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

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The relationship between Maximal aerobic capacity and Functioning in patients with chronic low back pain

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ABSTRACT

Objective. Maximal exercise testing is considered the gold standard to assess VO_2max. However, maximal exercise testing has been deemed unfeasible and unsafe in patients with chronic low back pain (CLBP). Consequently, the vast majority of previous studies on aerobic capacity and functioning in patients with CLBP were performed with submaximal testing protocols. A recent study demonstrated the safety and feasibility of maximal exercise testing in patients with CLBP. Therefore, the relation between aerobic capacity and functioning should be re-evaluated. The aim of this study is to determine the relationship between maximal aerobic capacity and four measures of functioning: lifting capacity, work ability, pain-related disability and physical functioning; in patients with CLBP.

Methods. Maximal aerobic capacity of patients with CLBP was assessed with a maximal cardiopulmonary exercise test. Functioning was measured with a floor-to-waist lift capacity test and three questionnaires: Work Ability Score, Pain Disability Index, and Physical Functioning subscale of Rand36. The associations between maximal aerobic capacity and each of the functioning measures were analyzed with multiple linear regression analyses, while controlling for potential confounders.

Results. Data of n=74 patients with CLBP were analyzed. After controlling for potential confounders, maximal aerobic capacity was moderately associated with lifting capacity ($\beta=0.32$; $p=0.006$), but not with any of the other functioning measures ($\beta=-0.08$ to 0.12; $p>0.288$).

Conclusion. A higher level of maximal aerobic capacity is moderately associated with a higher lifting capacity, but not with self-reported work ability, pain-related disability and physical functioning.

INTRODUCTION

Chronic low back pain (CLBP) has negative psychosocial and physical effects on patients and leads to decreased functioning and disability [1,2]. In patients with CLBP, a higher level of physical activity is associated with higher physical functioning and lower pain-related disability [3–7]). Patients with CLBP may be deconditioned due to reduced physical activity, resulting in low maximal aerobic capacity (VO_2max) [8,9]. The majority of research investigating the relationship between maximal aerobic capacity and functioning in patients with CLBP is performed using submaximal cardiopulmonary exercise testing (CPET) [8,10,11]. These studies provide inconsistent results on the relation between maximal aerobic capacity and functioning, pain and disability. Furthermore, submaximal CPET is inaccurate and invalid to determine maximum aerobic capacity, because VO_2max is estimated and not measured directly [12–14]. Consequently, the results of previously reported studies may be flawed. A maximal CPET, although considered the gold standard [15], has only seldom been applied, because it was not considered feasible or tolerated by patients with CLBP [14]. Recently, however, feasibility and tolerance of maximal CPET were established in patients with CLBP [9]. It was demonstrated that 69.3% to 91.1% of the participating patients with CLBP managed to complete a maximal CPET [16]. One study used maximal CPET and showed the absence of a relation between maximal aerobic capacity and several reported measures of functioning and disability [17]. Recently the relationship between maximal aerobic capacity and disability in patients with complaints of arm, neck and/or shoulder was explored [18]. With maximal CPET being in reach for use in patients with CLBP, the current knowledge on the relationship between maximal aerobic capacity and functioning should be re-examined and expanded.

The research question in this study was: what is the relationship between maximal aerobic capacity acquired by maximal CPET and functioning in patients with CLBP? Functioning was operationalized by four measures: lifting capacity, work ability, pain-related disability and physical functioning. It was expected that patients with CLBP with higher maximal aerobic capacity would have higher levels of functioning. Results of this study can be used to re-asses current knowledge on this relationship and may result in new insights in treatment options for patients with CLBP.

MATERIALS AND METHODS

Study design

An observational study with a cross-sectional design was conducted from September 2017 to June 2019 in the Center for Rehabilitation of the University Medical Center Groningen (CvR–UMCG) in the Netherlands. This study is part of an extensive project of which the protocol is described elsewhere [19]. Medical ethical approval was obtained from the Medical Research Ethics Committee of the UMCG (METc2016/702) and procedures are in accordance with the declaration of Helsinki [20].

Participants

Patients between the age of 18 and 65 years at the time of recruitment who were primarily referred to the CvR–UMCG due to CLBP, deemed mentally competent and capable of following instructions, were eligible for the study. Exclusion criteria were the following: a specific diagnosis that would specifically account for the symptoms (e.g. herniated disc or osteoarthritis), a neuralgia and/or radicular pain in the legs, a severe psychiatric condition, a contraindication to CPET or the lifting capacity protocols [21,22], being pregnant or planning to be.

