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ORIGINAL ARTICLE
SPORT INIURIES AND REHABILITATION

The effects of lumbar extensor strength on disability and mobility in patients with persistent low back pain

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ABSTRACT

BACKGROUND: It is assumed that low back pain patients who use pain-avoiding immobilizing strategies may benefit from specific back flexion and extension exercises aimed at reducing sagittal lumbar hypomobility. The aim of this study was to test this potential working mechanism in chronic low back pain patients undergoing lumbar extensor strengthening training.

METHODS: A single-group prospective cohort design was used in this study. Patients with persistent low back complaints for at least 2 years were recruited at a specialized physical therapy clinics center. They participated in a progressive 11-week lumbar extensor strength training program, once a week. At baseline, sagittal lumbar mobility in flexion and extension was measured with a computer-assisted inclinometer. Self-rated pain intensity was measured using a visual analogue scale, back-specific functional status was assessed with the Quebec Back Pain Disability Scale and the Patient Specific Complains questionnaire.

RESULTS: Statistically significant improvements were found in pain (28% decrease) and functional disability (23% to 36% decrease). Most progress was seen in the first 5 treatment weeks. Lumbar mobility in flexion showed non-significant increases over time (+12%). Pre-post treatment changes in flexion and extension mobility did not contribute significantly to the models. The retained factors together explained 15% to 48% of the variation in outcome.

CONCLUSIONS: Specific lumbar strengthening showed clinically relevant improvements in pain and disability in patients with persistent chronic low back pain. These improvements did not necessarily relate to improvements in lumbar mobility. Parameters representing other domains of adaptations to exercise may be needed to evaluate the effects of back pain management.

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Key words: Low back pain - Exercise therapy - Pain measurement.

Exercise therapy is a widely used conservative treatment in low back pain management. Recent systematic reviews indicate that structured exercise therapy is a (cost-) effective intervention to treat patients with chronic non-specific low back pain (CNSLBP).[1-3] Still, the clinical relevance of the reported effects of exercise therapy have been questioned, since effect sizes are generally small (10% or less) and short-lived.[4]

A common explanation for these disappointing results relates to the heterogeneity of the CNSLBP population and the apparent failure to recognize subgroups of patients, each reflecting different symptom mechanisms, that need targeted treatment for better results.[5] Some researchers have reported that interventions previously shown to have little effect when provided to heterogeneous populations can be more (cost-)effective when provided to selected subgroups.[6, 7] Others, however, did not find beneficial results from classification-based treatment strategies in LBP patients, thereby challenging the 'subgrouping paradigm'.[8, 9]

Another reason given for the reported marginal effects of exercise therapy in LBP management is that reviewers have routinely attempted a single summary conclusion on the efficacy of "exercise" as a single class of treatment, not recognizing the high variation among exercise programs and treatment protocols. More research is needed in which the effectiveness of specific exercises that make use of a singular, protocolized concept, is investigated.[10-12] In addition, studies on working mechanisms of specific exercises are needed, *i.e.*, studies that focus on the relationship between the targeted aspects of the exercise protocol (*e.g.*, strength, mobility) and improvements in the key outcome variables (*e.g.*, functional disability, self-rated pain).[13]

Specific exercise therapy concepts that make use of isolated lumbar extensor strength (LES) training aim at restoring physical impairments associated with LBP, *i.e.*, objective structural and physical limitations such as loss of lumbar strength and flexibility, and the resulting loss of function (disability).[11, 14, 15] It is assumed that low back pain patients that use (pain-avoiding) immobilizing strategies may benefit from specific back flexion and extension exercises aimed at reducing sagittal lumbar hypomobility.[16-20] The aim of this study was to test this potential working mechanism in a cohort of CLBP patients undergoing LES. Overall research questions were: 1) does a 11-week supervised LES treatment program lead to clinically important improvements in sagittal spinal mobility, self-perceived pain and disability, respectively, and 2) do these improvements interrelate?

