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Treatment of Chronic Lower Back Pain with Lumbar Extension and Whole-Body Vibration Exercise

A Randomized Controlled Trial

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Study Design. A randomized controlled trial with a 6-month follow-up period was conducted.

Objective. To compare lumbar extension exercise and whole-body vibration exercise for chronic lower back pain.

Summary of Background Data. Chronic lower back pain involves muscular as well as connective and neural systems. Different types of physiotherapy are applied for its treatment. Industrial vibration is regarded as a risk factor. Recently, vibration exercise has been developed as a new type of physiotherapy. It is thought to activate muscles *via* reflexes.

Methods. In this study, 60 patients with chronic lower back pain devoid of "specific" spine diseases, who had a mean age of 51.7 years and a pain history of 13.1 years, practiced either isodynamic lumbar extension or vibration exercise for 3 months. Outcome measures were lumbar extension torque, pain sensation (visual analog scale), and pain-related disability (pain disability index).

Results. A significant and comparable reduction in pain sensation and pain-related disability was observed in both groups. Lumbar extension torque increased significantly in the vibration exercise group (30.1 Nm/kg), but significantly more in the lumbar extension group (+59.2 Nm/kg; SEM 10.2; $P < 0.05$). No correlation was found between gain in lumbar torque and pain relief or pain-related disability ($P > 0.2$).

Conclusions. The current data indicate that poor lumbar muscle force probably is not the exclusive cause of chronic lower back pain. Different types of exercise therapy tend to yield comparable results. Interestingly, well-controlled vibration may be the cure rather than the cause of lower back pain. [Key words: back pain, physiotherapy, resistance training, treatment] **Spine 2002;27:1829–1834**

In Western countries, chronic lower back pain (CLBP) constitutes a major health care problem. Moreover, it challenges the social insurance systems. In Germany, for example, CLBP is one of the most important reasons for early retirement.[12]

It is thought that CLBP emerges from acute pain of muscle and connective tissues, which persists in approximately 30% of acute cases and becomes chronic.[30] This generally occurs without specific damage or symptoms that could be shown through imaging or neurophysiological techniques. Besides somatic factors, psychological and social factors play an important role in chronification.[20] Therefore, CLBP often is referred to as "unspecific."

The pathophysiologic emergence of CLBP is as unclear as its diagnostic criteria. Besides pain sensation, findings generally encountered in patients with CLBP are reduced lumbar flexibility, reduced flexion–relaxation observed in healthy subjects, and static balance.[2,7,14,18,28] Hence, it is mostly accepted that muscular systems as well as connective tissues and neural systems are involved in the pathophysiology of CLBP.

An often-repeated view is that different initial damages may lead to a muscular hypertonus, and hence to an inadequate circulation, which promotes and enhances pain. In the long run, this leads to immobilization,[20] followed by muscular atrophy[17] and pathophysiological loading patterns, which further establish pain chronification.[1,19]

Although exercise therapy appears to be without benefit in the acute state, some types of exercise seem to be effective once the pain has become chronic.[33] Among these types are conventional physiotherapy, medical resistance training, stretching, or freely chosen exercise.[10,13,15,31] In particular, lumbar extension has turned out to be effective.[23]

Whole-body vibration exercise (VbX) is a new type of exercise currently being tested in sports, geriatrics, and rehabilitation.[3,8,24] It is thought to elicit muscular activity *via* stretch reflexes. Recently, we have shown that metabolic power increases during whole-body vibration exercise,[26] and that this VbX-related metabolic power is augmented by the application of additional loads to the shoulders,[25] suggesting an enhanced activity of the trunk muscles.

In experimental acute lower back pain, stretch reflexes are unchanged, whereas EMG modulation during voluntary lumbar flexion–extension clearly is affected.[34] Hence, we hypothesized that VbX could elicit trunk muscle stretch reflexes, and thus be a means of activating and strengthening these muscles. It has been shown that

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vertical platform vibration of 3 to 10 Hz evokes electrical activity of the erector spinae muscle, indicating an increased muscular torque caused by vibration.[27] The researchers, however, discussed their results mainly with respect to the emergence and chronification of lower back pain. Generally, industrial and nonindustrial exposure to vibration is viewed as a risk factor for CLBP rather than its cure.[29]

Personal experience, however, and single case observations have shown that controlled VbX may indeed be beneficial for lower back pain. Therefore, the current study was designed to test the applicability of VbX for patients with CLBP in a randomized therapy control study. Isodynamic lumbar extension exercise (LEX), an established intervention for patients with CLBP, was used as a reference therapy.

