Musculoskeletal Science and Practice 39 (2019) 136–143

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Original article

Clinical assessments can discriminate altered body perception in patients with unilateral chronic low back pain, but not differences between affected and unaffected side

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ARTICLE INFO

Keywords:
Altered body perception
Chronic low back pain
Two-point discrimination
Left/right judgment task
Body image drawing

ABSTRACT

Chronic pain disorders appear to be associated with altered body perception. The clinical tools of two-point discrimination (TPD), left/right judgment task (LRJ) and body image drawing (BID) can all be used to assess altered body perception in people with chronic low back pain (CLBP). The aim of this observational study was to examine whether values from TPD, LRJ and BID can determine altered body perception between unilateral CLBP patients' painful and pain-free trunk sides, through the evaluation of some of the underlying mechanisms of body perception. Twenty-seven eligible participants completed all tasks. Inclusion criteria were: unilateral CLBP with duration of over 12 weeks; pain level higher than two out of ten on the numeric rating scale; a minimum score of four points on the Roland Morris Disability Questionnaire (RMDQ). Findings from TPD and BID tests showed an alteration in body awareness. However, no significant interaction effects were found between the affected sides and their measurements (TPD $p = 0.310$, LRJ response time $p = 0.571$, LRJ accuracy $p = 0.190$, BID $p = 0.751$). The profiling of people with high levels of distorted body perception for other factors known to contribute to CLBP may be a useful direction for further investigation.

1. Introduction

Back pain is a significant cause of disability in industrialized countries (Murray et al., 2015). Most treatments currently available for the management of chronic low back pain (CLBP) have shown limited success (Maher et al., 2017). Recent evidence reveals that there is a wide range of structural, functional and neurochemical changes in the brains of some people with CLBP (Wand et al., 2011). Though the impacts of these changes are not fully understood (Apkarian et al., 2009; Wand et al., 2014; Wand et al., 2010), it is plausible that they might contribute to a state of persistent pain by influencing the processing of noxious information, attentional processing and alterations in body perception (Wand et al., 2016). The role of altered body perception and persistent pain has been discussed often in recent years (Lotze and Moseley, 2007; Luomajoki and Moseley, 2011; Moseley, 2008; Wand et al., 2011). Though various definitions have been offered, most authors agree that body perception emerges from an interaction of internally-held body maps, multiple streams of sensory information, motor commands and beliefs and attitudes about the body (Moseley and Flor, 2012; O'Sullivan et al., 2014; Rabey et al., 2015a; Tsay et al., 2015). Several psychophysical tests have been proposed to explore the mechanisms that underlie body perception, such as two-point discrimination (TPD), the left/right judgement task (LRJ) and body image drawing (BID).

The TPD test is a simple method of assessing tactile acuity (Lotze and Moseley, 2007). The assessment determines the smallest distance that a person can perceive between two points. Tactile acuity is associated with the response profiles of the primary sensory cortex (S1) cells and it is suggested that it provides a clinical signature of S1 representation, an area of the brain that makes an important contribution to body perception (Flor, 2000). Data suggests that tactile acuity is degraded in people with CLBP compared to healthy controls (Catley et al., 2014; Luomajoki and Moseley, 2011). These findings can be difficult to apply clinically due to the wide variation of CLBP present in the population. It has recently been proposed that the non-painful side could be used as a comparator to the painful side in people with unilateral back pain (Wand et al., 2014). Data from people with complex regional pain syndrome (CRPS) of the hands demonstrate a clear

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https://doi.org/10.1016/j.msksp.2018.12.006
Received 6 April 2018; Received in revised form 6 December 2018; Accepted 16 December 2018

difference in tactile acuity between the affected and non-affected hands (Lewis and Schweinhardt, 2012). However, there is currently insufficient data comparing the painful and non-painful sides of people with unilateral LBP.

During the LRJ task participants are required to view images of a model that is bent or rotated to the left/right and to make a judgement as to which direction the person is moving. A mental rotation of the scene is necessary in order to determine the direction of deviation from the trunk's neutral position. This task invokes the participant's cortical proprioceptive map (Bowering et al., 2014). Evidence indicates that patients with upper limb pain disorders are significantly less accurate in recognizing their affected side (Moseley, 2004; Schmid and Coppieters, 2012). Significant differences in accuracy and decision-making time have been observed between back pain patients and healthy controls (Bray and Moseley, 2011). Furthermore, people with bilateral back pain were found to make more mistakes than people with unilateral back pain (Bray and Moseley, 2011). Whether people with altered body perception of the trunk show similar assessment outcomes to those with limb pain disorders has, as yet, been insufficiently examined. There is also very little data comparing the painful and non-painful sides of people with unilateral CLBP.

