KIESER TRAINING

Article translated from the March 2011 edition of the German Journal of Sports Medicine, the official journal of the German Society for Sports Medicine and Prevention

Stephan A[1], Goebel S[1], Schmidtbleicher D[2]

Effects of Machine-Based Strength Training in the Therapy of Chronic Back Pain

Effekte maschinengestützten Krafttrainings in der Behandlung chronischen Rückenschmerzes

1) Research & Development Department, Kieser Training AG
2) Institute for Sport Sciences of Johann Wolfgang Goethe-University Frankfurt/Main

SUMMARY

Objective: The aim of this article is to quantify the effects of machine-based strength training on sufferers of back pain, predominantly in its early stage of chronification and with a minor to moderate effect on daily life. Methods: In a multi-centre, prospective, random study, 58 individuals completed a 30-minute session of strength training 6 times a month for 6 months. The waiting-list control group consisted of 16 individuals. In order to measure pain and its effects, participants were assessed at the start, after 3 months and after 6 months using the pain scales Pain Severity (PS), Effects of Pain (EP), a numeric rating scale for average pain intensity and the Oswestry Disability Index (ODI). Effects were described by the effect-size d and corrected effect-size d_{corr}. Results: After 6 months, mean pain intensity had declined by 38% in the training group and by 26% in the control group, i.e. a net benefit from strength training of $d_{corr} = -0.34$. PS showed no net effect. After 6 months, the reduction in the effects of the pain was mainly evident in the training group with a net effect of $d_{corr} = -0.46$ (ODI) and 0.13 (EP). Discussion: Based on the statistical and clinical guidelines for interpretation, strength training produced a relevant reduction in both pain and the effects of pain. The control group showed predominantly non-significant moderate effects. The net effects of strength training, which were calculated on a conservative basis, were in the expected range for meta-analytical data on physical training for chronic back pain. Strength training was shown, therefore, to be an effective way of reducing symptoms.

Key Words: Disability, single-set training, strengthening, lumbar extensors, net effect.

Cite as: Stephan A, Goebel S, Schmidtbleicher D: Effects of Machine-Based Strength Training in the Therapy of Chronic Back Pain, Deutsche Zeitschrift für Sportmedizin 62 (2011) 69-74.

INTRODUCTION

PROBLEM AND AIM

This article looks at the effect of a 6-month programme of independent machine-based strength training on individuals with back pain in the early stage of chronification as compared with a control group on a waiting list. It is assumed that intervention reduces the level of pain experienced and its effects.

Episodes of mild or moderate pain in the early stage of chronification often ease without treatment. Existing data shows that this can be up to 20% within 6 months [12]. To ensure that this factor is reflected in the evaluation of an intervention, the net effect is calculated (the difference between the effect of the intervention and the changes in control group).

The bio-psychosocial explanatory model for back pain has gained general acceptance, i.e. the potential triggers or risk factors are not only biological in origin but psychological and social factors also play a role. Pfingsten has stated: "In most cases of prolonged back pain, although the origin could be traced back to an existing physical process (e.g. muscular dysfunction), the physical origin quickly lost its significance and was replaced by psychological factors in which cognitive beliefs and their associated effect on behaviour become paramount" [14, p. 84[1]]. In the longer term, the anxiety surrounding physical exertion and the resultant physical inactivity cause a deconditioning of the muscles. Following an analysis of the main functional muscles in the trunk and neck, Denner found that patients with back pain had poor levels of strength and performance [2]. The current treatment for patients with chronic back pain is designed to restore function, reduce the effects of pain and the anxiety associated with certain movements, control pain and overcome physical inactivity.

Physical training offers the potential to achieve the above treatment aims. Most randomised, controlled studies in this field have been carried out on patients with chronic lumbar pain. Reviews show that physical training is at least as beneficial in terms of effectiveness as conservative treatments [9]. The studies that have produced superior results primarily included exercises to strengthen muscles and stabilise the trunk [9].

