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Do Patients With Chronic Low Back Pain Have a Lower Level of Aerobic Fitness Than Healthy Controls?

Are Pain, Disability, Fear of Injury, Working Status, or Level of Leisure Time Activity Associated With the Difference in Aerobic Fitness Level?

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Study Design. Prospective case series with historical controls (normative data).

Objectives. To compare the aerobic fitness level of patients with chronic low back pain (CLBP) with healthy controls matched for gender, age, and level of sport activity and to evaluate the association of the difference in aerobic fitness level with pain intensity, duration and degree of disability, fear of injury, and level of activity during work, including household and leisure time.

Summary and Background Data. Controversy exists whether patients with CLBP have a lower level of aerobic fitness and whether this level may partly depend on the patients' activity level.

Methods. A total of 108 CLBP patients completed questionnaires regarding pain, disability, fear of injury, and activity level and performed a modified Åstrand submaximal cycling test. The maximum oxygen consumption (VO_2max) was calculated and compared with normative data. Multiple linear regression analysis was performed with the difference of the level of aerobic fitness as dependent variable.

Results. VO_2max could be calculated in 78% of the patients. Both men and women with CLBP had significant lower VO_2max than the healthy referents (10 mL/kg LBM • min^{-1} and 5.6 mL/kg LBM • min^{-1} respectively, $P < 0.001$), and this difference was significantly greater in men ($P = 0.03$). Multiple regression analysis showed that the level of aerobic fitness was not associated with the presumed variables. The patients who stopped the test prematurely were older ($P = 0.02$) and more disabled ($P = 0.01$).

Conclusion. CLBP patients, especially men, seem to have a reduced aerobic fitness level compared with the normative population. No explanatory factor for that loss could be identified.

Key words: low back pain, aerobic fitness, activity level, fear of injury, pain, disability, rehabilitation. **Spine 2006;31:90–97**

Current rehabilitation for patients with chronic low back pain (CLBP) is often based on the assumption that these patients have low levels of aerobic fitness and are deconditioned.[1–3] The deconditioning syndrome was postulated in the mid 1980s as a factor contributing to the intolerance to physical activities and subsequent further loss of function and disability in patients with CLBP. More recently, physical disuse has been presented as one of the factors that perpetuate chronic pain in the fear avoidance model.[4–6] Because of catastrophizing, the patient experiencing pain might become fearful, start to diminish activities, and then become more and more deconditioned, disabled, and depressed.

Despite the long existence of the deconditioning theory, it is still not clear whether symptoms of physical deconditioning, especially a reduced level of aerobic fitness, develop or even exist in patients with CLBP. A number of studies have investigated aerobic fitness in patients with CLBP with conflicting results.[5,7–10] However, authors have been consistent in suggesting that differences in levels of physical activity may contribute to their discrepant findings. For instance, Nielens and Wittink found male-female differences in VO_2max and suggested that these differences are attributable to different levels of physical activity, especially regarding work, household, sport, and leisure time. Data to confirm their hypothesis are not available to date.[9,11] Although it is known that VO_2max has a moderate correlation with sport activity,[12] no study has been published in which patients and healthy controls are matched for their level of sport activities before comparing their aerobic fitness levels. As it seems plausible that sport and physical activity matter to the level of aerobic fitness, it is important that studies in patients with CLBP incorporate information about the preceding as well as the current level of physical activities.[5,7,9,13]

According to the deconditioning theory and fear avoidance model of pain, other relevant factors related to the level of aerobic fitness might be pain intensity, the duration and degree of disability, and fear of injury. Controversy exists as some cross-sectional studies showed a correlation between these factors and the level of aerobic fitness and others did not.[4,9,14–16]

We hypothesized that 1) patients with CLBP have a reduced level of aerobic fitness after adjustment for age, gender, and level of sport activity as compared with healthy controls; and 2) if there is a difference in the level of aerobic fitness between the CLBP patients and their

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healthy controls, this difference is associated with pain intensity, duration and degree of disability, fear of injury, and especially with the level of activities at work, including household and leisure time.

