Long-term effects of an outpatient rehabilitation program in patients with chronic recurrent low back pain

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Abstract

Purpose This longitudinal study investigated long-term effects of a multidisciplinary rehabilitation program consisting of resistance and sensorimotor training, patient education, and stress management over 6 months in patients with chronic low back pain.

Methods Ninety-six patients with chronic recurrent low back pain performed a multidisciplinary rehabilitation program. We assessed pain-free lumbar spine range of motion (ROM), strength of the lumbar extensor muscles, and pain by visual analog scale (VAS). Furthermore, the Roland–Morris (RM) questionnaire and SF-36 were used. The examinations were performed before and after rehabilitation, and a long-term follow-up was performed after 18 months.

Results All outcome measurements (ROM, VAS, RM, muscle strength, and SF-36 scores) improved significantly from baseline to the post-rehabilitation evaluation. These improvements were found to persist until a follow-up evaluation 18 months after cessation of the intervention.

Conclusions Our findings confirm the results of former studies evaluating the short-term effects of multidisciplinary rehabilitation programs. In addition, our data demonstrate that well-balanced outpatient rehabilitation programs may induce persistent improvements in muscle strength, pain, function and quality of life in patients with chronic low back pain.

Keywords Resistance training · Long-term treatment · Multidisciplinary treatment · Pain · Lumbar muscle strength · Sensorimotor training · Quality of life

Introduction

Musculoskeletal pain syndromes are a common health problem. In Austria, the number of sick leave days caused by musculoskeletal disorders accumulated to a total of 8,196,907 days (8,387,742 habitants in 2007) [1]. Among these musculoskeletal disorders, low back pain has a high incidence and prevalence [2]. 60–80 % of adults experience episodes of low back pain, which typically occur between 35 and 55 years of age [3].

The risk of chronic low back pain appears to be associated with a number of modifiable factors, including decreased strength of lumbar extensors and dysfunction of the trunk muscles [4–7]. A reduction in quality of life is a known consequence [8].

In former studies, resistance training (RT) has been shown to improve muscle strength and reduce pain in patients with chronic low back pain [9–12]. Most of these studies performed RT over 8–16 weeks and lacked follow-up evaluations after the end of the training period [9, 11, 13, 14]. Long-term benefits were only found by Helmhout et al. [15] and Harts et al. [12] who performed isolated

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lumbar extensor muscle RT over a period of 3 months and 8 weeks, respectively, and evaluated the outcomes 9 months after randomization and 16 weeks after treatment.

Most interventional studies published to date examined the efficacy of single intervention strategies, thus failing to account for the multifactorial aetiology of the syndrome. As opposed to these therapeutic approaches, the European Guidelines for the management of chronic nonspecific low back pain recommend the inclusion of cognitive behavioral therapy and educational interventions and also suggest brief educational interventions [16].

Furthermore, the validity of the results of previous surveys was either hampered by relatively small sample sizes (n 27–65 [9, 11–13]), short study periods [9, 11, 13, 14], restricted inclusion criteria like only males [13] or females [14] or missing evaluation of quality of life [14].

Therefore, the aim of our longitudinal study was to evaluate the long-term effects of a 6-month multidisciplinary outpatient rehabilitation program including resistance and sensorimotor training, patient education, and stress management on muscle strength, pain, mobility, disability and quality of life in patients with chronic low back pain.

Methods

Inclusion criteria comprised male and female adults with chronic recurrent low back pain, employed or unemployed, who participated in an inpatient rehabilitation program and were willing to carry on with an outpatient rehabilitation program. Patients were allocated by the Austrian social insurance system and recruited in consecutive order. Patients suffering from systemic rheumatologic disease, ankylosing spondylitis, neurologic deficits, malignant disease, infections, serious cardiovascular disease or severe musculoskeletal impairment (inability to participate in the training) and those recovering from fusion or artificial disc operations in the lumbar spine were excluded from participation in the study. In addition, patients already retired at the beginning of the intervention as well as pregnant women were not considered. The study protocol was approved by the Ethical Review Board of the City of Vienna.

Assessment

All assessments were performed before and at the end of the rehabilitation period as well as after 18 months following the cessation of the intervention.