METHODOLOGY

The data was generated during a multi-centre study between April and October 2009 with a group of volunteers displaying differing states of health. The study was conducted in the strength-training facilities of an international provider of strength training.

Design and Procedure

Participants were recruited via the media from members of the adult German population. The intervention lasted 6 months. All participants were provided with written information on the aims of the study and consented in writing to their participation. In order to achieve greater representation, the study was conducted at multiple centres. Diagram 1 shows the procedure adopted starting with the procedure to draw lots in order to select participants through to the random sampling procedure used for the sub-study "Chronic Back Pain", which is the subject of this article.

Inclusion criteria:

- Back pain for more than 12 weeks or a minimum of two recurring episodes of pain each year for at least 2 years
- Chronification stage 1 or 2 [7]
- Able to do independent strength training following an assessment by the doctor

Exclusion criteria:

- Known osteoporosis
- Non-stabilised cardio-vascular disorder, acute injury or inflammation affecting the musculoskeletal system, motor disorder, state post surgery
- Current or previous customer of the provider

Data was collected at the start of the study, after 3 months and after 6 months. In order to ensure a standard methodology for both training and data collection, all trainers and doctors involved in the study were given identical training. All facilities had identical training equipment and the training programmes and load norms used were the subject of binding rules.

Participants

Table 1 describes the sample and the characteristics of the sample group at the start of the intervention (no significant differences). Most of the participants had back pain in Stage 1 of chronification and moderate levels of pain. Individual diagnoses were not divulged to the study, which was only informed of the symptoms as shown in Table 1. Almost all participants reported lumbar pain in the last month.