Methods

Participants and Setting. A total of 115 patients of the eligible 150 patients who were referred by their general practitioner or medical specialist during the period of April 2002 until September 2003 for treatment to an outpatient unit of three rehabilitation centers in the province of Noord-Brabant in The Netherlands agreed to participate in a randomized controlled trial to evaluate the effectiveness of different treatments for CLBP disability. The inclusion criteria were: 1) first referral to a rehabilitation center to reduce disability due to nonspecific low back pain existing at least 3 months, 2) age between 18 and 65 years, and 3) ability to walk at least 100 m. Exclusion criteria were lumbar disc herniation with neurologic symptoms; inflammatory or neoplastic disease; fracture of the spine; spondylolisthesis or spondylolysis; lumbar spondylodesis; major psychiatric, cardiac, and/or pulmonary conditions; severe addiction to drugs, narcotics, or alcohol; and pregnancy. A total of 35 patients did not participate in the randomized controlled trial. The reasons for not participating were as follows: not willing to participate in this research ($n = 4$); not meeting criteria ($n = 11$); preference for a particular treatment ($n = 10$); logistic problems to attend treatment ($n = 8$); waiting time too long ($n = 2$).

For this study on the level of aerobic fitness, 7 of the 115 patients who agreed to participate in the randomized controlled trial were excluded because they were taking medication that influenced heart rate (*e.g.*, β-blockers). A total of 108 patients remained. All data were obtained during a prerandomization testing session. Patients completed questionnaires and performed a submaximal bicycle test and several performance tasks. In this study, the results of several questionnaires and the submaximal test will be presented. All patients gave written informed consent to participate. The medical ethics committee of the Rehabilitation Foundation Limburg and Institute for Rehabilitation Research at Hoensbroek in The Netherlands approved the research protocol.

Testing Procedure

Modified Submaximal Åstrand Bicycle Test. To predict the maximum oxygen consumption (VO_2max in mL/kg lean body mass/min [mL/kg LBM • min^{-1}]), a modified submaximal Åstrand bicycle test was performed. In this test, developed for CLBP patients by the Department of Rehabilitation of the University Hospital Groningen, The Netherlands, the workload is gradually increased. Sufficient test-retest reliability ($r = 0.87$) and validity ($r = 0.84$, when compared with maximal VO_2 uptake measured with a maximum exercise test) have been established.[17,18] Patients' LBM was measured according to the protocol of Durnin and Womersley by using a skinfold caliper (Servier Nederland BV, Leiden, The Netherlands).[19]

The participants performed the test on a calibrated cycle ergometer (Tunturi E3, Turku, Finland; Jaeger ER 800, Bitz, Germany; Lode Concord 1.0, Groningen, The Netherlands). The heart rate was monitored by a monitor placed on the patients' chest (Polar Favor, Kempele, Finland). The patients started cycling with a workload of 0.5 W/kg LBM at a constant rate of 60 rpm. After 2 minutes, the workload was increased to 1.5 W/kg LBM. If the heart rate was still below 120 beats/min, the workload was increased to 2.0 W/kg LBM and, when necessary, to 2.5 W/kg LBM. When the heart rate exceeded 120 beats/min, the patient cycled 6 minutes with a fixed workload to reach a steady state phase, meaning that the heart rate did not vary more than ± 5 beats/min during the last minute of exercise. The average heart rate during the last minute was calculated. The VO_2max was estimated by using the Åstrand's nomogram based on the linear association between heart rate and increase in oxygen uptake.[20]

If the heart rate during the last minute varied more than ± 5 beats/min, no VO_2max could be estimated. The test was stopped if the patient did not reach a heart rate of at least 120 beats/min, the heart rate exceeded the predefined maximum rate ($[220 - \text{age}] \times 0.85$), the blood pressure reached the level of 220/115 mm Hg, or if the patient showed signs of serious cardiovascular or pulmonary difficulties.

Normative Data. Normative data on the aerobic fitness level of healthy Dutch people from all over the country were gathered from 1991 until 2003 using the submaximal Åstrand bicycle test.[21] This database includes 18,082 healthy people 17 to 70 years of age. All healthy people were already classified into groups specified by age, gender, and the level of sport activity during the preceding half year. People undertaking 1 to 2 hours of sport weekly for at least half a year were categorized as "recreational," and those sporting less than that or not at all were categorized as "untrained."

In the normative dataset, mean values and standard deviations (SD) of VO_2max in mL/kg LBM • min^{-1} are available for groups stratified by gender, age, and level of sport activity.

To match patients and controls for sport activity during the preceding half year, the patients completed the Baecke Physical Activity Questionnaire (BPAQ).[22] Based on the answers to the questions concerning sport activity, the patients were stratified using the same criteria as used for the normative sample.