Patients were examined with a computerized MedX Lumbar extension machine[®] (Ocala, Florida) [17]. Before testing, patients were familiarized with the machine and

protocol. The pelvis was stabilized during trunk extension to isolate the extensor muscles [18]. First, the pain-free range of motion of the lumbar spine in the sagittal plane was evaluated. After a standardized warm-up, the maximum voluntary isometric muscle strength of the lumbar extensor muscles (Nm/kg) was obtained at 12°, 24°, 36°, 48°, 60°, and 72° of lumbar flexion, but measurements were restricted to the described pain-free range of motion. This procedure has been shown to yield reliable results in both healthy individuals and patients with chronic low back pain [19].

Pain in the lumbar spine was assessed by the use of the visual analog scale (VAS). The VAS consists of a 100-mm long line, with the extreme ends labeled as ‘no pain’ and ‘worst pain imaginable’, respectively. Patients were asked to indicate as to which point along the line best represented their current pain intensity.

For evaluation of the functional status, the Roland–Morris questionnaire (RM) was used. A study previously performed by our group demonstrated the reliability and validity of the RM for the assessment of the functional status in German-speaking patients with low back pain [20].

Health-related quality of life (QoL) was assessed with the use of a generic instrument, the SF-36 health survey [21]. The score ranges from 0 to 100 with 100 indicating the best function. For the present study, a German version of the questionnaire and reference values for both healthy individuals and patients with back pain were used [21, 22].

Multidisciplinary rehabilitation program

The rehabilitation program was performed over a period of 6 months and comprised 40 training sessions (focus on whole-body RT), six sessions of psychological interventions and two sessions for information related to ergonomics and healthy alimentation. Each session lasted 90 min. All patients received the same program as well as the same number of sessions. Based on the results of the MedX Lumbar extension machine[®] a supervised and progressive RT program was composed. The exercises included dynamic exercises for all major muscle groups. The lumbar extensor muscles were trained with the MedX Lumbar extension machine[®] [23] and the other major muscle groups (arms, shoulders, chest, abdomen, hips, and legs) with MedX resistance machines[®] (Ocala, Florida) [24]. This kind of training has been shown to be effective in improving strength and reducing symptoms of low back pain [25]. The importance of pelvic stabilization during lumbar extension exercise for improvements in strength and reducing pain and associated disability was recently reported by Smith et al. [25] and considered in our training sessions. The training intensity was chosen such that

patients could perform a maximum of 10–15 repetitions, with each contraction lasting 4 + 4 s (concentric and eccentric phase). The progression of the training was conducted according to the recommendations of the American College of Sports Medicine [26]. The training frequency was two sessions/week in the first 3 months and then reduced to a single training session/week in the latter phase of the intervention. All sessions included 5 min of sensorimotor training on unstable devices and supervised by experienced personnel. Additionally, one session was used to inform patients about the structure of the spine and possible pathologies, with the aim to reduce fear avoidance behavior. Furthermore, sessions concerning ergonomics and healthy alimentation as well six sessions of psychological interventions in groups with autogenic training and progressive muscle relaxation were offered.

Statistical analyses

All variables assessed violated the assumption of normality (Kolmogorov–Smirnov test, $p < 0.05$). Therefore, Friedman tests and post hoc Bonferroni-adjusted Wilcoxon tests were used to detect longitudinal changes. In the absence of a non-parametric alternative to factorial repeated-measures ANOVAs, torque values were log-transformed to approximate normal distribution. Two-way repeated-measures ANOVAs were then used to assess the influence of the main factors ‘joint position’ and ‘testing day’ on the outcomes of torque measurements. Mauchly’s test indicated that the assumption of sphericity had been violated for the main effect of ‘joint angle’ ($\epsilon = 0.19$), so degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity. Bonferroni-adjusted paired-samples t tests and contrasts were performed to follow up significant ANOVA results. Partial η^2 (ANOVA) and Pearson’s r (pairwise comparisons) were calculated as estimates of effect size.