The BID test uses a graphic approach to examine body perception (Moseley, 2008; Nishigami et al., 2015). Participants must complete a partial drawing of a back silhouette by adding the outline, while tracing their own back mentally. Some CLBP patients draw their body outline shrunken, expanded or with missing parts. It has also been demonstrated that tactile acuity is impaired in patients with altered body image drawings and that the increase in the TPD value is specific to the site and side of pain (Moseley, 2008). To date, only studies with small samples have included participants with unilateral CLBP.

TPD and LRJ are already used successfully in the clinical assessment of limb pain disorders (Moseley, 2005; Schmid and Coppieters, 2012), while TPD is also used to detect altered body perception in LBP patients. BID is also used occasionally to assess the trunk. The aim of this study was to evaluate whether simple clinical tests can determine altered body perception between unilateral CLBP patients' painful and pain-free trunk sides, through the evaluation of some of the underlying mechanisms of body perception. If significant interactions between measurement and the participant's painful and pain-free trunk sides are found, then they could be transferred from limbs to the trunk and this could lead to the development of new treatment options for the unilateral CLBP population in the future.

2. Methods

2.1. Design

An observational cross-sectional study of individuals with unilateral CLBP was undertaken. The study was approved by the Ethics Committee of the Canton of Zurich, Switzerland (KEK-ZH 2015-0386). All participants provided prior signed, informed consent and all procedures conformed to the declaration of Helsinki.

2.2. Sample size

A paired *t*-test power calculation was computed with R statistical software. To be clinically meaningful, an estimated difference in TPD had to be a minimum of 13 mm (Wand et al., 2014). To detect a side-difference of 13 mm in TPD between the affected and non-affected sides of the back, with an estimated standard deviation of 8 mm, with a medium effect of 0.5 with 80% power and significance set at $\alpha = 0.05$, the sample size should be comprised of 34 participants.

2.3. Participants

Participants were considered eligible if they had experienced unilateral non-specific LBP for more than 12 weeks, reported an average pain-level of higher than two out of ten points on the numeric rating scale and obtained a minimum score of four points on the Roland Morris Disability Questionnaire (RMDQ) (Roland and Morris, 1983). Exclusion criteria were the current use of tranquilizers or opioids, any visual or motor impairments (including dyslexia), pregnancy, or presentation with any neurological disease or significant mental illness.

2.4. Procedure

Between October 2015 and May 2016 a convenience sample was recruited from a large general hospital in Winterthur, Switzerland. On the day of testing, participants were presented with detailed project information and signed a consent form. Each participant underwent a brief physical examination to confirm eligibility and thereafter supplied basic demographic and clinical data. Finally, the participants performed the three clinical body-perception tests. The BID test was performed first, followed by the LRJ test. The four TPD measures where then collected in random order by a researcher blinded to the participant's painful and pain-free trunk sides.

2.5. Measurements

2.5.1. Two-point discrimination (TPD) test

Plastic callipers with a precision of 1 mm were used to assess the TPD thresholds. With the participant placed in the prone position, TPD was assessed on each side of the lower back. TPD was measured on a line drawn between the participant's iliac crests, centred on a point 5 cm lateral to the spinous process. Three taps with both tips of the calliper were applied in a rapid rhythm by the assessor, using a light pressure until the first blanching of the skin. As described by Moberg (1990), the participant was instructed to say “two”, when the two points of the calliper were detected and “one”, when only one point of the calliper was detected. If unsure, they were free to say “I can't tell”. The test started with a distance of 100 mm between the tips of the calliper. For every correct answer of “two”, the distance between the calliper tips was decreased by 10 mm. For every incorrect, or “I can't tell” answer, the distance between the calliper tips was increased by 5 mm. Catch trials, in which only one point was presented, were used to verify that participants were not guessing. This decrease and increase of the calliper distance continued until the smallest distance at which the participant could detect the two points was verified. This value was noted as the TPD outcome. For healthy persons, normative data for TPD of the lower back are within the range of 43.2 mm–50.1 mm. For the group of LBP pain persons, a range of 49.7 mm–76.8 mm has been reported (Catley et al., 2014).