■ Material and Methods

Study Survey. The minimum sample size was computed according to Dixon and Massey.[6] Improvement in pain and the standard deviations on LEX were taken from Leggett et al.[16] Given an alpha of 0.05 and a beta of 0.1, the sample size required was 23. With an expected dropout of approximately 20%, 60 female and male patients with CLBP were recruited by a local newspaper announcement. The inclusion criteria required lower back pain without any specific underlying disease, either continuously for more than 6 months or intermittently for more than 2 years, and an age of 40 to 60 years.

An orthopedic and, if required, radiologic examination was performed to exclude specific lesions or dysfunctions. The medical exclusion criteria specified vertebral osteoporosis, spinal tumors or metastases, acute vertebral disc herniation, recent fractures of the axial skeleton, inflammatory diseases of the spine, cauda equina syndrome or progressive neurologic deficits, rheumatoid arthritis, osteogenesis imperfecta or other generalized bone diseases, a poor state of health because of tumors or inflammatory diseases, heart failure (NYHA III or IV), recent abdominal surgery, hip or knee endoprothesis or other metal implants, aortic aneurism, recent venous thrombosis, arterial occlusive disease (II or higher), and pregnancy.

Patients also were excluded if they were currently applying for early retirement or taking pain medication regularly (once per day or more often). During the study, patients were asked not to engage in any other fitness or training program, or any other therapy (including pain medication) for their back pain.

After the patients had given their written informed consent, they were randomly assigned to a group that practiced VbX or a group that practiced LEX. The training for both groups was free of charge. Among the 60 participants recruited, 19 were smokers and 41 were nonsmokers. In terms of work, 38 of the participants were employed, 10 self-employed, 5 occupied as housewives, 5 early retired, and 2 unemployed. They had a mean age of 51.7 ± 5.8 years, and mean CLBP history of 13.1 ± 10.0 years. During the study, nine subjects dropped out for nonspecific reasons. One subject who did not pass the honesty criteria[11] in the psychological test for depression (ADS) was discarded from further analysis.

Training. In both groups, 18 exercise units were performed within 12 weeks: 2 units per week during the first 6 weeks and 1 unit per week thereafter. This schedule was maintained very strictly. On the average, the participants spent 12 weeks and 4 days in the training phase.

The participants performed LEX on an LE Mark1 (MedX, Gainesville, FL). After 1 minute of warming up with lumbar extension (61 Nm for the women and 102 Nm for the men), the participants rested for 1 minute. Then they exercised, performing repetitive contraction cycles at a constant speed with a torque corresponding to 50% of the baseline maximum isometric values. As soon as the patient was capable of performing the LEX longer than 105 seconds (11 cycles), the load was increased in steps of 2.5 kg. After completion of the LEX units, an additional resistance exercise of the abdominal and thigh muscles was performed (sit-ups and leg presses).

The performance of VbX was on a Galileo2000 (Novotec, Pforzheim, www.galileo2000.de). This exercise device has been described elsewhere.[26] In brief, it consists of a platform that oscillates around a resting axis between the subject's feet. Hence, the amplitude can be controlled by adjusting the foot distance. As applied in the current study, the device had a maximum amplitude of 6 mm, a vibration frequency set at 18 Hz, and 4 minutes of duration for each exercise unit at the beginning, with 2 minutes of warm-up on the vibration platform (mere standing or squatting with small amplitude). The exercise duration was increased in steps to 7 minutes. During the exercise units, the subject performed slow movements of the hips and waist, with bending in the sagittal and frontal planes, and rotation in the horizontal plane. After three sessions, all the participants exercised at the maximum amplitude of 6 mm. In a further progression of the program, increasing weights up to 5 kg were applied to the shoulders in subsequent sessions. The complete exercise instructions are given in the Appendix.