Procedure

All data were collected at the baseline assessment of an interdisciplinary pain rehabilitation program. All participants were informed about the study's measurements and signed informed consent before the start of the study.

Measurements

Maximal aerobic capacity was measured by means of a CPET. CPET was performed with a cycle ergometer (Ergoselect 200p or Ergoselect 200k, Ergoline, Bitz, Germany) following a defined continuous ramp protocol. Patients started with an unloaded warming-up for 3 minutes at 60-70 rotations per minute before the test began. Depending on the estimated patient's level of fitness, the starting workload (25-100 watts) and ramp (5-25 watts) were determined. During the test, the workload was progressively increased while the patient was asked to maintain a constant cadence until their maximum performance was reached. Maximum performance was determined by several variables: a temporary loss of strength and energy (=exhaustion), a plateau in peak oxygen uptake in ml/min, a respiratory exchange ratio higher than 1.15 and/or a heart rate higher than 85% of the maximal predicted heart rate [21]. During the test, patients were monitored on their cardiac activity with an ECG, blood pressure with a cuff algometer and on their ventilatory gases on a breath-by-breath basis with a metabolic cart (JAEGER Vyntus CPX, Jaeger, Germany, Hoechberg). The peak oxygen uptake in ml/min (VO_2max) was obtained as the mean of VO_2 over the last 30 seconds of the test.

Lifting capacity was measured with a floor-to-waist lift capacity test which is based on the Work-Well Functional Capacity Evaluation (FCE) protocol [22]. The lift test has high test-retest (ICC=0.81) and inter-rater reliability (ICC=0.76) in patients with CLBP [23,24]. Assessors trained in the test procedure, provided standardized instructions to repetitively lift a crate with weights from a shelf at waist height to the floor and back. The test started with a weight that could easily be lifted, followed by a progressive increase in load. The tests ended when maximum capacity was reached. The endpoint was determined by various parameters, whichever came first: cardiac endpoint (85% of maximum heart rate), biomechanical endpoint (unsafe increasing weight because of lack of load handling control), patient endpoint (patient decides to stop) and criterion endpoint (normal end of the test) [25]. The maximal load lifted was recorded in kilograms.

Work ability was measured by means of the Work Ability Score (WAS), a single-item question comparing patient's lifetime best work ability with their current work ability. The WAS ranges from 0 (unable to work) to 10 (best working ability). The single-item question is part of the Work Ability Index (WAI), a questionnaire which measures work ability and has shown to be test-retest reliable (difference between test and retest=- 0.53 in construction workers) [26]. The WAS is highly correlated to the 28 items of the WAI among woman on a long-term sick leave (r=0.87) [27] and among active workers (r=0.63) [28].

Pain-related disability was measured with the Pain Disability Index (PDI) which is a questionnaire containing seven items [29]. It measures the interference of pain in daily functioning and life activities: family/home responsibilities, recreation, social activities, occupation, sexual behavior, self-care and life support activities. Each item ranges from 0 (no interference) to 10 (maximal interference). The sum score ranges from 0 to 70, where a higher score means more interference in daily life [18]. In this study the Dutch translation of the PDI was used, which has shown a good internal consistency (Cronbach's α=85) and test-retest reliability (ICC=0.76) in patients with musculoskeletal pain [30].

Physical functioning was measured by means of the Physical Functioning subscale of the Rand36 (Rand36-PF) questionnaire. Patients answered ten questions about the limitations they experience during their daily activities.

The sum score ranges from 0 to 100, where a higher score indicates a greater level of reported limitation [31]. The Dutch translation was used, which has shown good internal consistency (Cronbach's α=0.92) and test-retest reliability (r=0.72–0.82) in the general population [31].

Clinical information was collected by means of questionnaires, all of which are explained in more detail elsewhere [19]: pain intensity (Visual Analogue Scale – VAS-pain, 0–10) [32], catastrophizing (Pain Catastrophizing Scale – PCS, 0–52) [33], perceived injustice (Injustice Experience Questionnaire – IEQ, 0–48) [34] and psychological traits (Brief Symptom Inventory Global Severity Index T-score – BSI-SGIT, 0–100) [35]. In all these questionnaires, higher scores represent worse states. For each patient, age, sex, height, weight, pain symptoms characteristics (body area and duration), educational level and employment details (physical work demands per Dictionary of Occupational Titles) [36] were collected with a custom-made form.

