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Central Sensitization and Physical Functioning in patients with Chronic Low Back Pain

Ansuategui Echeita, Jone

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Lifting capacity is associated with Central Sensitization and Non-Organic Signs in patients with chronic back pain

Jone Ansuategui Echeita, Peter van der Wurff, Vera Killen, Mike F. Dijkhof,
Floor M. Grootenboer, Michiel F. Reneman

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ABSTRACT

Purpose. To analyze the associations between lifting capacity, and central sensitization (CS) and non-organic signs (NOS) in patients with chronic back pain (CBP) attending Vocational Rehabilitation.

Materials and methods. Cross-sectional observational multicenter study among patients with CBP undergoing a return to work assessment within care as usual.

Main analyses. Step 1) Partial correlation between lifting capacity, and CS, NOS, and additional variables; Step 2) Multiple regression in stepwise forward method for dependent variable lifting capacity, and for independent variables CS and NOS, and additional variables significant ($p < 0.05$) at Step 1. All analyses were controlled for sex.

Results. Fifty-six patients mean age 42.5 years and 59% women participated in the study. Correlations between lifting capacity and CS and NOS were $r = -0.53$ and $r = -0.50$ respectively. CS and NOS, as well as age and sex, contributed significantly to the final regression model, which explained 57.6% of variance.

Conclusions. After controlling for confounders, CS and NOS were negatively associated with lifting capacity in patients with CBP. Explained variance was substantially higher than previously reported studies.

INTRODUCTION

Fifty percent of work absences and 60% of permanent incapacity in Europe are due to musculoskeletal disorders, of which back pain is the highest contributor to years lived with disability (YLD) [1,2]. Vocational rehabilitation (VR) is one of the interventions of choice to help patients with chronic back pain (CBP) to return to work. One of the main goals of VR is to improve functional capacity for a successful return to work. Functional capacity evaluations (FCE) are batteries of tests that may be used to predict return to work, determine aspects of disability, and guide suitable intervention approaches [3–11], reasons for which they are used in VR. One of the best FCE tests to predict return to work is a lifting capacity test [3]. Patients with CBP who perform better on a lifting capacity test have higher likelihood of returning to work within the six months following the assessment [3,4]. Furthermore, lifting capacity test should not just be regarded as an assessment of physical capacity only, but of many biopsychosocial factors [5].

Several studies suggested that non-organic signs (NOS) should be part of routine screening in chronic pain rehabilitation, to help identify patients who require thorough psychosocial evaluation and to distinguish from conditions mainly determined by biological factors [6,12]. The NOS, introduced in 1980 by dr. Gordon Waddell [12], consist of eight simple physical tests which reflect ‘non-organic’ behavior, providing an opening for a biopsychosocial approach. A Swiss study revealed that the addition of NOS to FCE in patients with CBP resulted in an increase of 23% of explained variance in lifting capacity [7]. This study has not been replicated.

Modern advances in pain sciences have revealed better understanding of the processing of pain, especially the role of the central nervous system (CNS). In a subgroup of patients with chronic pain, pain might not be a direct reflection of the presence of a noxious peripheral stimulus (nociceptive pain) nor the nervous system (neuropathic pain), but could be the result of a condition in which the CNS is in a hypersensitive state; central sensitization (CS) [13]. Several symptoms described for CS may be observed in patients with CBP, suggesting a possible link between a subgroup of CBP and CS [13,14]. If the link exists, CS could also be related to lifting capacity performance and, ultimately, to the return to work of patients with CBP. The relationship between CS and lifting capacity has not yet been studied. More insight into the relation between the degree of CS and lifting capacity could add understanding to the construct of FCE, and guide clinicians and patients in VR decisions. This could lead to more patient focused treatment and potentially faster return to work.

The most recent and most comprehensive study on FCE revealed an explained variance for lifting capacity of 42%, with a mix of biological, psychological, and social factors as independent predictors [5]. While this was the most comprehensive study and it had the highest explained variance; there was still a large proportion unexplained, and a known confounder (NOS [6]) and potential new confounder (CS) were not included. The value of CS over known variables such as NOS, pain-related disability, pain intensity, psychosocial variables, and patient characteristics to predict lifting capacity in patients with CBP is unknown. This study was designed to answer the following research question: are CS and NOS independently associated with lifting capacity in patients with CBP attending VR?