Materials and methods

A single-group prospective cohort design was used in this study. After obtaining informed consent, data at baseline (T_0), after 5 weeks (T_1), and after 11 weeks (T_2) of treatment were collected, respectively, of patients recruited at one of the specialized physical therapy clinics centers of a large Dutch franchise of back clinics (Fysius Back Experts BV, Nijverdal, The Netherlands). These clinics use LES training as their core intervention in LBP management. Patients were included who started a 11-week LES treatment program between March 1st and May 31st 2010, and who met either of the following inclusion criteria: low back pain for at least 2 years, with continuous or recurrent pain; pain localized between posterior iliac crests and angulus inferior scapulae, with or without radiation in the legs; age between 18 and 80 years. Excluded were patients with: specific pathology (*i.e.*, hernia nuclei pulposi, active ankylosing spondylitis, osteoporotic vertebral fracture, vertebral metastases, active Scheuermann's disease, Bechterew, trauma) and with contraindications for strength and/or mobilizing exercises (*i.e.*, pregnancy for more than 6 weeks; aneurysm in the past; instable angina pectoris or other severe heart problems; badly-tuned hypertension (SBP>160 mmHg and/or DBP>105 mmHg; badly-tuned epilepsy; severe neurologic degenerative disease; active rheumatoid arthritis; severe thrombotic disorders). Patients gave permission for data analyses by signing an informed consent letter.

Intervention

Patients participated in progressive resistance training of the isolated lumbar extensors for 11 consecutive weeks, once a week. The training program was carried out on a Lower Back Revival System® (OriGENE Concepts BV, Delft, The Netherlands). This treatment device uses pelvic stabilization to minimize the contribution of the hip and leg muscles during dynamic back exercise, thereby enhancing lumbar muscle recruitment.[21] Patients were instructed to extend and flex the upper body in a slow and controlled manner (2 to 3 seconds forth and back) through the full range of lumbar motion. Each treatment session took 15 to 20 minutes and was supervised by a physical therapist. Both treatment protocol and training device have been described elsewhere in greater detail.[22]

Outcomes

Spinal mobility

Functional assessment of sagittal lumbar mobility in flexion and extension was carried out, using a Spinal Mouse® (SM) inclinometer (Idiag, Voletswil, Switzerland). This hand-held, computer-assisted electronic device records spinal curvature, *i.e.*, segmental angles of inclination between vertebrae, in various postures.

Clinimetric studies on SM report good intra-rater and inter-rater reliability for standing sagittal curvatures and ranges of motion of the lumbar and thoracic spinal regions, with between-day ICCs ranging from 0.57 to 0.95, and inter-examiner ICCs ranging from 0.062 to 0.94.[23-25]

Pain and functional disability

Self-rated pain intensity was measured using a 100-mm Visual Analogue Scale (VAS). To analyze low back specific functional status at each time point, patients completed the Quebec Back Pain Disability Scale (QBPDS) and the Patient Specific Complains (PSC) questionnaires, respectively.[26, 27] The QBPDS is a self-administered instrument that contains 20 items in the field of daily activities, selected from relevant sub domains of functional abilities for patients with low back pain. The PSC is used to examine the functional status of the patient. From a list of different daily activities, patients had to select the 3 most important activities that were hampered by their back pain in the past period, rating them on a 100-mm VAS. Both questionnaires have previously been validated in Dutch.[26, 28]

Statistical analysis

Treatment effects

A one-way repeated measures ANOVA was performed to analyze temporal changes (T_0 *vs*. T_1 *vs*. T_2) in pain (VAS), disability (QBPDS, PSC), lumbar spinal flexion (Flex), lumbar extension (Ext), respectively. Testing of within-subject contrasts was performed to determine statistically significant pairwise comparisons, using Bonferroni corrections between levels of evaluation. Normality was tested using the Kolmogorov-Smirnov test; nonparametric statistical analyses were used in case of significant test results. Mauchly's test was used to check whether the assumption of sphericity (equality of variances) was met. If not, a Greenhouse-Geisser correction was used to produce valid F ratios.[29]

Association between changes in lumbar mobility and clinical outcomes

Linear regression analysis was used to evaluate the relationship between temporal changes in the two variables representing spinal mobility on the one hand, and pain and disability on the other hand. Post-treatment scores (T_2) in VAS, QBPDS, and PSC were each used as dependent variables in the regression models. Pre-post differences in lumbar flexion and extension, respectively, were included as independent variables while adjusting for age, gender, and baseline level of the dependent variable. In order to lower the risk of model overfitting, the number of included independent factors did not exceed 10 to 15 events per variable, as indicated by Babyak.[30] The adjusted R^2 was used as a measure of the predictive power of the model, indicating the percentage of variation in the outcome explained by the model. We used residual regression diagnostics provided by the software package to assess the goodness-of-fit of each model; collinearity diagnostics were used to check if factors were highly correlated.[29]

Missing data were analyzed according to the last-observation-carried-forward method. All analyses were performed using SPSS for Windows Version v.18.0 (SPSS, Chicago, IL, USA). Levels of statistical significance were set at $P<0.05$, and values are given as means (± standard deviation), unless otherwise stated.