Measures of Outcome. The primary measures of outcome were pain sensation and pain relief. Pain sensation was assessed on a visual analog scale (P-VAS) ranging from 0 (pain free) to 10 (maximum pain). At the beginning of each visit, P-VAS was assessed using a slide with the numerical scale hidden from the patient. The patients were asked to visualize their worst back pain in the preceding 24 hours. Pain relief was assessed as the P-VAS difference (dVAS) between the last and the first visit. The secondary measures of outcome were the pain-related limitation, the maximum isometric lumbar extension torque, the range of motion (ROM) in lumbar flexion and extension, and the general depressivity.

Pain-related limitations in everyday life were assessed by the pain disability index (PDI). This questionnaire of seven questions was answered on a visual analog scale with a range from 0 to 10.[5] To quantify the improvement in pain-related limitation, dPDI-0 was computed as the difference between the PDI values immediately after the training phase and the baseline values. The same computation 6 months after completion of the training program yielded the variable dPDI-6.

The maximum isometric lumbar extension torque was measured using the LE Mark1 lumbar extension machine on which the LEX was performed. Maximum voluntary isometric lumbar extension torque was assessed in several positions, starting with 72° of flexion, and then moving in 12° steps to full extension. Integration of the values in all positions and division of the sum by the patient's body weight yielded the lumbar extension torque (LET). Two measurements were obtained before the intervention, with at least a 2-day interval between. The greatest LET value was taken. The same procedure was performed after the intervention, yielding the post values. Gain in

Table 1. Baseline Data*

	LEX	VbX
n (completed/included)	25/30	25/30
Males (completed/included)	14/15	12/15
Age (years)	49.8 (6.6)	54.1 (3.4)†
Weight (kg)	80.0 (24.4)	79.8 (10.9)
Height (cm)	169.7 (6.8)	178.8 (9.1)‡
BMI (kg/m)	27.5 (7.3)	24.9 (2.3)
Pain years	11.6 (10.0)	14.5 (10.2)
P-VAS§	4.5 (2.2)	4.2 (1.9)
LET (Nm/kg)*	181 (73.8)	160 (52.5)

* The number of study subjects and male subjects is given for patients that completed all the measurements and for all who were included in the study.
† $P < 0.01$.
‡ $P < 0.001$.
§ Assessed on the first visit before the start of the training program.

torque (*i.e.*, increases in LET after the training phase as compared with the baseline values) was computed as the difference in the values (dLET). The range of motion was assessed in 3° steps on the lumbar extension machine according to the pain-related tolerance of the patient.

The tendency to depression was assessed by a general depression scale, the Allgemeine Depressions Skala (ADS), which is based on 20 items that cover emotional, motivational, cognitive, somatic, and motor symptoms.[11] The ADS is a validated German equivalent to the CES-CD scale. The normal range lies between 40 and 60. Changes in ADS from baseline to completion of the training phase were computed as for PDI, yielding the variables dADS-0 and dADS-6.

Statistical Analyses. Statistical analyses were conducted with SPSS for Windows, version 10.0. Differences between groups in interval-scaled and normally distributed data were checked with Student's *t* test or ANOVA. Otherwise, the Wilcoxon or Mann–Whitney tests were applied. Differences in the P-VAS over treatment weeks within groups were tested with Friedman's test. Spearman's rank correlation coefficient was computed to test correlations between LET on inclusion, dLET, dVAS, and dPDI-0.

■ Results

Baseline Data

Dropout and exclusion based on honesty criteria in psychological testing yielded 25 patients in each group (for survey see Table 1). There was no significant group difference in baseline data in weight, P-VAS, PDI, ADS, or LET. The VbX group, however, was significantly older and taller on the average.

Torque and Range of Motion

After completion of the training program, isometric lumbar torque, as measured by LET, increased significantly both in the LEX (59.2 Nm/kg; SEM, 10.2) and VbX (30.1 Nm/kg; SEM 5.7) groups. This increase in LET (dLET) was significantly more pronounced in the LEX group ($P < 0.05$). In the LEX group, seven participants had an increased lumbar ROM after completion of the program, whereas only three participants in the VbX group had a gain in ROM. This difference, however, was not significant.