Results

One hundred patients were included in the study per protocol. Four patients dropped out due to lack of the time required to participate in such an intensive rehabilitation program. The presented sample of 96 patients (66 female, 30 male) included all patients who finished the rehabilitation and performed the follow-up evaluation after further 18 months. Age, height, and body mass were 48.6 ± 6.7 years, 165.4 ± 5.7 cm, and 84.8 ± 13.7 kg in females; and 52.3 ± 6.5 years, 178.8 ± 7.5 cm, and 69.3 ± 13.6 kg on average in males. 60.4 % of all patients worked full-time, 20.8 % part-time and 13.5 % were currently unemployed, with the remaining 5.4 % being retired (retirement

during the study period) or housewives. The chronicity of low back pain, defined as the time since the first occurrence of a low back pain event, was 1 year in 4.2 %, 1–5 years in 18.8 %, 5–10 years in 72.9 %, and more than 10 years in the remaining 4.1 % of patients.

ROM (Table 1)

The pain-free range of motion changed significantly over the study period [$\chi^2(2) = 70.82$, $p = 0.001$]. Wilcoxon tests performed for post hoc analyses revealed that ROM increased from pre-intervention to post-intervention ($ROM_{PR} < ROM_{PO}$: $T = 2414$, $p < 0.001$; $r = 0.70$) and decreased again until follow-up ($ROM_{PO} > ROM_{FU}$: $T = 111.5$, $p < 0.001$; $r = -0.46$). However, as compared to pre-intervention levels, ROM remained significantly improved until the end of the study period ($ROM_{PR} > ROM_{FU}$: $T = 1775.5$, $p < 0.001$; $r = 0.41$).

VAS (Table 2)

Values of VAS [$\chi^2(2) = 149.55$, $p < 0.001$] decreased strongly following the intervention ($VAS_{PR} > VAS_{PO}$: $T = 0$, $p < 0.001$; $r = -0.85$) and exhibited a small, yet significant increase thereafter ($VAS_{PO} < VAS_{FU}$: $T = 531$, $p = 0.007$; $r = 0.28$). Still, follow-up values remained significantly below pre-intervention levels ($VAS_{PR} > VAS_{FU}$: $T = 41$, $p < 0.001$; $r = -0.83$).

Table 1 Pain-free range of motion over the study period (in degrees)

	Numbers	Median	Q25	Q75	Minimum	Maximum
ROM PR	96	60	48	72	24	72
ROM PO	96	72	66	72	39	72
ROM FU	96	72	60	72	31	72

PR Baseline, PO after rehabilitation, FU follow-up evaluation after one-and-a-half years, ROM range of motion, Q25 and Q75 lower (25 %) and upper (75 %) quartile

Table 2 Pain (VAS) over the study period

	Numbers	Median	Q25	Q75	Minimum	Maximum
VAS PR	96	41	24	69	0	100
VAS PO	96	0	0	5	0	63
VAS FU	96	0	0	20	0	70

PR Baseline, PO after rehabilitation, FU follow-up evaluation after one-and-a-half years, VAS visual analog scale, Q25 and Q75 lower (25 %) and upper (75 %) quartile

Table 3 Roland–Morris questionnaire over the study period

	Numbers	Median	Q25	Q75	Minimum	Maximum
RM PR	96	5	2	8	0	20
RM PO	96	1	0	2	0	13
RM FU	96	2	1	4	0	15

PR Baseline, PO after rehabilitation, FU follow-up evaluation after one-and-a-half years, RM Roland–Morris questionnaire, Q25 and Q75 lower (25 %) and upper (75 %) quartile

Table 4 Isometric muscle strength over the study period [torque normalized to body mass (Nm/kg)]

	Angle (°)	Mean	Standard error	95 % Confidence interval	
				Lower bound	Upper bound
PR	0	1.296	0.113	1.055	1.537
	12	1.872	0.059	1.746	1.998
	24	1.962	0.056	1.842	2.082
	36	2.005	0.047	1.906	2.105
	48	2.034	0.049	1.931	2.138
	60	2.074	0.050	1.968	2.180
	72	2.116	0.043	2.026	2.207
PO	0	1.861	0.064	1.724	1.998
	12	2.210	0.022	2.164	2.256
	24	2.215	0.025	2.161	2.269
	36	2.237	0.024	2.186	2.287
	48	2.237	0.028	2.176	2.297
	60	2.266	0.035	2.191	2.340
	72	2.293	0.029	2.232	2.354
FU	0	1.492	0.142	1.188	1.795
	12	2.141	0.034	2.069	2.213
	24	2.195	0.030	2.131	2.260
	36	2.220	0.033	2.151	2.290
	48	2.202	0.042	2.113	2.292
	60	2.244	0.035	2.169	2.318
	72	2.235	0.037	2.157	2.314