Results

In total, 141 patients with low back pain received an intake between March 1st and May 31st 2010. Of these patients, 111 were indicated to start the LES therapy, whereof 90 patients who met the inclusion criteria were included for analyses. This study group comprises 62 men and 28 women, respectively, aged 18 to 76 years (mean age 52 years), with mostly longstanding back pain (66% more than 10 years of complaints). Table I provides an overview of the demographic and clinical characteristics of the study group. Fifty-three patients completed the treatment program, *i.e.*, receiving 11 treatments or more, while 15 patients received between 6 and 11 treatments, and 22 patients received less than 6 treatments. Subjects discontinued their therapy due to the following reasons: "therapy has no effect" (N.=18); "no more complaints" (N.=6); "not financially feasible" (N.=5); contraindications (N.=1); and "unknown reason" (N.=7). Numbers of participants with missing data per outcome variable are presented in Table II.

Treatment effects

All outcome data were normally distributed. The ANOVA analyses (Table II) showed statistically significant improvements over time in the outcome variables: 28% decrease in VAS score, 23% decrease in QBPDS score, and 36% decrease in PSC. Most progress was seen in the first 5 weeks of the treatment period. Lumbar range of motion in flexion showed small increases over time (+12%), though not significant when corrected in pairwise comparison. Lumbar range of motion in extension did not show any significant change over time.

Associations among lumbar mobility, and pain and disability

Table III summarizes the results of the regression analyses. All final regression models for the outcome variables contained baseline values, with the factor age included in the models of VAS and QBPDS. Neither pre-post treatment changes in flexion range of motion nor changes in extension range of motion contributed significantly to the models. The retained factors together explained a variation of 15% to 48% in outcome. All models showed regression diagnostics within normal ranges, indicating adequate model fit. Collinearity diagnostics indicated that the assumption of lack of multicollinearity was met in all models (results not presented).

TABLE I.—*Baseline demographics and clinical characteristics of study participants (N.=90).*

Characteristic	Value
Demographic characteristics	
Gender	62 (69%)
Male	
Female	28 (31%)
Mean age, years	52±14
Range	18-76
Age distribution	
<35	8 (9%)
35-45	21 (23%)
45-55	19 (21%)
55-65	19 (21%)
65-75	20 (22%)
≥75	3 (3%)
Clinical characteristics	
Duration of complaints	
3-5	16 (18%)
5-10	15 (17%)
10-20	24 (27%)
≥ 20	35 (39%)
Pain radiation in lower leg	
Above knee	60 (67%)
Below knee	31 (34%)
Spinal mobility*	
Hypomobility in flexion	48 (53%)
Hypomobility in extension	72 (80%)
Hypermobility in flexion	9 (10%)
Hypermobility in extension	16 (18%)
Currently on medication due to back complaints	20 (29%)
Work limitations due to back complaints	23 (34%)
Limitations in daily activities due to back complaints	37 (54%)
Limitations in sports activities due to back complaints	26 (38%)

Data are presented as number of participants (percentage), unless otherwise stated.
*Spinal mobility assessed by means of a SpinalMouse inclinometer (Idiag, Voletswil, Switzerland).

Discussion

The purpose of this study was to test whether, in a group of CNSLBP patients performing lumbar strengthening exercises, improvements in self-rated pain and disability were related to sagittal lumbar mobility. Based on the results, this hypothesis is rejected: the 11-week lumbar strengthening intervention led to significant and mostly clinically important improvements in pain and disability, but only with minor accompanying improvements in lumbar flexion and extension range of motion. These small and mostly statistically non-significant changes in spinal mobility are unlikely to have caused the clinical improvements in self-perceived functional status in our study group.