2.5.2. Left/right judgement (LRJ) test

LRJ performance was assessed using the NOI “Recognise” online program (www.noigroup.com) (Moseley, 2004). The participant was seated in front of a computer with the index and middle finger of the dominant hand on the keyboard buttons “a” and “d”, which were aligned to the centre of the screen. The participant was instructed to press “a” when they judged the shown torso to be flexed or rotated to the left side, or “d” when flexed to the right side. Each picture of a torso was displayed for a maximum of eight seconds on the screen. The participant was asked to perform the task as quickly and accurately as possible. A familiarisation trial of 20 pictures of the hand was first performed, followed by two sets of 40 photos of the back. The average time for decision-making (response time) and percentage of correctly judged pictures (accuracy) were noted separately for the affected and non-affected sides. Normal healthy values for response time are suggested to be within the range of 1.6 s, ± 0.5 s. (Moseley et al., 2012).

2.5.3. Body image drawing (BID) test

To assess the BID, the participant was provided with a body chart in

Table 1
Characteristics of the participants (n = 27).

Variables	Mean	Min. to max.
Age (years)	54.8 (SD 14.1)	22–86
Gender female/male	13 (48.1%)/14 (51.9%)	
Affected side left/right	12 (44.4%)/15 (55.6%)	
Pain duration since first appearance (weeks)	260 (SD 446.4)	12–1924
Pain Intensity (NRS 0-10)	4.1 (SD 1.6)	2–7
RMDQ (0-24)	11.1 (SD 4.2)	4–20

SD: Standard Deviation. NRS: Numeric Rating Scale. RMDQ: Roland Morris Disability Questionnaire.

which the silhouette of the lower back was left blank. The instructions were those used by Moseley, but translated into German: concentrate on your lower back; complete this drawing by following the outline of your own back as you trace it in your mind; concentrate on where you feel your back to be; do this without touching your back; do not draw any part you cannot sense; do not draw what you think your back looks like, draw what it feels like. (Moseley, 2008). The drawings were evaluated according to the methods used by Nishigami et al. (2015). Two blinded assessors conducted the rating, with a third addressing any discrepancies to make the results more robust. Thus, decisions were made using the "best out of three" concept. The assessors could rate either the left or right body side as asymmetric.

2.6. Data management and statistical analysis

All analyses were performed using R statistical software, R version 3.3.0 (2016-05-03) (R-Core-Team, 2015). Descriptive statistics were used to describe the demographics and clinical status. To optimise the statistical analyses, the notation of values was split into the following subgroups: affected left, affected right, non-affected left and non-affected right. A two-factor analysis (affected x measure) of variance (ANOVA) with significance level set at $\alpha = 0.05$ was conducted for each measurement. This was used to evaluate whether there were statistically significant interaction effects between the assessment outcome and the affected side. Paired t-tests ($p \leq 0.05$) were used to assess the differences between the affected and non-affected sides of the back.

For the statistical analysis of the BID, the drawings were dichotomised into asymmetry of either the left or right body side. A McNemar's Chi-squared test with continuity correction was conducted to evaluate whether being affected on one side was associated with a positive test outcome on that side.

3. Results

Of the 30 recruited participants in this convenience sample, two were excluded on the ground of opiate drug intake and one due to inadequate German language skills. Thus, 27 eligible participants completed all the tasks. The mean age of the sample was 54.8 years; the mean pain intensity was 4.1 out of 10 on the numeric rating scale (NRS), with a mean duration of 260 weeks; the mean score on the Roland Morris Disability Questionnaire was 11.1 out of 24. Gender and side of pain were equally represented. See Table 1. There were no missing data.

All TPD values were normally distributed ($p > 0.05$). In this sample, the average TPD on the affected side was 67 mm (standard deviation SD 20) and 65 mm (SD 16) on the non-affected side. This difference was not statically significant, see Table 2. The interaction between the affected side and its assessment outcomes were not significant in TPD assessment, see Table 3.