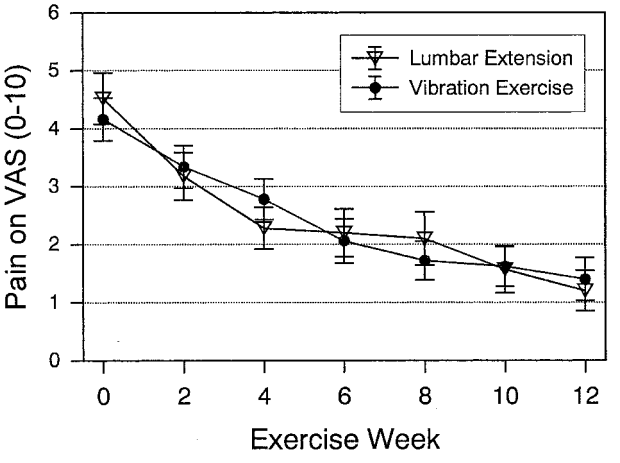

Figure 1. Pain sensation, assessed on a visual analog scale ranging from 0 to 10, during the 12 exercise weeks with lumbar extension training and whole-body vibration exercise. Bars denote the standard deviation. In both groups, there was a significant reduction in pain sensation, with no significant difference between the groups.

Pain Sensation

In both groups, there was a significant decrease in pain sensation, as measured by P-VAS ($P < 0.001$, Friedman's test). In the LEX group, P-VAS decreased from 4.52 ± 2.21 on the first visit to 1.20 ± 1.76 on the last visit (Figure 1). In the VbX group, P-VAS decreased from 4.16 ± 1.86 to 1.40 ± 1.83. No significant difference in P-VAS values was observed between the groups in any of the weeks ($P > 0.2$ in all cases, Mann–Whitney test).

Pain-Related Limitation

On the average, PDI baseline values were 3 for each item, indicating a moderate pain-related limitation during everyday life in our test subjects. The observed data in the LEX group did not follow a normal distribution. A significant change was observed in the LEX group immediately after completion of the training program ($P < 0.01$, Wilcoxon test), and also 6 months thereafter ($P < 0.01$, Wilcoxon test; Table 2). Likewise, there was a significant reduction in the VbX group immediately ($P < 0.01$) and 6 months afterward ($P < 0.01$). No significant group

Table 2. Psychological Test Data*

	LEX	VbX
Pre-PDI	20.3 ± 9.9	20.7 ± 14.3
PDI after 0 months	10.5 ± 12.8	11.6 ± 11.1
PDI after 6 months	12.0 ± 12.4	14.8 ± 13.6
Pre-ADS	48.0 ± 9.6	45.5 ± 12.0
ADS after 0 months	43.7 ± 11.1	43.0 ± 11.8
ADS after 6 months	43.7 ± 10.1	46.0 ± 10.9

* The PDI (pain disability index) measures limitations in everyday life because of pain, and the ADS quantifies depressive mood. A value less than 60 is considered normal.
† $P < 0.01$, compared with the Pre value.
‡ $P < 0.05$, compared with the Pre value.
LEX = isodynamic lumbar extension exercise; Vbx = vibration exercise; PDI = pain disability index; ADS = general depression score; Pre = value before start of the training program; Post = value immediately and 6 months after completion of the program.