Statistical analysis

The sample size was estimated at 63 participants and has been calculated with GPower (G*Power for Windows, Version 3.1.9.7) with an α error of 0.05 and a power of 0.85. Before any analysis were done, data were prepared as described in the protocol published elsewhere [19]. The analysis of the data were performed with SPSS (SPSS Statistics version 25, IBM Corp., USA).

Data-distribution was assessed by using the Kolmogorov-Smirnov test, and skewness and kurtosis. Data not normally distributed were analyzed with non-parametric tests. Differences in maximal aerobic capacity and lifting capacity between males and females were evaluated using two-tailed independent samples t-tests. Correlation coefficients were generated using bivariate correlation analyses to explore relationships between main measures (maximal aerobic capacity, lifting capacity, work ability, pain-related disability and physical functioning) and potential confounders (demographic and clinical characteristics). Bivariate correlations were explored using Pearson correlation for continuous normally distributed data, Spearman's rho for continuous not normally distributed and categorical data, and Pearson's Point-Biserial for dichotomous data. Associations with a significance level of $p<0.05$ were considered potential confounders and were added to the regression analyses. If a bivariate correlation was significant in either males or females, the potential confounder was added to the regression analysis. Correlation coefficient values >0.70 were considered strong, values between 0.30 and 0.70 moderate, and values <0.30 weak [37].

Four multiple linear regression analyses were performed. Lifting capacity, work ability, pain-related disability and physical functioning were the dependent variables, whereas maximal aerobic capacity and potential confounders were used as the independent variables. Dummy variables were created for categorical data and used as a group in the analyses. A backward selection method was applied and the least significant variables were manually excluded. Criterion for removal was $F_{change}>0.05$. For the final regression analyses, the enter method was used. Multicollinearity was checked with the variance inflation factors. Statistical significance was assumed when $p<0.05$.

RESULTS

A total of 97 patients with CLBP enrolled in the study. Five patients declined participation and fifteen patients were not assessed due to not proceeding to rehabilitation program treatment. Additionally, one patient was retrospectively excluded because of an existing condition interfering with measurements and two patients did not perform maximal CPET assessment. Eventually 74 patients were included in our analyses.

All missing data were accounted for and missing values were not imputed. Kolmogorov-Smirnov and skewness and kurtosis revealed normal distribution for all variables, except for 'Pain duration (in years)' (median: 2.1, IQR: 1.3–4.2). All other demographic and clinical characteristics are presented in Table 1. T-tests revealed higher maximal aerobic capacity and lifting capacity in males than in females ($p<0.01$).

Table 1. Description of participating patients.

	n	mean ± SD / %
Age (years)	74	40.4 ± 12.4
Sex	74	
Male	30	40.5%
Female	44	59.5%
BMI (kg/m^2)	74	27.7 ± 5.4
Diagnosis area	74	
Low back	24	32.4%
Generalized back	23	31.1%
Back and legs	10	13.5%
Multiple sites	17	23.0%
Educational level	70	
Primary	2	2.9%
Secondary	40	57.1%
Higher	28	40.0%
Physical work demands	74	
Sedentary	18	24.3%
Light	32	43.2%
Medium	20	27.0%
Heavy	4	5.4%
Pain intensity (VAS; 0–10)	73	4.7 ± 2.2
Catastrophizing (PCS; 0–52)	65	18.9 ± 10.2
Injustice (IEQ; 0–48)	70	16.8 ± 9.7
Distress (BSI-GSIT; 0–100)	65	39.7 ± 9.2
VO_2max (l/min)	74	2.0 ± 0.6
Male	30	2.4 ± 0.7
Female	44	1.8 ± 0.3
Lifting capacity (kg)	72	14.4 ± 9.4
Male	30	20.1 ± 9.9
Female	42	10.2 ± 6.5
Work ability (WAS; 0–10)	73	4.6 ± 2.4
Pain-related disability (PDI; 0–70)	72	36.7 ± 11.9
Physical functioning (Rand36-PF; 0–100)	73	51.5 ± 19.5

< Abbreviations: BMI, Body Mass Index; BSI, Brief Symptom Inventory; GSIT, Global Severity Index Total Score; IEQ, Injustice Experience Questionnaire; PCS, Pain Catastrophizing Scale; PDI, Pain Disability Index; Rand36-PF, Physical Functioning; VAS, Visual Analogue Scale; VO_2max, maximal aerobic capacity; WAS, Work Ability Score.