PR Baseline, PO after rehabilitation, FU follow-up evaluation after one-and-a-half years

RM (Table 3)

Similarly, the scores from the Roland–Morris questionnaire [χ^2 (2) = 117.70, $p < 0.001$] decreased significantly from pre- to post-intervention ($RM_{PR} > RM_{PO}$: $T = 0$, $p < 0.001$; $r = -0.59$), to increase partially until follow-up measurements were performed ($RM_{PO} < RM_{FU}$: $T = 546.5$, $p < 0.001$; $r = 0.26$). However, RM scores remained significantly below pre-intervention levels ($RM_{PR} > RM_{FU}$: $T = 176.5$, $p < 0.001$; $r = -0.51$).

Isometric muscle strength (Table 4)

The main factor ‘position’ strongly and significantly affected the measures of isometric muscle strength [$F(1.12, 16.76) = 48.56$, $p < 0.001$; $\eta^2 = 0.76$]. Post hoc pairwise comparisons showed that isometric muscle strength values gradually increased from the 0° to the 72° joint position: $T_{0^\circ} < T_{12^\circ} < T_{24^\circ} < T_{36^\circ} = T_{48^\circ} < T_{60^\circ} = T_{72^\circ}$.

Similarly, the main effect of ‘testing day’ was found to be strong and significant [$F(2, 30) = 37.13$, $p < 0.001$; $\eta^2 = 0.71$]. The results of post hoc pairwise comparisons revealed that isometric muscle strength increased following the intervention ($T_{PR} < T_{PO}$), decreased until follow-up ($T_{PO} > T_{FU}$), but still remained above baseline values ($T_{PR} < T_{FU}$). These findings were confirmed by contrasts comparing the post-intervention [$F(1, 15) = 69.49$, $p < 0.001$; $r = 0.91$] and follow-up measures of isometric muscle strength [$F(1, 15) = 26.97$, $p < 0.001$; $r = 0.80$] to pre-intervention values.

SF-36 (Table 5)

After the intervention, outcomes in all items increased statistically significantly as compared to the pre-intervention measurement, with the most prominent improvements observed for PFI ($r = -0.50$) and the smallest changes seen for ROLEM ($r = -0.17$). The values of PFI, PAIN, and VITAL decreased significantly from the post-intervention to the follow-up measurement, although by a small amount ($0.18 < r < 0.23$). Comparisons between baseline and follow-up measurements revealed that all item values except ROLEM and SOCIAL remained significantly above baseline levels until the end of the study period, with the latter showing higher values at follow-up by trend ($p = 0.09$).

Discussion

This is the first study to investigate a long-term follow-up evaluation after 1.5 years of an intensive, multidisciplinary rehabilitation program consisting of resistance and sensorimotor training combined with educational intervention and stress management in patients with chronic low back pain. The training, which was performed over a period of 6 months, induced improvements in muscle strength, pain, function, and QoL over a study period of 2 years. All outcome measurements like ROM, VAS, RM, muscle strength, and QoL improved statistically significantly from baseline to the post-training evaluation. These improvements were still seen at the long-term follow-up evaluation, performed 1.5 years after cessation of the intervention. The

Table 5 Health-related quality of life (QoL) assessed with the SF-36 health survey