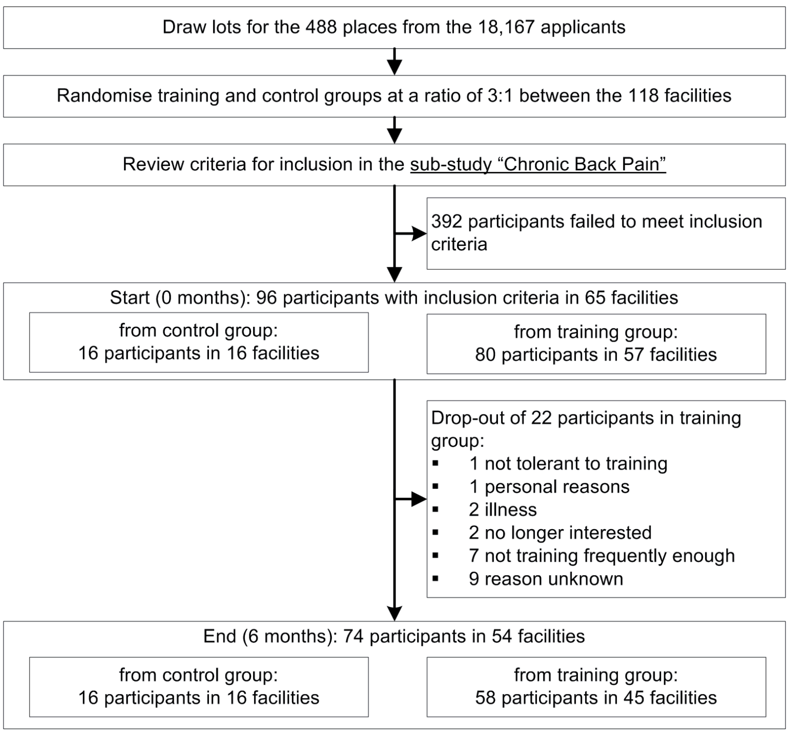

Diagram 1: Flow Chart for randomisation and sampling procedure

[1] *translated by author*

Table 1: Sampling characteristics

	Training group (n=58)			Control group (n=16)		
	Percentage in group (%)	Mean ±SD	95% Confidence interval	Percentage in group (%)	Mean ±SD	95% Confidence interval
Percentage – female	53.4%			62.5%		
Age (years)		44.37 ±15.20	[40.59;48.65]		44.88 ±13.56	[37.65;52.10]
Height (cm)		174.52 ±10.22	[171.70;177.06]		170.41 ±10.43	[164.85;175.97]
Weight (kg)		75.39 ±15.97	[70.90;79.39]		71.63 ±15.02	[63.62;79.63]
Predominantly sedentary activity	56.9%			62.5%		
No sport	34.5%			43.8%		
Experience of strength training	27.6%			12.5%		
Pain in lumbar/thoracic/cervical spine (multiple answers)	96.9% / 5.2% / 22.4%			93.8% / 12.5% / 37.5%		
Chronification Stage I / II (7)	87.9% / 12.1%			75% / 25%		
Radicular radiation	5.2%			18.8%		
Pseudo-radicular radiation	12.1%			18.8%		
Perception disorder	0%			18.8%		
Intensity of pain in last 4 weeks (0-100)		25.78 ±13.6	[22.20;29.35]		21.56 ±7.24	[17.71;25.42]
Pain Severity (PS, 0-100)		56.03 ±13.58	[52.46;59.60]		57.00 ±14.65	[49.20;64.80]
Effects of Pain (EP, 0-100)		73.43 ±22.54	[67.51;79.36]		71.61 ±15.75	[63.22;80.01]
Oswestry Disability Index (ODI, 0-100)		10.37 ±9.66	[7.83;12.91]		9.03 ±7.32	[5.13;12.94]
Lumbar extension strength (Nm)		222.80 ±103.11	[192.65;249.05]		207.94 ±84.35	[161.23;254.65]
% with significant strength deficit (PR<16 compared with those with no back problems)	22.2%			12.5%		

Radiating pain and sensory disorders were rare. Physical deconditioning, as measured by the strength of lumbar extensors, had not yet advanced significantly compared with those without back problems. The effects of the back pain and the reduction in function were slight to moderate.

Intervention

The training group completed progressive hypertrophy-oriented strength training on training machines with a variable resistance. The aim was to improve the function and structure of muscles, particularly the trunk muscles. The programme included lumbar-extensor training with the pelvis stabilised (Diagram 2). Participants received a personal induction by qualified staff during the first three training sessions. An individual check session was provided at the 10th session and then every 20th session and if necessary an individual's training programme was modified. The training programme covered all muscle groups in the body. Table 2 shows the load norms used during the strength training.

The control group received no training during the intervention period. However, they were given the opportunity subsequently to train for 6 months free of charge (waiting list control group).

Measuring systems

To determine the pain experienced in the last 4 weeks, the study used two pain scales from the Medical Outcomes Study (MOS) and the Oswestry Disability Index (ODI) (10, 3). For this purpose, participants were asked to complete a written questionnaire. In addition, the maximum strength of the lumbar extensors was measured.

Severity of back pain

The questions in the MOS scale "Pain Severity" (PS) cover frequency of pain, duration and the average and maximum pain. PS is expressed as a scale of 0-100; the higher the score the less the severity of pain.

The item on average pain was analysed separately in order to allow comparability with other studies. The results were then transformed from the MOS scale of 0-20 to a scale of 0-100.

Effects of back pain

The MOS scale "Effects of Pain" (EP) expresses the extent to which the pain affects certain aspects of a person's life (mood, walking ability, sleep, leisure activities and vitality). EP is represented by a scale of 0-100, the higher the score, the less the effect.

The ODI looks at the level of pain and its effect on the ability of individuals to care for themselves, to lift/carry things, walk, sit, stand or sleep plus the effect on their sex life, social activities and travel. The higher the score (0-100), the greater the effect of the pain.

Lumbar extension strength

The lumbar extension strength was tested as an isometric maximum strength test The test was conducted on a MedX Lumbar Extension machine at a maximum of seven different angles. On this machine, the pelvis is secured in such a way that the lumbar extensors are isolated. This allows their function to be tested as other trunk extensors are unable to assist as strength is exerted onto the backrest of the test machine. The weight of the upper body is offset during the strength measurement. The reliability of this test method is between r=0.81 and 0.98 [8].