MATERIALS AND METHODS

Design

A cross-sectional multicenter observational study was conducted within VR as care as usual. Data were gathered from three rehabilitation centers affiliated with the 'Vroege Interventie' (in English: Early intervention) network across the Netherlands. Data were collected from patient files and physical examination at patients' first visit to the rehabilitation centers from October 2018 to August 2019. Each center had a liaison assigned, who was responsible for data collection, merging, and delivery from the centers' clinicians to the project team. A waiver from the Medical Ethical committee of the University Medical Center Groningen (METc) was obtained for this study (M18.238357). All procedures follow the ethical standards of the Helsinki Declaration of 1975 and its later amendment in 2014 [15].

Participants

Patients were included if they were between 18 and 65 years of age, were diagnosed with CBP, and had sufficient language skills to understand the instructions and fill out questionnaires independently. Patients were excluded if they were pregnant, diagnosed with specific back pain related conditions (e.g. tumors, fractures, 3rd and 4th degree spondylolisthesis, or radicular syndromes), and/or relevant comorbidities which could influence FCE results (e.g. psychiatric or cardiovascular conditions).

Measurements

Dependent variable

Lifting capacity test was performed according to the WorkWell protocol [9,11]. This is a progressive test beginning with an easy to lift weight which is gradually increased in four to five steps until the patient reaches a 'safe maximum lift'. Patients were asked to lift a crate with weights from a shelf (height: 75 cm) to the floor and vice versa five consecutive times, after which the weight increased. The maximum weight lifted (kg) five consecutive times was recorded. As per regular clinical procedures, participants were allowed to terminate the lifting capacity test at any given moment and clinicians were instructed to stop the test if any (risk of) unsafety occurred. The reliability and predictive validity of this test are sufficient [3,4,8-11].

Main independent variables

CS symptoms were measured with the CS Inventory part A (CSI-A), a self-reported questionnaire to quantify the severity of symptoms originating from CS [16]. The CSI-A consists of 25 Likert-type scale questions related to somatic and emotional indices of CS syndromes. Patients can answer these questions with five options: never (0), rarely (1), sometimes (2), often (3), and always (4). The scores for all 25 questions are summed in a score ranging from 0–100; where a higher score reflects a higher severity of CS symptoms. The Dutch translation of the CSI has shown to reveal four distinguishable domains, good discriminative power, excellent test-retest reliability, and good internal consistency for three out of the four domains [17,18].

NOS were measured with the Waddell NOS, consisting of eight tests assessing five clusters of signs: tenderness, simulation, distraction, regional disturbance, and overreaction (for a detailed description of NOS, see Appendix 1) [12]. Any individual sign present on each of the tests counts as positive; thus, the NOS score can range from 0 to 8 and a positive score of 3 or more signs is considered clinically relevant [12]. During the first visit to the rehabilitation center, clinicians assessed the NOS as part of the physical examination. The NOS were recorded for each patient and added to the dataset. A Dutch study found that the inter-observer reliability of the Waddell NOS is moderate and the intra-observer reliability is good in trained observers [19].

Additional independent variables

Demographic characteristics were extracted: age, sex, and body mass index (BMI).

Pain-related disability was measured with the Pain Disability Index (PDI) [20]. The PDI evaluates the self-reported limitations in activities and participation (disability) experienced by individuals due to pain. This seven-item questionnaire measures across a range of daily activities: family/home responsibilities, recreation, social activity, occupation, sexual behavior, self-care, and life-support activity. The score for each item ranges from 0 to 10; with 0 being no interference and 10 being total interference. The total maximum sum score for the PDI is 70 points which indicates total interference in activities of daily living. Clinimetric properties of the PDI Dutch Language Version are sufficient [20].

Patient-reported and clinician-observed effort during lifting capacity tests were measured with the Borg CR-10 scale. The scale ranges from 0 to 10 and beyond; with 0 being no load, 10 being very heavy effort, and additional undefined effort [21]. Clinicians determined patients' effort based on observed biomechanical cues, during the administration of the lifting capacity test and prior to patient's self-reported rating of effort [4]. Validity and reliability of effort by means of visual observation when expressed on the CR-10 scale is sufficient [4].

