as being neuropathic pain.[2,3]

Disclosures

The authors declare no conflict of interest.

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Author contributions: A. Schilder performed the experiments, analyzed the data, and wrote the manuscript. W. Magerl analyzed

the data. W. Magerl, T. Klein, and R.-D. Treede designed the study and edited the manuscript. All authors approved the submitted version of the manuscript.

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