All LRJ values were normally distributed ($p > 0.05$). The average LRJ accuracy on the affected side was 88.6% (SD 8.9) and 87.1% (SD 8.3) on the non-affected side. In the subgroup of right-side affected, a statistically significant difference in accuracy was found (mean difference 1.5%, 95%CI subgroup right side 0.90–14.70, p-value 0.028), although this was not found for the subgroup of left-side affected. Taking both sides together, affected and non-affected sides, no statistically significance differences were found in LRJ accuracy, see Table 2. The average decision-making time needed on the affected side was 1.67 s (SD 0.5) and on the non-affected side 1.64 s (SD 0.5). All values fell within the normal healthy range of 1.6 s, ± 0.5 s (L. G. Moseley et al., 2012). The difference was not statistically significant, see Table 2. The interaction between the affected side and its assessment outcome were not significant in both LRJ assessments, see Table 3. The graphs in

Table 3
Two-factor analysis of variance (ANOVA) interaction effects between being affected on a side and its assessment outcome.

		Df	Sum Sq	Mean Sq	F value	Pr (> F)
TPD		1	2.1	2.13	1.07	0.310
LRJ	Accuracy	1	33	33	1.83	0.19
	Time	1	0.01	0.008	0.33	0.571
		Df	Deviance.	Resid Df	Resid Dev	Pr (> Chi)
BID		1	0.00	25	0.0	0.751

TPD: two-point discrimination. LRJ: left/right judgment task. BID: body image drawing.

Table 2
Main outcomes.

		Affected side	Unaffected side	Mean Differences	Subgroup Differences	95% CI	P- value
TPD	Mean, SD, Range	67 (20) mm [35, 110]	65 (16) mm [35, 90]	2 mm	Right	−0.89–1.74	0.512
					Left	−1.85–1.37	0.760
LRJ	Accuracy Mean, SD, Range	88.6 (8.9) % [73,100]	87.1 (8.3) % [65,100]	1.5%	Right	0.90–14.70	0.028
					Left	−1.46–10.73	0.130
	Response time Mean, SD, Range	1.67 (0.5) sec [0.9,2.6]	1.64 (0.5) sec [1,2.8]	0.03 s	Right	−0.56–0.21	0.356
					Left	−0.59–0.14	0.215
BID	Correct	17/27	17/27				

TPD: two-point discrimination. SD: Standard Deviation. LRJ: left/right judgment task. BID: body image drawing.

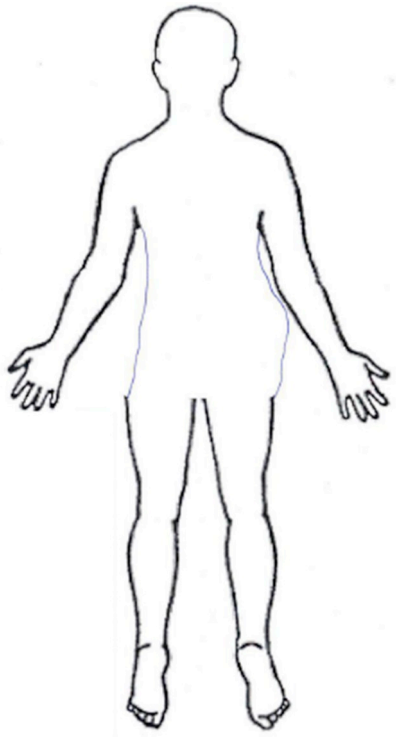


Fig. 1. Example of a Body Image Drawing test result of a patient with right-sided unilateral low back pain, showing clear asymmetrical perception.

Fig. 2 show the mean values of the TPD and the two LRJ assessments, split into the subgroups of left side and right side affected.

The blinded evaluation of the BID showed that most of the silhouettes were drawn in such a way that distortion of the lumbar area was suggested, as shown in exemplary form in Fig. 1. Of the 27 body images, 17 were rated as consistent with the participants' painful side and ten were mismatched. Thus, no significant results were found (p-value 0.751), see Table 3.

4. Discussion

Outcome values from the TPD and BID tests in this study on people with unilateral chronic low back pain were found to deviate from published healthy person control data. The LRJ test outcomes fell within the range of normative values. The primary analysis, however, showed no statistically significant differences between the affected and non-affected sides for any of the three clinical tests.