Results of the correlation analyses between maximal aerobic capacity, lifting capacity, work ability, pain-related disability and physical functioning on the one hand, and demographic and clinical characteristics on the other hand are presented in Table 2. When correlations were significant, their strengths were weak to moderate.

Results of the regression analyses are presented in Table 3, with lifting capacity, work ability, pain-related disability and physical functioning as dependent variables respectively. The final model for lifting capacity explained 35% of the variance. Both maximal aerobic capacity and sex were significant contributors to the model. The final model for work ability explained 38% of the variance. Maximal aerobic capacity did not significantly contribute to the model, while diagnosis area, educational level and distress did. The final model for pain-related disability explained 18% of the variance. Maximal aerobic capacity did not significantly contribute to the model while pain intensity did. The final model for physical functioning explained 23% of the variance. Maximal aerobic capacity did not significantly contribute to the model, while body mass index and pain intensity did.

Table 2. Results of correlation analyses of the associations of maximal aerobic capacity and lifting capacity, work ability, pain-related disability and physical functioning with demographic and clinical characteristics.

	VO_2max (l/min) n= 74		**Lifting capacity (kg) n=72**		**Work ability (WAS) n=73**	**Pain-related disability (PDI) n=72**	**Physical functioning (Rand36-PF) n=73**
	Male	**Female**	**Male**	**Female**			
VO_2max (l/min)	.	.	0.35	0.29	0.23	-0.13	0.17
Sex [a]	.	.	.	.	-0.02	0.06	-0.02
Age (years)	-0.44*	-0.37*	-0.10	-0.05	0.00	-0.01	-0.21
BMI (kg/m^2)	-0.06	-0.07	-0.10	-0.19	-0.17	0.10	-0.33**
Diagnosis area	0.15	-0.12	-0.06	0.13	-0.24*	0.25*	-0.09
Pain duration (years)	-0.18	0.38*	-0.07	-0.02	0.11	0.00	0.00
Education level	0.50**	0.19	0.41*	0.10	0.35**	-0.14	0.18
Work demands	-0.49**	0.09	-0.14	0.08	0.07	0.11	-0.20*
Pain intensity (VAS)	-0.17	-0.03	-0.31	-0.08	-0.36**	0.41**	-0.35**
Catastrophizing (PCS)	-0.09	-0.14	-0.04	-0.35*	-0.18	0.16	-0.26*
Injustice (IEQ)	-0.06	-0.21	0.11	-0.38*	-0.21	0.25*	-0.21
Distress (BSI-GSIT)	-0.17	0.00	0.20	-0.20	-0.27*	0.29*	-0.07

[a], Reference category=male. Significance levels: * , $p<0.05$; ** , $p<0.01$. Abbreviations: BMI, Body Mass Index; BSI, Brief Symptom Inventory; GSIT, Global Severity Index Total Score; IEQ, Injustice Experience Questionnaire; PCS, Pain Catastrophizing Scale; PDI, Pain Disability Index; Rand36-PF, Physical Functioning; VAS, Visual Analogue Scale; VO_2max, maximal aerobic capacity; WAS, Work Ability Score.

Table 3. Final multiple linear regression models of the association between four determinants of functioning and maximal aerobic capacity and potential confounders.

		β	Unst. β	95% CI	p	R^2
Lifting capacity (kg)	(Constant)	.	7.83	[-1.31 , 16.98]	0.092	0.35
	VO_2max (l/min)	0.32	5.24	[1.57 , 8.90]	0.006	
	Sex [a]	-0.37	-6.93	[-11.16 , -2.70]	0.002	
Work ability	(Constant)	.	4.50	[0.93 , 8.06]	0.014	0.38
	VO_2max (l/min)	0.12	0.49	[-0.43 , 1.41]	0.288	
	Educational level	0.33	1.42	[0.45 , 2.39]	0.005	
	Distress (BSI-GSIT)	-0.33	-0.09	[-0.14 , -0.03]	0.003	
	Diagnosis area:					
	Generalized back [b]	-0.06	-0.31	[-1.58 , 0.97]	0.629	
	Back and legs [b]	-0.42	-2.85	[-4.46 , -1.23]	0.001	
	Multiple sites [b]	-0.29	-1.61	[-2.97 , 0.25]	0.021	
Pain-related disability	(Constant)	.	29.93	[18.19 , 41.67]	<0.001	0.18
	VO_2max (l/min)	-0.08	-1.75	[-6.36 , 2.86]	0.452	
	Pain intensity (VAS)	0.40	2.18	[0.99 , 3.37]	0.001	
Physical functioning	(Constant)	.	89.99	[59.85 , 120.14]	<0.001	0.23
	VO_2max (l/min)	0.09	2.95	[-4.37 , 10.26]	0.425	
	Pain intensity (VAS)	-0.34	-2.97	[-4.84 , -1.11]	0.002	
	BMI (kg/m^2)	-0.30	-1.10	[-1.88 , -0.32]	0.006	