Pain and fatigue intensities were measured with a Numeric Rating Scale (NRS) prior to the lifting capacity test. The NRS assesses the current level of pain and fatigue. This 11-point numeric scale ranges from 0 to 10; with 0 as no pain or fatigue and 10 as worst pain or fatigue imaginable. The clinimetric properties of the NRS are sufficient [22,23].

Occupational psychosocial factors were measured with the Vragenlijst ArbeidsReintegratie (VAR, Dutch Work Reintegration Questionnaire). The VAR assesses the occupational psychosocial factors that could contribute to maintaining CBP and increase the risk of long-term absenteeism. This 78-item questionnaire consists of eight scales: distress, perceived disability, job strain, control, job dissatisfaction, avoidance/insecurity, perfectionism, and stressful home situations. The total sum of all scale-scores is used in this study, ranging from 78 to 312; where higher scores indicate a worse state [24]. The clinimetric properties of the VAR are sufficient [24,25].

Data-analyses

Datasets from each center were merged into one dataset and entered into SPSS (SPSS Statistics version 25, IBM Corp., USA) for analyses. This dataset was checked for missing data and outliers. Substitution with means was used to replace for missing items in questionnaires. The influence of outliers (larger than three SD) was examined. The descriptive statistics of patients' collected variables were calculated and presented as means and standard deviations for continuous variables (m and SD) or as counts and percentages for categorical variables (n and %). Because large differences exist in lifting capacity between men and women [5-7], all correlations and regression analyses were performed controlling for sex.

The main analyses consisted of two steps. Step 1: Spearman's rho partial correlation analyses were performed between each of the independent variables and the dependent variable (lifting capacity). The CSI-A, NOS, and the additional variables correlating significantly ($p < 0.05$) were progressed to the next step. Correlations of $r_s < 0.30$, $r_s = 0.30-0.60$, and $r_s > 0.60$, were respectively considered weak, moderate, and strong [26]. Step 2: multiple regression analysis was performed. All the assumptions of the multiple regression analysis were checked and the models were built with the stepwise forward method. Results were expressed in the model's explained variance (R^2) and p-value, and independent variables' unstandardized beta (B), 95% Confidence Intervals (95% CI), partial correlations (r_{partial}), and p-values. Results of the multiple regression analysis were considered significant at $p < 0.05$.

RESULTS

A total of $n=56$ patients with CBP attending VR participated in this study, descriptive statistics for women and men are presented in Table 1. Thirty-three participants (59%) were women, mean age was 42.5 years and mean BMI was 26.3 kg/m^2 . On average women lifted 10 kg less than men and had higher CSI-A scores, no differences were seen in the total Waddell NOS score but in the distribution of scores of the NOS tests. Missing data were observed in three variables: pain-related disability (PDI, $n=51$), patient-reported effort (CR-10, $n=55$), and occupational psychosocial factors (VAR, $n=48$). Only in the latter, the missing data were in more than 10% of the cases and only in the work-related subscales; this was due to the fact that these patients were not actively working at that time.

Table 1. Description of personal and clinical characteristics of participating patients (n=56), for women and men.

	mean \pm SD / n and %			
	Women (n=33)		Men (n=23)	
Age (years)	40.2 \pm 13.1		46.0 \pm 13.0	
BMI (kg/m ²)	26.4 \pm 5.3		26.2 \pm 4.0	
Pain-related disability (PDI, 0–70)	35.6 \pm 11.3		31.5 \pm 14.9	
Lifting capacity (kg)	18.1 \pm 10.5		28.2 \pm 14.8	
Clinician-observed effort (CR-10, 0–10)	5.9 \pm 3.1		7.2 \pm 2.8	
Patient-reported effort (CR-10, 0–10)	7.9 \pm 2.2		7.8 \pm 2.8	
Pain intensity (NRS pain, 0–10)	5.3 \pm 1.9		4.0 \pm 2.3	
Fatigue intensity (NRS fatigue, 0–10)	4.4 \pm 2.5		4.2 \pm 3.3	
CS (CSI-A, 0–100)	36.8 \pm 12.4		32.1 \pm 13.9	
NOS (Waddell NOS, 0–8)	2.1 \pm 2.0		2.2 \pm 2.1	
Superficial tenderness ^a	8	24.2%	3	13.0%
Deep tenderness ^a	18	54.5%	11	47.8%
Axial loading ^a	10	30.3%	4	17.4%
Rotation ^a	12	36.4%	16	69.6%
Straight leg raising ^a	2	6.1%	4	17.4%
Sensory disturbance ^a	3	9.1%	2	8.7%
Weakness ^a	6	18.2%	5	21.7%
Overreaction ^a	9	27.3%	6	26.1%
Occupational psychosocial factors (VAR, 78–312)	176.3 \pm 27.3		182.4 \pm 32.5	
Distress (13–52)	26.1 \pm 7.1		25.7 \pm 7.0	
Perceived disability (10–40)	28.7 \pm 6.7		29.0 \pm 8.4	
Job strain (7–28)	14.2 \pm 5.1		14.8 \pm 4.3	
Control (6–24)	18.4 \pm 4.7		15.6 \pm 5.0	
Job dissatisfaction (12–48)	24.0 \pm 8.0		24.4 \pm 7.6	
Avoidance / Insecurity (11–44)	20.2 \pm 4.7		22.4 \pm 5.6	
Perfectionism (12–48)	34.6 \pm 5.0		36.2 \pm 7.3	
Stressful home situation (7–28)	11.5 \pm 3.5		14.0 \pm 5.1	