Instruments, Reliability, and Validity

Demographic Data and Clinical Characteristics. For each patient, the age, gender, duration of complaints and disability, extent of radiation of pain to leg, and the history of back surgery and/or trauma were recorded.

Pain. A 100-mm-long visual analogue scale with on the left side "no pain" and on the right side "unbearable pain" was used to measure the pain intensity. Relevance, validity, and reliability have been sufficiently tested for patients with low back pain.[23–25]

Perceived Disability. The Dutch version of the Roland Disability Questionnaire (RDQ) measures perceived low back pain disability. The questionnaire consists of 24 items with yes or no answers and total score ranging from 0 to 24. The higher the score, the more disabled a patient is. The RDQ is sufficiently valid and reliable in CLBP.[26–31] In addition, the Dutch version of the Quebec Back Pain Disability Scale (QBPDS) was used.[32,33] This questionnaire consists of 20 items with a total score ranging from 0 to 100, with 0 meaning not being disabled and 100 being maximal disabled. The validity and reliability for the Dutch version in CLBP are good.[34]

Fear of Injury. The Dutch version of the Tampa Scale for Kinesiophobia (TSK), which measures fear of injury and movement and consists of 17 items with a total score ranging from 17 to 68, was used. A higher score on the TSK indicates more fear. The questionnaire is considered reliable and valid in CLBP.[35,36]

Level of Activity at Work and During Leisure Time. The BPAQ is used to quantify the amount of physical activity during the preceding year.[12,22] This questionnaire consists of 19 items addressing the three main types of physical activity: work, sport, and leisure time. For each type of activity, an index is calculated. For each question, the patient is asked to score on a 5-point Likert-scale ranging from "never" to "always" or "very often." In addition, the patient has to report his main occupation, which is then categorized into light, moderate, or heavy work according to the level of energy expenditure. The work index is calculated by adding the work-intensity score to the score of seven questions regarding work-related sitting, standing, walking, heavy lifting, tiredness, sweating, and comparison with others of same age, and dividing this total score by eight. The leisure time index is calculated by summing the scores of four questions about watching television, walking, and cycling and dividing this score by 4. The reliability[12,22,37,38] and validity in healthy populations appear to be good[39] and sufficient for patients with at least 1 month of low back pain.[40]

Since household activities might be responsible for maintaining a higher level of aerobic fitness, we categorized household duties exceeding 5 hours a week as work. Because the number of working hours is not assessed in the BPAQ, patients were additionally asked how many hours a week they worked and performed household activities. An alternative work index was calculated by multiplying the work-intensity score with the amount of hours of work or household activities per week. It was decided that all work and household activities performed during the 3 months previous to the testing contributed to the alternative work index; for example, when a person was sick listed for 4 weeks he was assigned the full score for 8 weeks and no score for 4 weeks on the alternative work index. This calculation is in accordance with the way the sport index is calculated in the BPAQ.

Statistical Analysis. For all variables, the mean and SD were calculated. Because only the mean and SD of VO_2max of healthy controls were available per group, matching on an individual basis was not possible. For each patient, the following formula was used:

$$Z_{patient} = (VO_2max\ observed_{patient} - VO_2max\ expected_{group})/SD_{group}$$

Next, all $Z_{patient}$ scores were summarized (Z_{total}), and SD_{Ztotal} and Standard $Error_{Ztotal}$ (SE_{Ztotal}) were calculated. To test the null hypothesis that patients have the same level of aerobic fitness as their healthy controls ($Z_{total} = 0$), a one sample Student's *t* test with a two-sided alpha of 0.05 was performed. Based on an estimated SD of 13.35 (50% higher than the mean SD of the healthy controls), 75 patients are needed to give a power of 90% to detect a real difference of 5 mL/kg LBM • min^{-1}. Comparisons between two groups (men and women, those who completed the test and those who stopped the test because of pain/fatigue) were performed by using the Student's *t* test for unpaired observations with a normal distribution of the data. In case of non-normal distribution of the data, the Mann-Whitney U test for unpaired observations was used. For normative data, χ^2 tests were used.