	PR		PO		FU		Friedman test <i>p</i> value	PR vs. PO		PO vs. FU		PR vs. FU	
	ME	IQR	ME	IQR	ME	IQR		<i>p</i> value	Effect size <i>r</i>	<i>p</i> value	Effect size <i>r</i>	<i>p</i> value	Effect size <i>r</i>
PFI	75	60–85	90	75–95	85	74–95	0.001	<0.001	−0.50	0.006	0.23	0.001	−0.39
ROLPH	75	25–100	100	75–100	100	75–100	0.001	<0.001	−0.37	0.975	−0.07	0.001	−0.33
ROLEM	100	67–100	100	100–100	100	67–100	0.023	0.049	−0.17	0.672	−0.09	0.281	−0.08
SOCIAL	100	63–100	100	75–100	100	75–100	0.001	0.018	−0.20	>0.999	−0.02	0.090	−0.22
MHI	72	56–84	78	64–84	76	64–84	0.027	0.009	−0.22	>0.999	−0.07	0.042	−0.18
PAIN	51	41–67	74	60–84	62	51–84	0.001	<0.001	−0.46	0.042	0.18	<0.001	−0.42
VITAL	55	43–60	65	50–75	60	50–70	0.001	<0.001	−0.36	0.024	0.20	<0.001	−0.28
GHP	67	52–77	77	57–87	72	57–82	0.001	<0.001	−0.35	0.747	−0.09	<0.001	−0.26

Values represent medians $\pm$ inter-quartile range. The *p* values of post hoc pairwise tests (Wilcoxon tests) were Bonferroni-adjusted for multiple comparisons ($p < 0.05$ represents statistical significance). Effect sizes *r* were calculated by *z* conversion [$r = z/\sqrt{N}$] using the output from these tests

PR Baseline, PO after rehabilitation, FU follow-up evaluation after one-and-a-half years, ME median, IQR inter-quartile range, PFI physical functioning, ROLPH role functioning/physical, ROLEM role functioning/emotional, SOCIAL social functioning, MHI mental health, PAIN bodily pain, VITAL vitality, GHP general health perception

degree of improvement, as reflected by effect sizes, was strong or very strong for VAS, RM, and strength, respectively.

Our data confirm and amplify the results of former studies, which evaluated the effects of RT in the short-term (observation period of 16 weeks) [9, 13]. Including only male patients, Jackson et al. [13] assigned 54 subjects suffering from low back pain to 10 weeks of isolated lumbar extensor muscle resistance training. The training was conducted two times a week in the first 4 weeks and once a week for the remaining 6 weeks and resulted in significant improvements in muscle strength, pain, functional ability and QoL of patients. Similarly, patients undergoing a 10-week exercise program demonstrated a significant increase in muscle strength and reduction of pain, as compared to non-training controls [11]. Holmes and colleagues applied a progressive training program for the lumbar extensor muscles, lasting between 13 and 14 weeks, performed two times per week in the first 4 weeks and once a week in the latter phase of the intervention, and reported significant increases in muscle strength and reduction in pain after treatment [14]. In this study only female patients were included. In the above-mentioned studies outcome parameters were evaluated before and after the training only. Among the few studies to include follow-up evaluations, Harts et al. [12] (16 weeks after lumbar extensor training) and Helmhout et al. [15] (9 months after randomization) reported improvements in muscle strength, functional disability, and QoL. As opposed to our study, Helmhout and colleagues included only male subjects in their 12 week resistance

training program, and the training was restricted to exercises strengthening the lumbar extensor muscles in most of the respective studies published to date [15]. Our resistance training program incorporated exercises to improve whole-body muscular strength, since former studies demonstrated the superiority of this approach [13].

As we aimed to provide a multimodal treatment, we included, considering the European Guidelines for the management of chronic nonspecific low back pain, educational interventions in our rehabilitation program [16]. Following the suggestions by Guzman et al. [27], van Tulder et al. [28] and Hayden et al. [29], who recommend high intervention intensities or volumes for long-term improvements of pain and functional ability, we conducted the multidisciplinary rehabilitation over 6 months, as opposed to the 8–16 weeks intervention periods in previous studies. Such a long training period may particularly benefit sedentary or older patients, who have been shown to require longer adaptation periods to get the optimal benefit from training interventions, both in terms of physical capabilities and health-related behavior patterns [26].