The strength of this study is that three different approaches to targeting altered body perception in patients with unilateral low back pain were compared in a representative sample. However, the targeted sample size of 34 was not reached, implying that the current investigation may have been underpowered to detect differences. Our study profiling was based purely on sensory characteristics. Other issues, such as the level of distress our subjects may have been experiencing, were not considered. Consequently, it is possible that the criteria for recruitment and analysis in this study were not sufficiently distinguishing. Biopsychosocial factors, such as maladaptive movement patterns, centrally-mediated nociceptive facilitation or behavioural responses to pain were not assessed. These have been mentioned in later evidence because of their supposed influence on central pain processes (Rabey et al., 2015b; Rabey et al., 2016). A similar study with a group of subjects with higher levels of psychological distress may have resulted in different findings.

In our study we chose to follow Wand et al.'s proposal to use the participants' non-painful side as a comparator to the painful side in unilateral pain conditions (Wand et al., 2014). We found no significant differences in TPD values between the affected and the non-affected sides in our study. It is possible that both our participants' body sides may have suffered from alterations in body perception, not only their painful sides. Thus, a major limitation of this study is a missing healthy control group that would have provided comparable outcomes. We

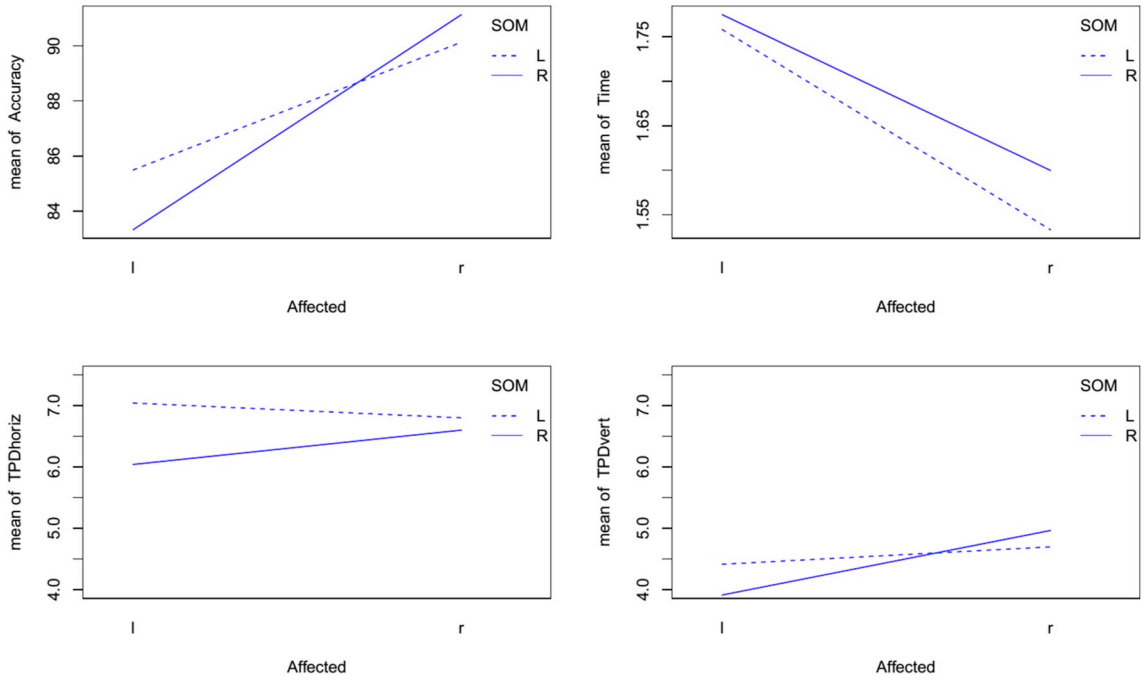


Fig. 2. Fig. 2 shows the interaction plots divided into the subgroups of left or right side affected. SOM: Side of Measurement, L: left side measurement, R: right side measurement Accuracy = left/right judgment task percent of correctly judged pictures Time = left/right judgment task response time.

relied on published healthy normative data for our comparator.

Our study found a mean TPD value of 67 mm on the painful side, which falls within the TPD data range of 49.7 mm–76.8 mm published in the review by Catley et al. for their LBP pain group (Catley et al., 2014). However, our study outcomes showed a mean TPD value of 65 mm for the non-painful side, compared with Catley et al.'s range of 43.2 mm–50.1 mm for the healthy population (Catley et al., 2014). Based on this data, it is likely that our sample was affected on both sides by altered body perception.