Our study group comprised a cohort of LBP patients with, in general, longstanding complaints that attended a specific exercise treatment program. With literature presenting minimal clinical important change values for chronic low back pain patients of 23 points using a 0-100 scale for PSC, and 8.5 to 24.6 points for QBPDS, the reported pre-post intervention differences (23% up to 36%) can be considered as clinically important.[31-33] Despite the fact that nearly one-fifth of the study group quitted therapy due to lack of improvement, average treatment effects still clearly exceeded the average improvement rate (≤10%) reported for exercise therapy in CNSLBP populations.[4] Since no control group was utilized in this study, we cannot rule out possible placebo effects that may have enhanced the reported clinical improvements. However, our study group had, on average, persistent and longstanding complaints, emphasizing

TABLE II.—*Output one-way repeated measures ANOVA*

		Mean ± SD	F (df_M, df_R)	$P_{overall}$	Pairwise mean difference ± SD	95% CI	$P_{pairwise}$
VAS	T_0	53.0±22.7	21.2 (1.4, 113.1)	0.000	$T_0 - T_1$: 9.7±2.9	3.6; 15.8	0.010
(N.=83)*	T_1	43.2±20.6			$T_5 - T_2$: 5.3±1.4	1.8; 8.7	0.010
	T_2	38.0±22.3			$T_0 - T_2$: 15.0±2.9	8.0; 22.0	0.000
QBPDS	T_0	41.3±16.3	28.5 (1.6, 130.7)	0.000	$T_0 - T_1$: 6.2±1.3	2.9; 9.4	0.000
(N.=82)*	T_1	35.1±16.6			$T_5 - T_2$: 3.5±1.0	1.1; 5.8	0.000
	T_2	31.7±17.8			$T_0 - T_2$: 9.6±1.5	5.9; 13.3	0.000
PSC	T_0	62.8±15.6	61.3 (1.6, 110.3)	0.000	$T_0 - T_1$: 13.7±2.3	8.1; 19.3	0.000
(N.=81)*	T_1	49.1±21.3			$T_5 - T_2$: 9.3±1.5	5.7; 12.9	0.000
	T_2	39.8±22.4			$T_0 - T_2$: 13.0±2.4	9.1; 19.3	0.000
Flex	T_0	15.9±12.5	3.9 (1.8, 155.8)	0.026	$T_0 - T_1$: -1.8±0.8	-0.1; 3.7	0.070
(N.=89)*	T_1	17.7±12.9			$T_5 - T_2$: -0.2±0.7	-1.7; 1.4	0.999
	T_2	17.9±11.0			$T_0 - T_2$: -2.0±0.9	-4.1; 0.2	0.088
Ext	T_0	-34.1±9.1	0.8 (1.8, 162.6)	0.458	$T_0 - T_1$: 0.6±0.9	-1.4; 2.7	0.999
(N.=89)*	T_1	-34.7±9.4			$T_5 - T_2$: -0.9±0.7	-2.5; 0.7	0.477
	T_2	-33.8±9.9			$T_0 - T_2$: -0.3±0.8	-2.2; 1.6	0.999

VAS: Visual Analogue Scale; QBPDS: Quebec Back Pain Disability Scale; PSC: Patient Specific Complains; Flex: degrees of lumbar flexion (deviation from vertical); Ext: degrees of lumbar extension (deviation from vertical); $T_{0/1/2}$: measurements at baseline/week 5/week 11; df_M: degrees of freedom for the model; df_R: degrees of freedom for the residuals of the model.
*Numbers of participants analyzed with the last-observation-carried-forward method. Numbers with missing data per outcome variable: VAS: N.=87 (T_0), N.=68 (T_1), N.=49 (T_2); QBPDS: N.=88 (T_0), N.=66 (T_1), N.=49 (T_2); PSC: N.=87 (T_0), N.=69 (T_1), N.=59 (T_2); Flex: N.=90 (T_0), N.=68 (T_1), N.=53 (T_2); Ext: N.=90 (T_0), N.=68 (T_1), N.=53 (T_2).