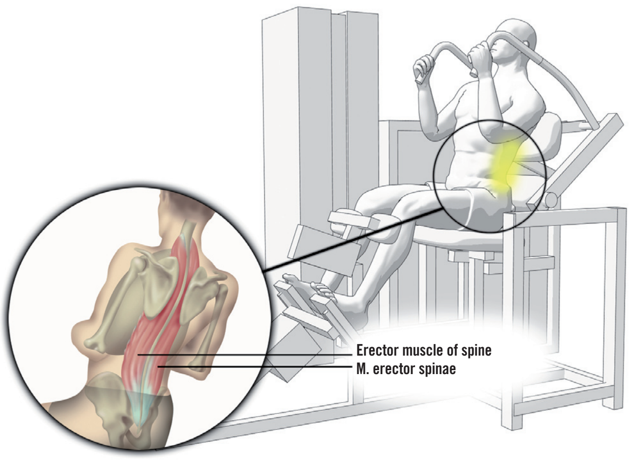

Diagram 2: Exercise Machine for lumbar extension: as pelvis is immobilised, lumbar extensors are the target muscles

Table 2: Standard load norms for strength training

Number of training sessions	1.6 times per week
Duration of training	24.5 weeks
Exercises	Programme for complete body consisting of 10 exercises on machines (incl. lumbar extensors, hip/abdominal/leg/back/shoulder muscles)
Order of exercises	Large muscle groups before small ones, "problem exercises" earlier in the programme
Load magnitude	Approx. 60% of dynamic maximum strength (1 repetition maximum)
Number of repetitions/sets	6-9 / 1
Duration of each contraction type per repetition	4 seconds concentric, 2 seconds isometric, 4 seconds eccentric
Time under load	Training sessions 1-20: 60-120 sec, from training session 21: 60-90 sec.
Muscle fatigue	Training sessions 1-20: sub-maximal number of repetitions to repetition maximum From training session 21: repetition maximum to point of temporary muscle fatigue
Range of motion	Individual maximum (pain-free) possible movement of joint
Recovery time between training sessions	At least 48 hours

Statistical procedures

For data evaluation, the software SPSS Statistics 17.0 was used. As some variables have no normal distribution (Shapiro Wilk Test), we used the Wilcoxon non-parametric signed-rank test to verify differences between paired means and for non-paired means, we used the U test of Mann Whitney. To verify the statistical significance, the significance level was set at $\alpha = 5\%$. With a sample of this size, effects are verifiable from $|d| \geq 0.37$ for the training group and $|d| \geq 0.75$ for the control group (power of test = 0.8). To evaluate the practical significance of differences, we calculated the effect sizes d and the corrected effect sizes d_{corr} [11]; the latter reflected group differences in the pre-test and the sample size.

RESULTS

Participants trained on average for 24.5 (±2.0) weeks. They trained 1.6 times (±0.4) per week (min: 0.7; max: 2.4). At the end of the intervention, 20 of those in the training group were completely free from pain, of which 9 had previously had moderate/strong pain and 11 slight/very slight pain. In the control group, 6 were completely free from pain, of which 3 had previously reported very slight and 3 moderate pain. None of this group had undergone any medical treatment during the intervention period. Table 3 provides a summary of the results of the two repeat tests. The statistical tests and the effect sizes relate to the start date. Diagram 3 shows the percentage change in outcome parameters.

Severity of back pain

For groups with lower baseline scores for pain, a change of 30% is classed as clinically important [4]. The training group achieved this change in both severity criteria after 3 months; the control group achieved it in the PS scale after 6 months. The corrected effect sizes for PS after 3 months and 6 months were d_{corr}=0.3 and 0.08. In both groups, the improvement in PS was comparable at the end of the 6 months but in the training group, the improvement took place earlier.