For LRJ, our sample performed with an accuracy of 88.6% (73%–100%) for the painful side. Results above 80% are within the reported range for healthy controls (L. G. Moseley et al., 2012). Other recent research has also found no differences in LRJ accuracy between healthy controls and patients with LBP (Linder et al., 2016). As in our study, outcome response time has also been found by other investigations not to differ between participants with or without low back pain (Bowering et al., 2014; Bray and Moseley, 2011). However, some of our results do conflict with other studies. Bray and Moseley found a mean accuracy for LRJ of 67.2% (60.2%–74.1%) for their group of unilateral CLBP patients and therefore described differences to healthy controls (Bray and Moseley, 2011). The main difference between our unilateral CLBP group and Bray and Moseley's was the average pain duration since first appearance, in our study 260 weeks versus 400 weeks in Bray and Moseley's (Bray and Moseley, 2011). Bowering et al. also found a mean accuracy under 80% (74%–78%) in patients with CLBP (Bowering et al., 2014). In their study, however, participants with a general CLBP state were examined, with no distinction made between the unilateral and bilateral pain states. The Bray & Moseley study found that the subgroup of bilateral pain condition performed with a lower accuracy than the unilateral pain group (Bray and Moseley, 2011), which may be a good explanation for the conflicting findings. Furthermore, the fact that no significant interaction between measurement outcomes and side of pain was found for LRJ, could be due to the test method itself, since the assessment used for the back is a modification of that used for limbs. The task focus was changed from the judgment of the sidedness of limbs to the recognition of the deviation of the back from a neutral position (Bowering et al., 2014). Consequently, the LRJ for the back was created for assessing the direction of movement, rather than an indication of the body side, as commonly used in LRJ for limbs. This could additionally explain why we found no difference to healthy controls in LRJ accuracy and response time.

The BID test showed that the majority of participants showed distortions compared to healthy normative values, as reported in other studies, further indicating that their body perception is altered (Moseley, 2008; Nishigami et al., 2015). Nevertheless, we found no significant interaction between BID side of pain and measurement outcomes. This could be because many drawings showed changes which were often not clearly side-dominant. Thus, the outcome depended strongly on the assessor's subjective decision. In contrast to Nishigami's protocol (Nishigami et al., 2015), the assessors in this study were blinded and had no opportunity to compare the drawing with the actual anatomical bodylines. This resulted in the problem that when a bodyline in a drawing appeared to be expanded, it may in reality have been a slim person with an expanded side, or alternatively, an overweight person with a contralateral shrunken bodyline.

The absence of TPD side differences for patients with CLBP differs from the results of studies on upper limb pain disorders, in which alterations were found to be associated with side of pain (Moseley, 2005; Schmid and Coppieters, 2012). This absence could be due to limited laterality in the back, which is one functional unit while limbs can be moved independently of each other. The objective of a movement is usually to move the whole back in a particular direction, rather than an independent movement of either the painful or pain-free side of the back. It is probable that the perception of the trunk and limbs work differently on the cortical level. This could explain why our assessments were not able to distinguish between the painful or pain-free side of patients with unilateral CLBP.

Examinations with functional Magnetic Resonance Imaging (MRI) indicate that emotional and cognitive factors in distressed patients seem to influence the cerebral processing of sensory information derived from the back (Lloyd et al., 2008). One study has looked at TPD in subgroups of CLBP with different levels of psychological distress (Rabey et al., 2016). No difference in TPD levels and subgroup membership was found, and therefore asks the question as to whether there is a relationship between psychological status and the measurements used in this study. Interestingly, body perception, as measured with the Fremantle Back Awareness Questionnaire, did find differences across their subgroups (Rabey et al., 2016), suggesting a complexity in body perception versus the measures utilised in the present study. Consequently, the differences between the perception of trunk and limbs should be the subject of further investigation in future studies. CLBP is such a complex and multidimensional problem, that the influence of other factors on altered body perception, such as pain intensity, pain mechanism, pain behaviours, as well as psychological factors, must be investigated in more depth. Furthermore, the question should be investigated as to whether body perception, as measured for example with the Fremantle Back Awareness Questionnaire, and simple clinical tests, such as TPD, reflect different perceptual constructs. Finally, the issue of whether the pain-free side can be used as a comparator to the painful side in people with unilateral back pain, as recently proposed by Wand et al., must be resolved (Wand et al., 2014).