Multiple linear regression analysis (stepwise regression with backward elimination) was performed to define the contribution of independent variables to the difference in observed *versus* expected level of aerobic fitness in CLBP patients. The $Z_{patient}$ score was the dependent variable. Visual analogue scale-pain, RDQ, duration of disability, TSK, BPAQ-work index, and BPAQ-leisure index were the six independent variables. In addition alternative regression analysis was performed using the QBPDS instead of the RDQ and using the alternative work index instead of the BPAQ-work index. Standardized beta coefficients and significance were tested under the null hypothesis that the coefficient did not differ from zero. For performing the multiple linear regression analysis with 6 independent variables, the number of the variables times 10 (60 patients) are needed, as recommended for multiple regression analysis by Dawson-Saunders and Trap.[41] All statistical analyses were performed with SPSS software, version 11.5.

Results

Demographic Data and Clinical Characteristics

Data for the whole sample and specified for men and women are presented in Table 1. Except for weight and length ($P < 0.001$), there were no statistically significant differences between men and women. According to the scores on the RDQ, most patients were moderate to severely disabled, and more than half of them were not working at all. This is in accordance with the Dutch state of affairs in which usually moderately to severely disabled patients are treated in outpatient rehabilitation centers for their CLBP disability.[42]

For the patients who did not participate, data concerning the age, gender, and level of disability at the moment they were referred for participation in the trial were available. Comparison between those who did not (n = 35) and those who did participate (n = 115) showed no significant difference regarding age, gender, and level of disability (Table 2).

Level of Aerobic Fitness

For 84 patients (78%), the VO_2max could be calculated, but 13 patients (12%) stopped the test prematurely due to pain or fatigue, and in 11 patients (10%) the VO_2max could not be calculated due to medical (exceeding predefined heart rate, reaching predefined blood pressure or paleness of patient, n = 5) or technical reasons (no steady state phase reached, incomplete skinfold measures, n = 6).

The results of the 84 patients for whom the VO_2max could be calculated are presented in Table 3. The CLBP patients had a significantly lower level of aerobic fitness compared with their matched healthy controls, with a mean lower VO_2max of 10.0 mL/kg LBM • min^{-1} (20%) in men and 5.6 mL/kg LBM • min^{-1} (11%) in women. Men with CLBP had a significantly greater difference in observed *versus* expected level of aerobic fitness than women with CLBP. Furthermore, 72 patients (86%) had a lower level of aerobic fitness than was predicted on the basis of their gender, age, and level of sport

Table 1. Demographic Data and Clinical Characteristic

	Total Sample (n = 108)	Men (n = 63) (58%)	Women (n = 45) (42%)
Age (yr)	41 ± 10 (20–61)	42 ± 9 (20–56)	39 ± 11 (20–61)
Weight (kg)	81 ± 15 (49–133)	87 ± 14 (57–133)	72 ± 11 (49–101)*
Height (cm)	177 ± 9 (157–200)	182 ± 6 (170–200)	169 ± 7 (157–184)*
Duration of LBP (mo)	62 ± 76 (3–396)	67 ± 80 (3–396)	54 ± 71 (6–384)
Radiation of pain (%)			
No radiation	10	11	9
Radiation above knee	34	33	35
Radiation below knee	56	56	56
Duration of disability (mo)	35 ± 39 (3–240)	38 ± 42 (3–240)	32 ± 35 (3–180)
Previous back surgery (%)	19	18	22
Trauma preceding LBP (%)	19	18	20
Work (%)			
Full-time	31	29	33
Modified hours	9	10	9
Modified work	7	8	5
Full sick leave	23	22	24
Disability payment	21	25	16
No job	9	6	13
Sport activity (%)			
Untrained	75	81	67
Recreational	25	19	33
Disability (RDQ)	14.2 ± 3.9 (3–21)	14.0 ± 4.3 (3–21)	14.4 ± 3.3 (7–20)

Values are mean ± SD (range) or percentage.
LBP = low back pain; RDQ = Roland Disability Questionnaire.
*$P < 0.001$.

activity. Only 12 patients (14%) had an equal or higher level of aerobic fitness compared with the healthy control group.

Determinants of the Difference Between Observed and Expected Level of Aerobic Fitness

Multiple linear regression analysis as well as the alternative multiple regression analyses showed that none of the hypothesized determinants (pain, level and duration of disability, fear of injury, activity level during work, household and leisure time) was significantly associated with the difference between the observed and expected level of aerobic fitness of the patients with CLBP (Table 4).

Difference Between Completed and Prematurely Stopped Submaximal Test

The patients that stopped the test prematurely due to pain or fatigue were significantly older and more disabled (higher RDQ and QBPDS scores) but were not significantly different regarding their level of activity during work and leisure time (Table 5). Also gender, fear of injury, pain, level of radiating pain, or duration of symptoms did not significantly differ between the groups, although it should be taken into account that the number of patients that stopped the submaximal test prematurely was small.