In a systematic review by Van Middelkoop et al. [30] a moderate quality evidence for the effectiveness of multidisciplinary treatment on pain in the short-term compared to no treatment and waiting list controls was found. She described a moderate quality evidence for not finding an effect on disability and outcomes in the long-term. These so far missing positive effects on disability and pain even in the long-term can be presented in our study. We are well aware that the missing control group is a major limitation of the study. Therefore, we have to acknowledge that

without a control group the impact of the positive changes can not be purely attributed to our rehabilitative treatment. But in the clinical setting of the study within the Austrian social insurance system, the implementation of a reliable control group was ethically not possible.

Besides methodological shortcomings, Carpenter and Nelson [31] criticized both the missing isolated testing and training of the lumbar muscles and the imprecise description of the RT as important limitations of previous studies. In our study, pelvic stabilization was a key requirement for the accurate testing and training of the lumbar extensor muscles and we had a specific prescription concerning the intensity and frequency of the RT [10, 26].

Further studies with a controlled randomized design are desirable to confirm the promising above-mentioned long-term positive effects on pain, muscle strength, disability and quality of life in patients with chronic low back pain.

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Conflict of interest None declared.

References

- Hauptverband der österreichischen Sozialversicherungsträger (2008) Statistisches Handbuch der österreichischen Sozialversicherung. pp 85
- Koes BW, van Tulder M, Lin CW, Macedo LG, McAuley J, Maher C (2010) An updated overview of clinical guidelines for the management of non-specific low back pain in primary care. *Eur Spine J: Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 19:2075–2094. doi:10.1007/s00586-010-1502-y
- Frymoyer JW, Pope MH, Clements JH, Wilder DG, MacPherson B, Ashikaga T (1983) Risk factors in low-back pain. An epidemiological survey. *J Bone Joint Surg Am* 65:213–218
- Biering-Sorensen F (1984) Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine (Phila Pa 1976)* 9:106–119
- Hides JA, Stokes MJ, Saide M, Jull GA, Cooper DH (1994) Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. *Spine (Phila Pa 1976)* 19:165–172
- Thorstensson A, Arvidson A (1982) Trunk muscle strength and low back pain. *Scand J Rehabil Med* 14:69–75
- Lee JH, Hoshino Y, Nakamura K, Kariya Y, Saita K, Ito K (1999) Trunk muscle weakness as a risk factor for low back pain. A 5-year prospective study. *Spine* 24:54–57
- Lang E, Liebig K, Kastner S, Neundorfer B, Heuschmann P (2003) Multidisciplinary rehabilitation versus usual care for chronic low back pain in the community: effects on quality of life. *Spine J: Off J North Am Spine Soc* 3:270–276
- Kell RT, Asmundson GJ (2009) A comparison of two forms of periodized exercise rehabilitation programs in the management of chronic nonspecific low-back pain. *J Strength Cond Res/Natl Strength Cond Assoc* 23:513–523. doi:10.1519/JSC.0b013e3181918a6e
- Graves JE, Pollock ML, Foster D, Leggett SH, Carpenter DM, Vuoso R, Jones A (1990) Effect of training frequency and specificity on isometric lumbar extension strength. *Spine (Phila Pa 1976)* 15:504–509
- Risch SV, Norvell NK, Pollock ML, Risch ED, Langer H, Fulton M, Graves JE, Leggett SH (1993) Lumbar strengthening in chronic low back pain patients: physiologic and psychological benefits. *Spine* 18:232–238
- Harts CC, Helmhout PH, de Bie RA, Staal JB (2008) A high-intensity lumbar extensor strengthening program is little better than a low-intensity program or a waiting list control group for chronic low back pain: a randomised clinical trial. *Aust J Physiother* 54:23–31
- Jackson JK, Shepherd TR, Kell RT (2011) The influence of periodized resistance training on recreationally active males with chronic nonspecific low back pain. *J Strength Cond Res/Natl Strength Cond Assoc* 25:242–251. doi:10.1519/JSC.0b013e3181b2c83d
- Holmes B, Leggett S, Mooney V, Nichols J, Negri S, Hoeyberghs A (1996) Comparison of female geriatric lumbar-extension strength: asymptotic versus chronic low back pain patients and their response to active rehabilitation. *J Spinal Disord* 9:17–22
- Helmhout PH, Harts CC, Staal JB, Candel MJ, de Bie RA (2004) Comparison of a high-intensity and a low-intensity lumbar extensor training program as minimal intervention treatment in low back pain: a randomized trial. *Eur Spine J: Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 13:537–547. doi:10.1007/s00586-004-0671-y
- Airaksinen O, Brox JJ, Cedraschi C, Hildebrandt J, Klaber-Moffett J, Kovacs F, Mannion AF, Reis S, Staal JB, Ursin H, Zanoli G (2006) Chapter 4. European guidelines for the management of chronic nonspecific low back pain. *Eur Spine J: Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 15(Suppl 2):S192–S300. doi:10.1007/s00586-006-1072-1
- Graves JE, Pollock ML, Carpenter DM, Leggett SH, Jones A, MacMillan M, Fulton M (1990) Quantitative assessment of full range-of-motion isometric lumbar extension strength. *Spine (Phila Pa 1976)* 15:289–294
- Graves JE, Webb DC, Pollock ML, Matkovich J, Leggett SH, Carpenter DM, Foster DN, Cirulli J (1994) Pelvic stabilization during resistance training: its effect on the development of lumbar extension strength. *Arch Phys Med Rehabil* 75:210–215
- Robinson ME, Greene AF, O'Connor P, Graves JE, MacMillan M (1992) Reliability of lumbar isometric torque in patients with chronic low back pain. *Phys Ther* 72:186–190
- Wiesinger GF, Nuhr M, Quittan M, Ebenbichler G, Wolff G, Fialka-Moser V (1999) Cross-cultural adaptation of the Roland-Morris questionnaire for German-speaking patients with low back pain. *Spine (Phila Pa 1976)* 24:1099–1103
- Bullinger M (1995) German translation and psychometric testing of the SF-36 Health Survey: preliminary results from the IQOLA project. *International quality of life assessment. Soc Sci Med* 41:1359–1366
- Bullinger M (1996) Assessment of health related quality of life with the SF-36 Health Survey. *Rehabilitation (Stuttg)* 35:XXVII–XXVII (quiz XXVII–XXIX)
- Choi G, Raiturker PP, Kim MJ, Chung DJ, Chae YS, Lee SH (2005) The effect of early isolated lumbar extension exercise program for patients with herniated disc undergoing lumbar discectomy. *Neurosurgery* 57:764–772 (discussion 764–772)
- Vincent KR, Braith RW, Feldman RA, Kallas HE, Lowenthal DT (2002) Improved cardiorespiratory endurance following 6 months of resistance exercise in elderly men and women. *Arch Intern Med* 162:673–678
- Smith D, Bissell G, Bruce-Low S, Wakefield C (2011) The effect of lumbar extension training with and without pelvic stabilization on lumbar strength and low back pain. *J Back Musculoskelet Rehabil* 24:241–249. doi:10.3233/BMR-2011-0301