Treated as an individual criterion, average pain intensity in the last 4 weeks of the 6-month period declined in the training group by 11.2 (±16.55, d=-0.55) points and in the control group by 6.87 (±17.4, d=-0.33) points. This corresponds to a relative reduction in the pain compared with start levels of 38.2% or 25.6%. This means that the reduction in average pain intensity can only be regarded as clinically important in the training group. The net effect of the strength training was d_{corr}=-0.42 after 3 months and d_{corr}=-0.34 after 6 months (= 4.33 points). This is within the expected range for the net effect of physical training for 6 months by patients with chronic back pain calculated from meta-analytical data and compared with no intervention (confidence interval there: 1.31-19.09) [9].

Effect of back pain

One of the recommendations for the interpretation of measures of quality of life – which includes EP and in its wider sense ODI as well – is an evaluation of the effect size. With most test tools, a shift in the mean by half of one standard deviation (d=0.5) is regarded as clinically relevant [13]. Both groups achieved this in both criteria within 3 months although EP change was not significant in the control group. After 6 months, the training group had improved further in both criteria but the control group had not improved. The average individual improvement in EP was 13.99 ±27.93 points (31.8%) in the training group and 11.46 ±25.25 points (19.3%) in the control group. The corrected effect size for 3 and 6 months was d_{corr}=0.13.

After 6 months, the ODI in the training group declined by 6.45 ±10.48 points (58.5%) and in the control group by 2.07 ±8.67 points (36.2%). The corrected effect size at 6 months was d_{corr}=-0.46 (= 4.38 points). This was also in the expected range of net effects calculated from meta-analytical data (confidence interval: -0.53-6.48 points) [9].

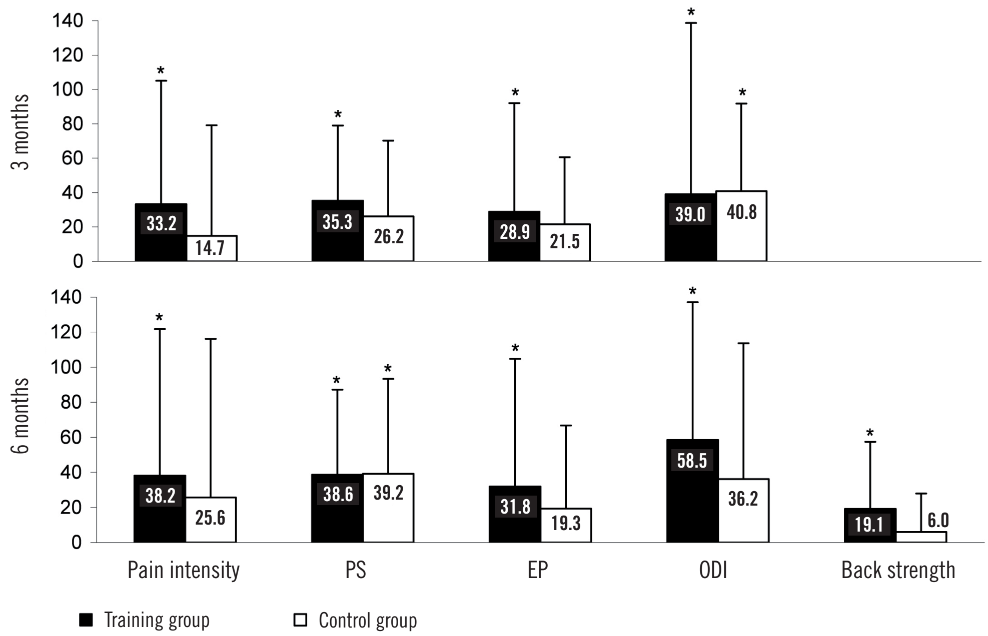

Diagram 3: Percentage change in outcome parameters after 3 and 6 months (*p<0.05 for change compared to start, PS: Pain Severity, EP: Effects of Pain, ODI: Oswestry Disability Index)