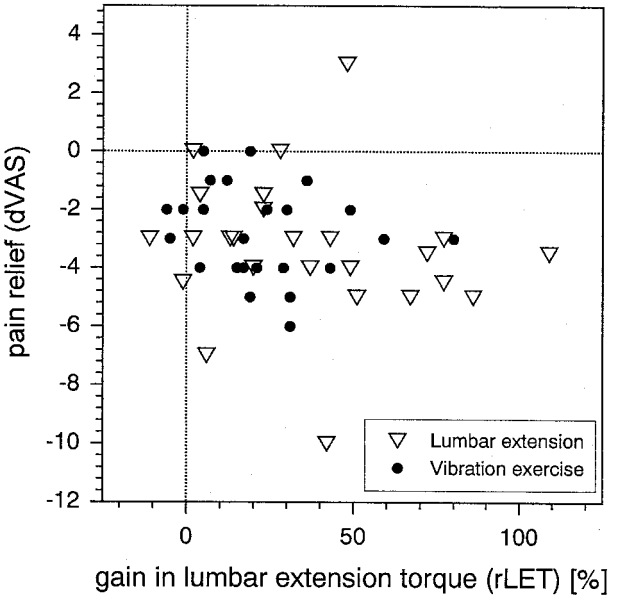

Figure 2. Relief of pain sensation (dVAS) and relative gain in maximum isometric lumbar extension torque (dLET). No significant correlation was observed ($P > 0.1$).

difference was found in PDI reduction, neither immediately nor 6 months after program completion (dPDI0 and dPDI6, $P > 0.2$).

Tendency to Depression

At baseline, the average ADS values were within the normal range in both groups, with no difference between the groups. Two subjects in the LEX and VbX groups were above the limit of 60 (maximum, 69), indicating a moderate tendency to depression. Average ADS values were reduced immediately after program completion and 6 months thereafter in the LEX group ($P < 0.05$; Table 2). No significant changes were observed in the VbX group.

Interrelation of Changes

To analyze the interrelation of gain in torque and pain relief with reduction in pain-related limitation, Spearman's rank correlation coefficient was computed. Since the LEX group had a significantly greater dLET, these analyses were made within groups. No significant correlation within the LEX group or the VbX group was found between baseline LET and dVAS, dPDI-0, or dLET ($P > 0.2$; Figure 2), indicating that pain relief, improvement in pain-related limitation, and gain in torque were unrelated to baseline torque. Likewise, no significant correlation within groups was found between dLET and dVAS or dPDI-0, suggesting that the gain in torque was unrelated to pain relief and to improvement in pain-related limitation.

Significant correlations, however, were found between dVAS and dPDI-0 ($r = 0.47$; $P < 0.001$) and between dVAS and dPDI-6 ($r = 0.343$; $P < 0.01$), indicating that pain relief was related to improvement in pain-related limitation, both immediately after the training program and 6 months thereafter.

■ Discussion

The results of this study suggest that both lumbar extension and whole-body vibration exercise can relieve pain and improve pain-related limitation in everyday life for patients with CLBP. Moreover, a gain in lumbar extension torque was observed in both groups, whereas a reduction in the tendency to depression was observed only in the lumbar extension group. The reason is unknown.

The patients enrolled in this study had CLBP. On the basis of our daily practice, they seem to be representative of a more general population. There was no group difference in baseline data, except in age and height. It would be more desirable, of course, to compare groups of the same age and height. On the other hand, it is not very likely that the group differences would have had a major influence on the main outcome of the study: pain relief. There are indications that lower back pain has a greater tendency to become chronic in older patients, but that height is no risk factor for chronification.[32] Thus, if group differences did play a role, the therapeutic effect in the current study will have been underestimated in the VbX group with respect to the LEX group.

There is another, in this case systematic, group difference that requires discussion. In the LEX group, training and assessment of force and motility (LET and ROM) was performed on the same device. This implies 4 measurement units and 18 exercise units in the LEX group, whereas the VbX group had only the 4 measurement units on the LEX device. It may be not too surprising, therefore, that the LEX group had a greater gain in LET and ROM.

No aggravation of pain or limitations was observed in the VbX group. The dropouts in the VbX group (15%) were for nonspecific reasons and comparable with those in the LEX group and with the dropouts reported in other studies.[31] Thus VbX seems to be applicable in CLBP. This is in apparent contrast to the literature, in which whole-body vibration in industrial and nonindustrial circumstances generally is regarded as a risk factor for the development of lower back pain and its chronification.[29] There are differences, of course, between industrial and therapeutic whole-body vibration, namely, the method of application, the subject's posture, the frequency of application, and the temporal duration of exposure and the resulting fatigue. Currently, we apply vibration exercise for training and therapeutic purposes for no longer than 7 minutes. Patients usually learn to tolerate whole-body VbX quite rapidly, but the first 1 to 2 exercise units should be performed under surveillance.