5. Conclusion

The findings of our study are consistent with recent evidence concerning increased TPD values in chronic low back pain patients. The test outcomes of TPD and BID indicated altered body perceptions, although no differences were detected between the painful and pain-free trunk sides. Unilateral trunk pain does not appear to have the same impact on cortical perception as unilateral limb pain. Based on the results of this study, the approaches taken from the assessment of pain disorders of limbs to examine altered body perception are not directly transferable to the trunk.

Conflict of interest

The authors declare no conflicts of interest.

This article was developed and written equally by the first and second authors.

Acknowledgements

The authors wish to thank all participants in the study.

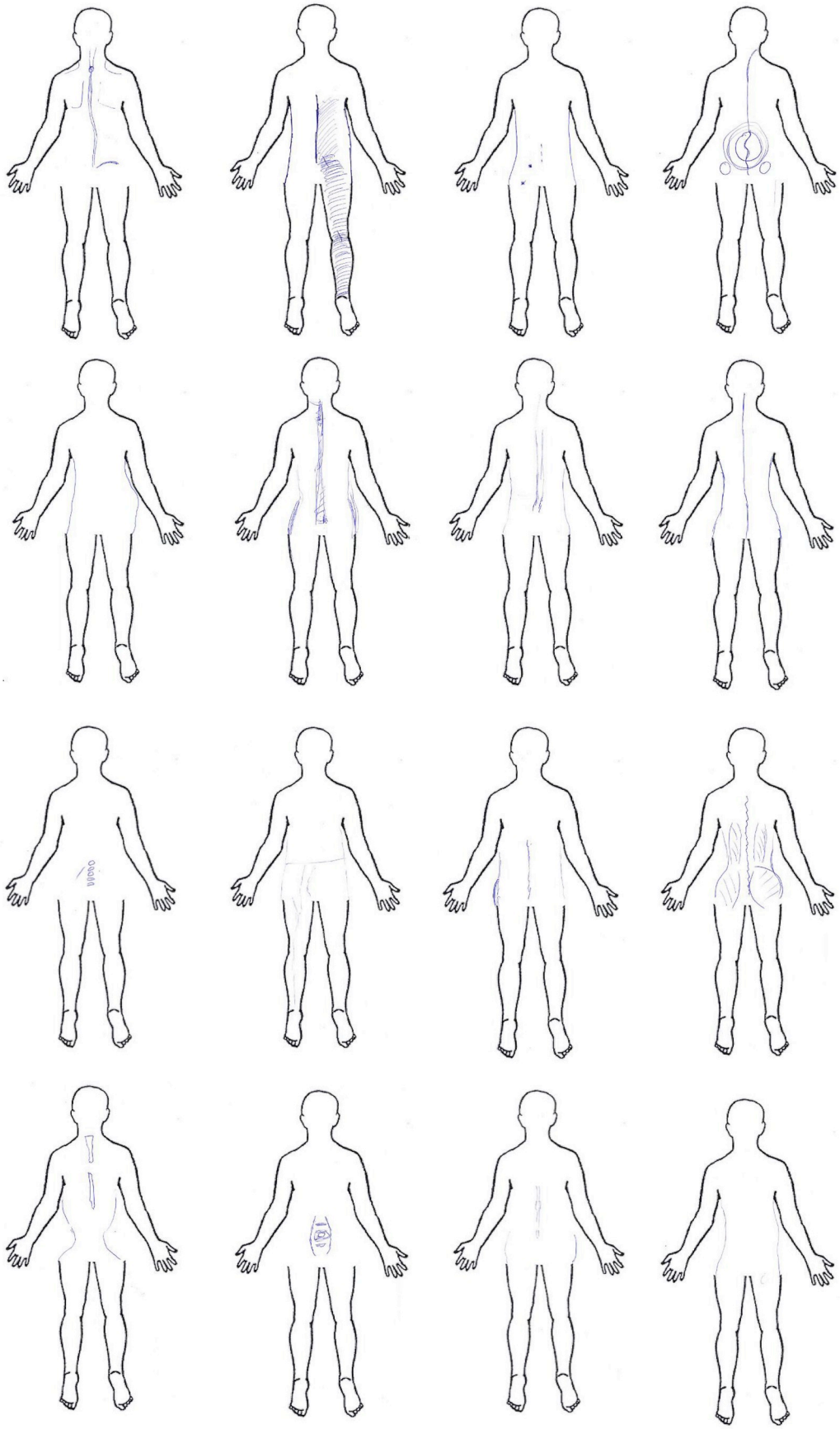
Our special thanks for their support go to:

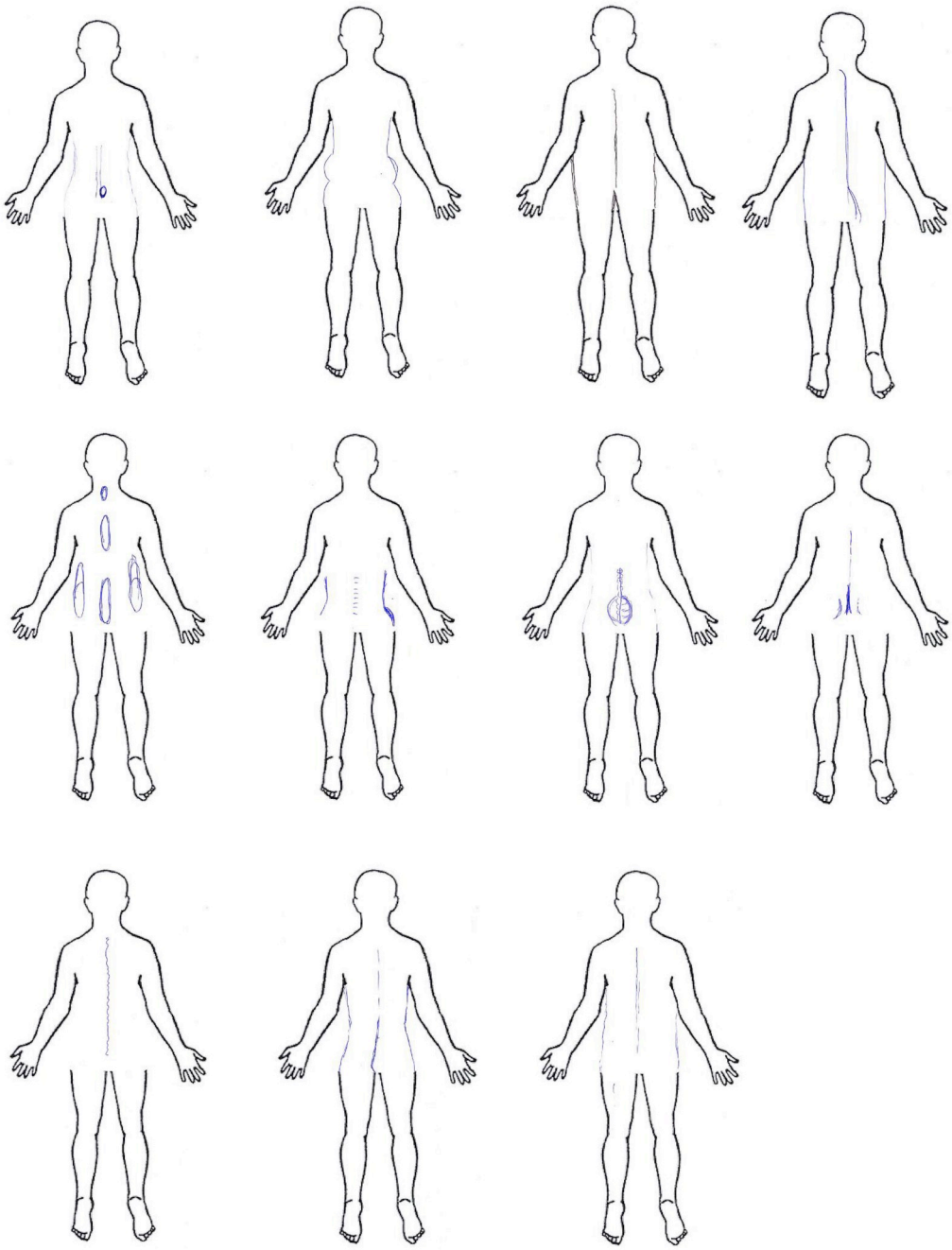
Benedict Martin Wand - School of Physiotherapy, University of Notre Dame Australia, Fremantle, Western Australia, Australia.

André Meichtry - Institute of Physiotherapy, Zurich University of Applied Sciences, Winterthur, Switzerland and Caroline Aubry - Bethesda Hospital, Basel, Switzerland.

Appendix A

Body Image Drawings





Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2018.12.006.

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