Table 2. Comparison Between Participants and Nonparticipants

	Participants (n = 115)	Nonparticipants (n = 35)	Significance
Age (yr)	41 ± 10 (20–62)	39 ± 11 (19–59)	0.36
Gender (% male)	57	60	0.72
RDQ	14.1 ± 3.5 (5–21)	12.8 ± 4.6 (6–20)	0.16

Values presented as means and SD (range) or percentage.
RDQ = Roland Disability Questionnaire.

■ Discussion

This study showed a significantly lower level of VO_2max in patients with CLBP compared with healthy controls matched for age, gender, and level of sport activity during the preceding half year. The overall mean difference was 8 mL/kg LBM • min^{-1}, equivalent to 2.3 METS

Table 3. Results of Modified Submaximal Åstrand Bicycle Test

	Observed VO_2max (mL/kg LBM ● min^{-1})	Expected VO_2max (mL/kg LBM ● min^{-1})
CLBP patients		
Total (n = 84)	42.1 ± 8.1 (18.6–61.2)	50.2 ± 5.0 (41.8–60.5)
Men (n = 46)	40.0 ± 7.9 (18.6–58.4)	50.0 ± 4.4 (43.7–59.7)
Women (n = 38)	44.8 ± 7.7 (31.1–61.2)	50.4 ± 5.6 (41.8–60.5)
	Mean Z-score (95% CI)	**Significance**
CLBP patients *vs.* controls		
Total (n = 84)	−0.87 (−1.06 to −0.69)	<0.001
Men (n = 46)	−1.06 (−1.30 to −0.82)	<0.001
Women (n = 38)	−0.64 (−0.93 to −0.35)	<0.001
Within CLBP patients		
Difference between men and women	−0.42 (−0.78 to −0.05)	0.03

Values are mean ± SD (range) for VO_2max data. Expected VO2max is based on normative data, with each patient being matched for age, gender, and sport activity.
LBM = lean body mass; CI = confidence interval; CLBP = chronic low back pain.

Table 4. Multiple Linear Regression Analysis for Z as Dependent Variable and Pain, Duration and Level of Disability, Activities During Work and Leisure Time, and Fear of Injury as Independent Variables

Independent Variable	Standardized ß	*F* Ratio	Significance
		0.31	0.93
Pain	0.06		0.70
Duration of disability	−0.10		0.39
Activity at work (BPAQ)	0.03		0.82
Activity during leisure time	0.01		0.91
Perceived disability (RDQ)	−0.02		0.90
Fear of injury	−0.07		0.62
		0.32	0.92
Pain	0.06		0.67
Duration of disability	−0.10		0.41
Activity at work and household (alternative work score)	0.04		0.76
Activity during leisure time	0.02		0.90
Perceived disability (RDQ)	−0.01		0.94
Fear of injury	−0.07		0.54

BPAQ = Baecke Physical Activity Questionnaire; RDQ = Roland Disability Questionnaire; QBPDS = Quebec Back Pain Disability Scale.
Regression analyses with QBPDS instead of RDQ showed similar results.

(Metabolic EquivalenT). This is a clinically relevant lower aerobic fitness level considering that most household activities have an energy cost of two METS more than standing or working at a desk. The finding that 86% of all CLBP patients had a lower observed than expected level of VO_2max additionally emphasizes that a lower level of aerobic fitness is present in many patients with CLBP.

No study could be found in which patients with CLBP were compared with controls matched for their level of sport activity. This study is the first to show significantly lower levels of aerobic fitness in CLBP when comparing them with matched healthy controls. The earlier studies differed greatly in their testing method, reported data in different units, included dissimilar populations, and reported by gender or for the whole population. When no appropriate controls were available, often less relevant normative data were used for comparison. Schmidt, for example, only used total testing time and heart rate as measure of aerobic fitness level.[43] Several other studies included patients with recurrent or previous back pain, and only a small proportion had CLBP.[44,45] One study did not present results separately for gender.[46] Several studies used normative data that were not valid.[15,46,47] The studies that used valid controls showed some resemblance with our data.[11,14,48–50] In the studies of Nielens and Plaghki, using a submaximal bicycle or step test, men with CLBP had a lower level and women a normal level of aerobic fitness, although only 50% to 60% of the sample had CLBP, mostly chronic lumbo-radicular pain.[11,48,49] Wittink *et al* found that men with CLBP while performing a maximal treadmill test had a aerobic fitness level equal to sedentary healthy men and women with CLBP had a level equal to active healthy women.[9,13] In the studies of van der Velde and Mierau[14] and Keller *et al*,[50] using a submaximal step test and bicycle test, respectively, patients with CLBP had a significantly lower level of aerobic fitness.