Our results also may be of some interest with respect to the pathophysiology of CLBP. There is general agreement that patients with CLBP have a reduced lumbar torque.[9,21] It has been shown that lumbar extension exercise in healthy normal subjects increases maximum lumbar extension torque.[22] On the basis of our observations, namely, that the LEX group had a somewhat higher gain in LET than the VbX group, but no greater

pain relief, and, more importantly, that there was no correlation in pain relief and force gain, the question arises whether the increase in LET is the cause or the effect of the pain relief. Obviously, the baseline data were recorded with a greater pain sensation than the end term data. This may have inhibited the motor output, thus leading to a lower measured torque than actually possible. If this view is correct, force cannot be a primary objective in the physical rehabilitation of CLBP patients, in contrast to that of common physiotherapeutic measures.

It should be kept in mind that the crucial point in CLBP is pain sensation. Pain sensation is determined by two different processes: peripheral nociception and central pain sensitivity. In CLBP patients, a major part of pain sensation is the result of increased pain sensitivity (*i.e.*, reduced pain thresholds).[4] In this context, the question arises whether the improvement in pain-related limitation, as suggested by a positive correlation between dVAS and dPDI-0, was a mere effect of the pain relief. Alternatively, the patients may have felt an increased capability to carry out their daily tasks, and may have experienced a reduction in pain sensation. This interpretation also might explain why the PDI improved in both groups, whereas there was virtually no change in ROM.

In conclusion, whole-body vibration exercise seems to be helpful rather than harmful in nonspecific chronic lower back pain. As to the practical aspects, and given that it yields about the same results as lumbar extension exercise, the spatial requirements favor the former. The LEX machine that we used requires an area of 12 m^2, whereas the VbX device could be placed on 3 m^2 with ease.

Other methods do exist, however. The challenge for the future will involve the search for the best therapeutic intervention. This may depend on patients' individual characteristics.

■ Key Points

- Physiotherapy in chronic lower back pain
- Whole-body vibration exercise is beneficial.
- Lumbar extension torque may not be the exclusive cause

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■ Appendix

Vibration Exercise Used as Strengthening Therapy for Chronic Lower Back Pain

The basic position on the vibration platform is with the knees slightly flexed and the hands placed on the hips. The lumbar spine has a slight hyperlordosis. The head is directly vertical to the feet, and the gaze is horizontal. The frequency is set at 18 Hz (display = 36).

In the first exercise unit, the patient starts with 1 minute of standing in the starting position (heels beyond the platform's edge), followed by 1 to 2 minutes with the heels on the platform and the feet about 5 cm apart (marked green). Once this standing position is steady, the feet should be placed further apart (yellow position). If the patient feels insecure, he or she can use the hand bars for a brief period. After 2 minutes of standing, the feet may be placed further apart until the entire width of the platform is spanned (red position). During changes in position, the hand bars can be held for a brief period.

In the following exercise units, the aforementioned program is run through more quickly, so that in the third and succeeding units, the exercise is predominantly in the widest stance (red position). The exercise time is 7 minutes at the maximum. Depending on the abilitiy of the patient, special exercises may be performed: 1) slow rotation of the pelvis in either direction with approximately 5 to 10 seconds per round, 2) slow tilting of the pelvis forward and backward with alternating kyphosis and hyperlordosis of the lumbar spine, and 3) slow torsion of the spine with the hands clasped behind the head and the shoulders swung alternately to the left and right (also 5 to 10 seconds per cycle). From the 10th unit on, an additional load comprising up to 30% of the patient's body weight may be attached to the shoulders or upper arms, depending on the ability of the patient.

Therefore, control of the training may be achieved by the distance of the feet, the duration of the exercise units, the additional weight load, the amplitude of the slow trunk movements, and the extension of the knee joint. The more the knee is extended, and the more the heel is put on the vibration platform, the larger the displacements transmitted to the vertebral column. Complete extension, however, should be avoided.

Finally, after a short period, most patients develop a feeling for which exercise, load, and position they can tolerate.