Lumbar extension strength

No changes occurred in the control group. In the training group, there was a significant increase in maximum strength at the following angles of extension: 12°, 24°, 36°, 58°, 60° and 72°. The test-retest differences for these test positions were 25.76 Nm, 28.74 Nm, 24.94 Nm, 23.58 Nm, 29.53 Nm and 34.91 Nm, which equates to strength increases of 42.8%, 24.2%, 18.8%, 20.2%, 15.2% and 19.7%. Similar results have been achieved elsewhere on patients with back pain who completed 2-3 months of training on special therapy machines, although in that study, the strength gains at 0° and 12° were greater [15]. By training for twice as long it was possible to achieve more or less comparable strength gains using independent training rather than specialist therapy machines.

DISCUSSION

This random study involved volunteers who were motivated to participate and the fact that participants were applying to do strength training indicates a certain level of affinity to exercise and sport. This must be taken into account when evaluating the effects on both groups. If training were prescribed to patients with back pain, the intrinsic motivation to participate would be less and the risk that they would drop out would be higher.

It would have been useful to have had more accurate data on diagnoses, back pain related sick days and further information on the pain history of participants.

Based on the statistical and clinical guidelines used for interpretation purposes, the strength training achieved a relevant reduction in pain and its effects. The are various reasons for this [6]: The varied compression load produced by strength training activates and normalises local metabolism; it reduces the sensitivity of the nociceptor system at both the periphery and spinally and centrally and this changes the perception of pain. It eliminates structural muscle atrophy, it improves intra- and intermuscular coordination and so stabilises joint partners (vertebrae, facet joints). This in turn reduces the shear forces that cause the pain. Similarly, the parameters from cognitive evaluation also influence the actual pain rating and from an empirical perspective, particular reference should be made to what patients expect from an intervention.

In the control group, the effects were mainly moderate and not significant. It could be argued that a larger control group would have achieved results that were significant. However, if we analyse the range of the confidence interval for these criteria, the picture looks different: in the control group it widened - as an expression of heterogeneous changes in characteristics.

In view of the small size of the control group, the net effects of the strength training were calculated on a conservative basis, i.e. a value correction was made based on effects in the control group even though the changes in the control group were not significant. The net effects were within the expected range. Particularly over a longer time frame, the authors assume that the increase in net effects from strength training would be greater.

SUMMARY

Independent strength training for the complete body six times a month is appropriate for those with chronic back pain in its early stages in order to reduce the level of pain and the effects experienced, to overcome physical inactivity and build up strength. The increase in strength should not just be interpreted as the result of better muscle function but "also a function of the subjective expectations of sensory consequences" [5, Page 8[1]]. It is known that strength training overcomes psychological inhibitors (anxiety, pain) [14]. The above findings are all important objectives in current rehabilitation programmes. The improvement in symptoms suggests a significant contribution to curtailing the process of chronification

Table 3: Results of repeat measurements

	Training group (n=58)					Control group (n=16)				
	Mean ±SD	Confidence interval	Median	Z	D	Mean ±SD	Confidence interval	Median	Z	d
3 months										
Intensity of pain in last 4 weeks (0-100)	15 ±15.15 **	[10.98;19.02]	15	-4.132	-0.56	16.25 ±10.25	[10.79;21.71]	15	-1.427	-0.33
Pain Severity (PS. 0-100)	72.68 ±20.28 **	[67.30;78.06]	71	-4.800	0.87	68.13 ±17.65	[58.72;77.53]	62	-1.863	0.69
Effects of Pain (EP. 0-100)	86.42 ±15.64 **	[82.27;90.57]	91.7	-3.981	0.68	83.07 ±16.42	[74.32;91.82]	89.6	-1.907	0.71
Oswestry Disability Index (ODI. 0-100)	5.10 ±6.66 **	[3.33;6.87]	2	-4.642	-0.65	4.83 ±6.80 *	[1.20;8.45]	2.1	-2.308	-0.60
6 months										
Intensity of pain in last 4 weeks (0-100)	14.57 ±16.66 **	[10.19;18.95]	10	-4.449	-0.55	14.69 ±15.76	[6.29;23.08]	10	-1.576	-0.33
Pain Severity (PS. 0-100)	75.71 ±23.03 **	[69.01;81.12]	76	-5.034	0.94	74.69 ±23.60 *	[62.11;87.26]	73	-2.224	0.84
Effects of Pain (EP. 0-100)	87.43 ±18.16 **	[82.65;92.20]	93.8	-3.595	0.69	83.07 ±26.50	[68.95;97.20]	95.8	-1.637	0.54
Oswestry Disability Index (ODI. 0-100)	4.10 ±7.98 **	[1.99;6.22]	0	-4.738	-0.71	6.97 ±12.45	[0.33;13.60]	1	-1.084	-0.21
Lumbar extension strength (Nm)	247.11 ±97.8 *	[219.61;274.62]	211.89	-3.412	0.25	193.99 ±72.35	[145.38;242.59]	163.86	-0.622	0.04