^a , positive NOS. Abbreviations: BMI, Body Mass Index; CR, Category Ratio; CS, Central Sensitization; CSI-A, CS Inventory part A; NOS, Non-Organic Signs; NRS, Numeric Rating Scale; PDI, Pain Disability Index; VAR, Vragenlijst ArbeidsReintegratie.

Step 1. Results of spearman's partial correlation analyses with lifting capacity and controlled for sex are shown in Table 2. Based on criterion of $p < 0.05$, the following variables progressed to the next step: age, pain-related disability (PDI), clinician-observed effort (CR-10), pain intensity (NRS pain), fatigue intensity (NRS fatigue), and occupational psychosocial factors (VAR).

Table 2. Spearman's partial correlations between lifting capacity, and CSI-A, NOS, and the additional independent variables; with the control variable sex.

	Lifting capacity (kg)	
	r_{partial}	p
CS (CSI-A)	-0.53	<0.001
NOS (Waddell NOS)	-0.50	<0.001
Age (years)	-0.54	<0.001
BMI (kg/m ²)	-0.13	0.343
Pain-related disability (PDI)	-0.55	<0.001
Clinician observed effort (CR-10)	0.44	0.001
Patient reported effort (CR-10)	0.19	0.160
Pain intensity (NRS pain)	-0.37	0.005
Fatigue intensity (NRS fatigue)	-0.35	0.008
Occupational psychosocial factors (VAR)	-0.35	0.015

Abbreviations: BMI, Body Mass Index; CR, Category Ratio; CS, Central Sensitization; CSI-A, CS Inventory part A; NOS, Non-Organic Signs; NRS, Numeric Rating Scale; PDI, Pain Disability Index; VAR, Vragenlijst ArbeidsReintegratie.

Step 2. Results of the multiple regression analysis for lifting capacity and controlled for sex are presented in Table 3. Both CSI-A and NOS remained significant in the multiple regression analysis. Of the additional variables significant at Step 1, only age was a significant addition to the model. The final model explained 57.6% of the variance ($p < 0.001$), and CSI-A and NOS maintained a moderate negative association with lifting capacity.

Table 3. Results of multiple regression analysis for lifting capacity with the control variable sex.

	B	[95% CI]	r _{partial}	p
(Constant)	48.87	[39.63, 58.12]		<0.001
Sex ^a	11.26	[6.23, 16.29]	0.53	<0.001
CS (CSI-A)	-0.30	[-0.50, -0.10]	-0.38	0.005
NOS (Waddell NOS)	-2.02	[-3.26, -0.77]	-0.42	0.002
Age	-0.39	[-0.58, -0.20]	-0.50	<0.001

^a, Reference category=Women. Abbreviations: CS, Central Sensitization; CSI-A, CS Inventory part A; NOS, Non-Organic Signs.

DISCUSSION

In this study it was aimed to analyze the associations between lifting capacity, and CS and NOS in patients with CBP. The final model explained 57.6% of the total lifting capacity variance. Women, higher scores in CSI-A and in Waddell NOS, and older age were found to be significantly associated to lower lifting capacity. While for the Waddell NOS the current results reinforce the previously described correlations with lifting capacity and return to work in patients with CBP [6,7]; for the CSI-A, to the authors' best knowledge, the results of an association with lifting capacity in patients with CBP has never been reported before. Furthermore, until now the study with the most variance explained in lifting capacity with patients was able to explain 42% of the total variance including eight biopsychosocial variables [5]. In the present study half of the variables explained substantially more variance, suggesting that the variables introduced in the current models, are stronger predictors for lifting capacity and should be taken into consideration during lifting evaluations.