This study has some potential weaknesses. By using the nomogram to calculate the VO_2max, one may tend to underestimate or overestimate VO_2max by 15% in normal subjects.[20] The use of a maximal test with direct calorimetry would give more accurate VO_2max values, although the validity and reliability of the maximal testing can be questioned because maximal testing is strongly influenced by motivation, fear, and pain.[7,51] In congruence with this statement, analysis of the data of the patients who underwent maximal treadmill testing in

Table 5. Comparison of Patients With Completed *Versus* Prematurely Stopped Submaximal Test

Variable	Completed Test (n = 84)	Prematurely Stopped Test Because of Pain/Fatigue (n = 13)	Significance
Gender (% male)	55	69	0.33
Age (yr)	39 ± 10 (20–57)	46 ± 7 (31–58)	0.02*
Pain (VAS, in mm)	51 ± 24 (1–95)	64 ± 24 (16–99)	0.11
Duration of LBP (mo)	62 ± 80 (3–396)	84 ± 69 (6–200)	0.12
Radiation of pain (%)			0.69
No radiation	8	23	
Radiation above knee	37	15	
Radiation below knee	55	62	
Duration of disability (mo)	35 ± 40 (3–240)	45 ± 44 (3–120)	0.65
Back surgery (%)	19	31	0.33
Trauma preceding LBP (%)	20	8	0.28
RDQ	13.6 ± 4.0 (3–21)	16.3 ± 2.8 (9–19)	0.01*
QBPDS	44.4 ± 15.0 (2–77)	54.5 ± 14.4 (28–71)	0.02*
TSK	38.4 ± 6.9 (26–57)	40.8 ± 5.7 (33–51)	0.17
BPAQ-work index	2.15 ± 1.16 (0.75–4.38)	2.47 ± 1.07 (0.75–3.75)	0.36
Alternative work index	37.1 ± 49.1 (0–210)	26.2 ± 24.9 (0–84)	0.95
BPAQ-leisure index	2.90 ± 0.63 (1.5–4.25)	2.58 ± 0.65 (1.5–3.5)	0.14

Values are means ± SD (range) or percentage.
VAS = visual analog scale; LBP = low back pain; RDQ = Roland Disability Questionnaire; QBPDS = Quebec Back Pain Disability Scale; TSK = Tampa Scale for Kinesiophobia; BPAQ = Baecke Physical Activity Questionnaire.
*$P < 0.05$.

the study of Wittink *et al* showed that the average CLBP patient did not reach the criteria of maximal performance.[7,13] Based on these results and because the normative data were already collected by using the Åstrand submaximal bicycle test, it seemed reasonable to use a submaximal bicycle test for the patients.

Although the reliability of the submaximal Åstrand bicycle test is reported to be very good in CLBP patients,[50] serious problems were expected when using this test in the present study population. In the submaximal Åstrand test, the workload is intensively increased during the first 1 to 2 minutes until the heart rate exceeds 120 beats/min. The research assistant determines the height of the workload on the basis of the increase of the heart rate and not according to a predefined increase of workload, making it difficult to choose the right workload. In daily practice, we noticed that many CLBP patients could not finish the Åstrand test because the initial workload was too high. Since reducing the workload is not allowed once the Åstrand test is started, we expected that we could not calculate the VO_2max for many patients, which would reduce the power of our study.

The modified Åstrand submaximal test we used was particularly developed to test CLBP patients presented for rehabilitation and proved to be reliable and valid.[17,18] Since the patients are tested by the modified test and the healthy controls by the Åstrand submaximal test, the comparability of both tests is an important issue. In both tests, the patient has to reach a steady state phase in which the heart rate does not vary more than ±5 beats/min. The calculation of the mean heart rate during the last minute of this steady state phase and the extrapolation of the corresponding VO_2max is exactly the same for both tests. The only difference is that in the modified test the workload, at which the patient has to cycle during 6 minutes, is reached in 2 to 6 minutes instead of the 1 to 2 minutes used in the Åstrand test. Although we did not perform a comparability study of both tests in CLBP patients, from an exercise physiology point of view it is not expected that the slower increase of workload leads to a higher or lower mean heart rate during the steady state phase. Based on this, we think that the results of the calculated VO_2max of both tests are comparable.