26. American College of Sports Medicine Position Stand (1998) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc* 30:975–991
27. Guzman J, Esmail R, Karjalainen K, Malmivaara A, Irvin E, Bombardier C (2002) Multidisciplinary bio-psycho-social rehabilitation for chronic low back pain. *Cochrane Database Syst Rev* 1:CD000963. doi:[10.1002/14651858.CD000963](https://doi.org/10.1002/14651858.CD000963)
28. van Tulder MW, Koes B, Malmivaara A (2006) Outcome of non-invasive treatment modalities on back pain: an evidence-based review. *Eur Spine J: Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 15(Suppl 1):S64–S81. doi:[10.1007/s00586-005-1048-6](https://doi.org/10.1007/s00586-005-1048-6)
29. Hayden JA, van Tulder MW, Tomlinson G (2005) Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain. *Ann Intern Med* 142:776–785
30. van Middelkoop M, Rubinstein SM, Kuijpers T, Verhagen AP, Ostelo R, Koes BW, van Tulder MW (2011) A systematic review on the effectiveness of physical and rehabilitation interventions for chronic non-specific low back pain. *Eur Spine J* 20:19–39. doi:[10.1007/s00586-010-1518-3](https://doi.org/10.1007/s00586-010-1518-3)
31. Carpenter DM, Nelson BW (1999) Low back strengthening for the prevention and treatment of low back pain. *Med Sci Sports Exerc* 31:18–24