It is surprising that pain intensity and pain-related disability, being some of the main factors associated to lifting capacity performance in patients with CBP, were not part of the predictors in the final model. Nevertheless, this could be possible if the effects of pain intensity and pain-related disability were already explained by both CSI-A and Waddell NOS. CSI-A, accounts for the somatic and emotional pain-related symptoms as a result of CS and one of its most distinct factor is general disability [18,27]. Meanwhile, several Waddell NOS (five out of eight) may be explained by pain and the presence of positive NOS may influence functional outcomes and return to work [28]. Therefore, it seems that the symptoms and disability developed due to pain, as measured by CSI-A and Waddell NOS, could be more accountable for lifting capacity performance in patients with CBP during return to work assessments. Moreover, because lifting capacity involves different factors and contributors interacting in a

biopsychosocial context [5], factors with important psychosocial components such as CSI-A and NOS may be more relevant predictors. The finding of moderate associations of CSI-A and NOS with lifting capacity performance ($r=-0.38$ and $r=-0.42$, respectively) after controlling for known confounders as sex and age (but with no other factors being significant additions to the model), underscores the importance of a biopsychosocial approach in the return to work assessments.

The data in the current study were obtained by means of tools which had sufficient clinimetric characteristics, which strengthens the study. Additionally, data were collected from three rehabilitation centers and by various clinicians; thus, participants of the study are representative of the actual Dutch population attending a return to work assessment. However, the results may not be generalizable to other societies or other patient samples. Moreover, some of the patients were not working, reason for which work-related domains of the VAR (Dutch Work Reintegration Questionnaire) were not filled in. To avoid bias due to the exclusion of these patients in VR, the analyses including occupational psychosocial factors (VAR) were performed pairwise. Also, the findings of this study have to be interpreted carefully due to its cross-sectional study design, a limitation that prevents us from drawing causal conclusions. Future studies may be able to replicate the current study in different societal context or with a longitudinal design, which may provide further insights on the association of lifting capacity with CS and NOS.

In conclusion, the outcomes of this study endorse the relevance of CS and NOS assessment in FCE administration. The moderate negative associations of lifting capacity with CS and NOS should be interpreted as a call for better understanding of psychosocial factors affecting the patients' lifting capacity [3,10,11]. In order to be able to provide patients with CBP more focused treatment and potentially improve their chances to return to work faster, more research regarding these topics is needed.

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APPENDIX

Appendix 1. The Waddell Non-organic Signs (NOS) [12].

Tenderness	
1. Superficial	The skin is tender to light pinch over a wide lumbar area. A localised band in a posterior primary ramus distribution may be caused by nerve irritation and should be discounted.
2. Deep	Tenderness is felt over a wide area. It is not localized to one structure and often extends to the thoracic spine, sacrum, or pelvis.

Simulation tests	
3. Axial loading	LBP is reported on vertical loading over the standing subject's skull by the examiner's hands. Neck pain is common and should be discounted.
4. Rotation	LBP is reported when shoulders and pelvis are passively rotated in the same plane as the subject stands relaxed with the feet together. In the presence of root irritation leg pain may be produced and should be discounted.

Distraction test	
5. Straight leg raising	Straight leg raising is the most useful distraction test. The subject whose back pain has a nonorganic component shows marked improvement in straight leg raising on distraction as compared with formal testing.

Regional disturbances	
6. Sensory	Sensory disturbances include diminished sensation to light touch pinprick and sometimes other modalities fitting a "stocking" rather than a dermatomal pattern.
7. Weakness	Weakness is demonstrated on formal testing by a partial cogwheel "giving way" of many muscle groups that cannot be explained on a localized neurological basis.

Overreaction	
8. Overreaction	Overreaction during examination may take the form of disproportionate verbalization, facial expressions, muscle tension and tremor, collapsing or sweating judgements should, however, be made with caution, minimizing cultural variations, and it is very easy to introduce observer bias or to provoke this type of response unconsciously.