A reasonable percentage (80%) of patients with a moderate to high degree of disability was able to perform the submaximal testing. Older patients with a higher level of disability had more difficulty in performing the modified submaximal test.

A potential selection bias between patients who participated and those who did not participate in this study is not likely because no significant differences regarding age, gender, and level of low back pain disability at the moment of referral were present.

By collecting data of 84 patients, we ensured sufficient power to test our two hypotheses. Because of the small sample size of the subgroup of 13 patients that stopped the test prematurely due to pain or fatigue, no firm conclusions can be made about the significance of the variables we hypothesized to play a role, although the levels of disability and age were significantly higher in the group that stopped the test prematurely. For these patients, an even less robust increase of workload should probably be used.

The fact that men showed an even lower level of observed *versus* expected aerobic fitness than women is intriguing. Nielens and Plaghki postulated that sociocultural factors could account for these findings as women were thought to be generally more active once they were at home as they were still engaged in childcare and various household duties.[11,48,49] In the present study, the level of work and household activities was specifically checked for by using the BPAQ complemented by questions regarding hours of work, sick leave, and household during the last 3 months. The level of these activities did not significantly differ between men and women. While performing multiple regression analyses, the level of physical activity during work, household, and leisure time was not associated to the difference of the level of aerobic fitness at all, so the hypothesis of Nielens and Plaghki could not be confirmed.[11,48,49]

It is also intriguing that, in this cross-sectional study, we did not find any association between the variables pain intensity, level and duration of disability, and fear of injury after adjusting for age, gender, and level of sport activity. It should be kept in mind, however, that this is a cross-sectional study and the results should be treated with caution, especially regarding the cause-and-effect relationship between the postulated factors and the difference in the level of aerobic fitness.

Possible explanations for the reduced level of aerobic fitness might be that the intensity (lower speed, less power *etc.*), duration, and frequency (decline in activities) of the activities performed by patients were much lower than before the low back pain started. In the questionnaires, we gathered no information regarding the quality and decline of the activities. Otherwise, it is known that, although patients state that they are moderately or severely disabled and less active, they still perform activities on a rather normal level.[52,53] In this study, we showed that patients that stopped the submaximal test prematurely reported higher levels of disability but were not significantly different regarding the level of physical activity, although the number of those who stopped the test was small. It is known that the VO_2max has a moderate correlation with the sport index of the BPAQ in healthy persons but only a minor correlation with the work and leisure activity score.[12] It might thus be possible that the questionnaires we used could not detect differences and changes in the level of activities that correlate with the lower level of aerobic fitness in CLBP. In future research, monitoring activities in daily life, preferably combined with methods to measure the total energy consumption, might provide more answers on how active patients really are.[39,52,54,55] Still, the potential decline of activities cannot be measured by these methods, and we have to rely on self-report methods.

Another explanation might be that patients with CLBP already have a lower level of aerobic fitness level before developing CLBP, as it is known that the VO_2max is explained for 40% by genetic factors.[56] Prospective research, however, has not identified a lower aerobic fitness level or being physically inactive as a risk factor for developing CLBP.[44,57] In conclusion, no satisfactory explanation of the findings in this study and no proof for a part of the fear-avoidance model of pain could be found. To get more insight in the development and impact of loss of the level of aerobic fitness, longitudinal studies should be performed in patients with acute low back pain.

■ Conclusion

This study provides evidence for an association between a lower level of aerobic fitness and chronic low back pain but does not support the associations with the "usual suspects," namely, fear of injury, pain, low level of activities, or duration and severity of disability.

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■ Key Points

- Aerobic fitness level in patients with chronic low back pain is lower compared with healthy historical controls matched for age, gender, and level of sport activities.
- Men with chronic low back pain are more affected than women.
- Contrary to current theories, the difference between observed and expected levels of aerobic fitness in patients with chronic low back pain was not explained by reported disability, pain, fear of injury or level of leisure and work activities.
- A total of 12% of patients stopped submaximal testing prematurely due to pain or fatigue, and this appeared to be influenced by age and level of disability.

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