[a], Reference category=male. [b] Reference category=low back. Abbreviations: BMI, Body Mass Index; BSI, Brief Symptom Inventory; GSIT, Global Severity Index Total Score; VAS, Visual Analogue Scale; VO_2max, maximal aerobic capacity.

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DISCUSSION

Results show that maximal aerobic capacity is positively associated with lifting capacity in patients with CLBP, but not with work ability, pain-related disability and physical functioning. Because this study is one of the first to use maximal CPET as a measure of maximal aerobic capacity, comparison with results from other studies is hindered. Indirect comparisons can be made with studies using submaximal exercise tests, different study populations or other measures of functioning. The absence of a relation between maximal aerobic capacity and self-reported measures of functioning is consistent with other studies using both submaximal CPET and maximal CPET to determine maximal aerobic capacity [8,10,11,17]. Our finding that maximal aerobic capacity is related to lifting capacity is not consistent with the results of the one other study that applied maximal CPET [17]. However, in our study lifting capacity was objectively measured whereas in this study physical functioning was a reported measure. Our results are consistent with the findings of one study using submaximal CPET to determine the relation between maximal aerobic capacity and objectively tested functioning [11].

The absence of a correlation between maximal aerobic capacity and self-reported work ability, pain-related disability and physical functioning might be attributed to a number of possible reasons. First of all, these variables of functioning are self-reported and not measured by means of performance-based testing. Earlier studies revealed that patients consider their own functioning to be more limited than it is observed in performance-based testing [38,39]. Secondly, despite the low maximal aerobic capacity of patients with CLBP [8], they may experience limitations in functioning when their present aerobic capacity is sufficient to perform their usual daily activities. Research shows that on average, patients with CLBP tend to reduce their physical activity [8,40]. This could explain why participants in our study with lower maximal aerobic capacity do not necessarily report lower scores on self-reported functioning. This could be considered a ‘deconditioning paradox’: while present aerobic capacity may be lower than preexisting levels, the present level may still be sufficient for their current desired functioning. Because lifting capacity is a performance-based test and maximal lifting requires a certain amount of aerobic capacity, this might have contributed to the relationship observed in the present study.

The main strength of this study is that it is one of the first to apply a gold standard method to determine the maximal aerobic capacity in patients with CLBP and uses this direct measure to determine the relationship with functioning. It also replicates the results of a single other study using similar approach [11], thereby adding robustness to the results of both studies. The generalizability of the outcomes is limited as a consequence of the selection criteria applied in this study. Another limitation is that, due to the cross-sectional study design, causal relationships between aerobic capacity and functioning cannot be made.

Further research is needed to better unravel the relationship between maximal aerobic capacity and functioning. Similar studies should expand by means of performing multiple measurements spread across a longer period of time, preferably during a rehabilitation program in which regular exercise is implemented. Additionally, a study with a prospective design would make it possible to estimate causal relationships. Because this study revealed no relations between maximal aerobic capacity and self-reported functioning, it does not justify the training of aerobic capacity during the rehabilitation program as a standard treatment option for patients with CLBP. On the other hand, if (heavy) lifting is required, for example for work, training to increase aerobic capacity may be considered as a treatment modality. Future research should investigate whether patients who might benefit form an increase of maximal aerobic capacity have specific characteristics, such as high physical work demands or high-level leisure demands, enabling better personalized rehabilitation.

CONCLUSION

In conclusion, maximal aerobic capacity was significantly associated with lifting capacity but not with self-reported functioning. The absence of a relationship between maximal aerobic capacity and the self-reported functioning variables at group level should not be interpreted as that relationships do not exist at the level of the individual patient. Clinically, the aerobic capacity of the majority of patients will be sufficient to defy the functional demands of everyday functioning. However, individual patient's capacity may be lower than functionally required and these patients' aerobic capacity will be a limiting factor to function normally. In these cases, aerobic capacity training and/or adaptations to match their functional demands should be considered to improve functioning.

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