TABLE III.—*Linear regression analyses models including pre- and post-treatment differences (T_0-T_2) in lumbar flexion and extension, respectively. Values are corrected for baseline levels, age, and gender.*

		β	B	95% CI of B	P value	F_{model} (df)	P value	R^2
VAS	$Flex_{diff}$	-0.04	-0.10	-0.64; 0.43	0.703	4.215 (4)	0.004	14%
(N.=82)	Ext_{diff}	-0.06	-0.16	-0.80; 0.48	0.624	4.244 (4)	0.004	14%
QBPDS	$Flex_{diff}$	0.02	0.04	-0.30; 0.37	0.830	17.91 (4)	0.000	45%
(N.=83)	Ext_{diff}	-0.02	-0.04	-0.43; 0.35	0.855	17.91 (4)	0.000	45%
PSC	$Flex_{diff}$	-0.11	-0.26	-0.78; 0.26	0.318	5.92 (4)	0.000	22%
(N.=81)	Ext_{diff}	-0.14	-0.43	-0.25; 1.11	0.211	6.12 (4)	0.000	22%

Interpretation: one-degree increase in flexion is associated with a 0.10-point improvement in pain.
β: standardized regression coefficient; B: regression coefficient; R^2: (adjusted) proportion of explained variance in outcome; $Flex_{diff}$: pre-post treatment difference in degrees of lumbar flexion.

the clinical relevance of the observed improvements. Moreover, training compliance was relatively low (<6 treatment sessions in 11 weeks) in almost 25% of the study group, which may have underestimated the full potential of the LES intervention.

In general, we were able to generate adequately fitted but moderately performing regression models, accounting for 14% to 45% of the variance in the observed outcomes. This implies that other factors determine to a large extent exercise-related improvements in pain and disability seen in CNSLBP populations undergoing exercise therapy. These results are in line with previous research examining relations between objective measurements of spinal function and subjective experience of measures such as pain and disability in CNSLBP patients.

In a study by Taimela *et al.*,[19] the association between lumbar mobility, measured with trunk training/measuring devices, and pain experience was examined in a group of CNSLBP patients that attended a 12-week functional rehabilitation program. No significant associations between increases in mobility and pain were found. Ferreira *et al.*[34] found weak but significant correlations (*r*=0.18 to 0.28) between manually assessed spinal stiffness on the one hand and functional disability or a global perceived effect on the other hand, in CNSLBP patients that were treated for 8 weeks with either spinal manipulative therapy, motor control exercises, or a general exercise program. Elnaggar *et al.*[20] compared the effects of spinal flexion and extension exercises on pain level and spinal mobility, measured with specialized motion sensors. They also found weak and mostly non-significant correlations (*r*=0.17 to 0.24) between changes in pain severity and changes in sagittal mobility. The relationship between lumbar mobility, amongst other physiological factors, and self-rated disability was also evaluated in an intervention study by Mannion *et al*.[18] Weak but significant correlations (*r*=0.17 to 0.22) were found. Physical performance factors (mobility, muscle activation, strength) together accounted for only 25% variance in disability in this study.

Contrary to these results, a study examining patients with herniated lumbar disc that were subject to spinal decompression surgery reported that pre-post intervention changes in lumbar spine mobility, assessed with Spinal Mouse, strongly correlated (*r*=-0.82) with self-rated disability.[15] As suggested by the authors, these results may be explained by the specificity of the study group (*i.e.*, diagnosed herniated disc), and the direct effect of surgery on mechanical obstructions in the lumbar region in these patients.

Evidence on the relationship between exercise-induced changes in clinical outcomes and changes in the targeted aspects of a broad range of physical functions, including sagittal spinal mobility, has been summed up in a comprehensive systematic review by Steiger *et al*.[13] Our study findings support their notion that such a relationship is hard to find. The authors state that coincidental factors that may influence symptom improvements, most likely representative of more centrally induced mechanisms (*e.g.*, psychological, cognitive, neurophysiological), need to be included in future research in this area. Adding to this point of view, two different reviews emphasize the lack of evidence that the (apparent) physical deconditioning in chronic back pain patients exceeds its presence in the general population.[35, 36] It is, thus, hypothesized that physical reactivation following active treatment, more than direct reconditioning effects, leads to the clinical improvements in self-rated disability.

Conclusions

Conclusively, our study shows that, in a group of CNSLBP patients performing specific exercise aimed at strengthening and mobilizing the lower back, clinically relevant improvements in pain and disability do not necessarily relate to improvements in lumbar mobility. These findings add to the current scientific evidence that changes in clinical outcomes are poorly related to changes in the targeted aspects of physical function in exercise therapy. There is a need for studies including parameters representing other (*e.g.*, more centrally-induced) domains of adaptations to exercise.

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