Wilcoxon non-parametric signed rank test as a comparison of start of intervention: ** $p<0.001$ * $p<0.05$

and avoiding a recurrence. If there is a recurrence, the improved structural and functional quality of muscles means that function is likely to be restored more quickly.

The time directly spent on training was only 3 hours per month; over the 6-month period, it was 18 hours. The independent machine-based training was well received by participants. The drop-out rate was 27%, which is less than the comparable figure from German fitness chains (35.3%) [1]. For those training at home, it is assumed that the drop-out rate would be significantly higher and the quality of the training insufficient [16].

Anika Stephan and Dr. Sven Goebel work for the Research and Development Department at Kieser Training AG. Prof. Dr. Dietmar Schmidtbleicher has been remunerated for his consultancy by Kieser Training AG.

BIBLIOGRAPHY

(1) **Deloitte & Touche GmbH:** Der deutsche Fitness- und Wellnessmarkt. Studie 2009, Logopublix, München, 2009.

(2) **Denner A:** Die Trainierbarkeit der Rumpf-, Nacken- und Halsmuskulatur von dekonditionierten Rückenschmerzpatienten. Manuelle Medizin 39 (1999) 34-39.

(3) **Fairbank J, Couper J, Davies J, O'Brien JP:** The Oswestry low back pain questionnaire. Physiotherapy 66 (1980) 271-273.

(4) **Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole RM:** Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain 88 (2000) 287-294.

(5) **Freiwald J:** Gedanken eines Wissenschaftlers zum Rückenschmerz. Sportorthopädie – Sporttraumatologie 20 (2004) 5-11.

(6) **Freiwald J:** Schmerz und Krafttraining. In: Kieser W (Hrsg.): Krafttraining in Prävention und Therapie. Huber, Bern, 2006, 71-85.

(7) **Gerbershagen HU, Korb J, Nagel B, Nilges P:** Das Mainzer Stadiensystem der Schmerzchronifizierung – Mainz Pain Staging System (MPSS). Mainz: DRK-Schmerzzentrum, 1986.

(8) **Graves J, Pollock M, Carpenter D, Leggett S, Jones A, MacMillan M, Fulton M:** Quantitative assessment of full range-of-motion isometric lumbar extension strength. Spine 15 (1990) 289-294.

(9) **Hayden JA, van Tulder MW, Malmivaara AV, Koes BW:** Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev 3 (2005), DOI 10.1002/14651858.CD000335.pub.2.

(10) **Hays RD, Sherbourne CD, Mazel RM:** User's manual for Medical Outcomes Study (MOS) core measures of health-related quality of life. RAND, Santa Monica, CA, 1995.

(11) **Klauer, KJ:** Denktraining für Jugendliche. Ein Programm zur intellektuellen Förderung. Handanweisung. Hogrefe, Göttingen, 1993, 58.

(12) **Menezes Costa L, Maher CG, McAuley CH, Refshauge KM, Henschke N:** Prognosis for patients with chronic low back pain: inception cohort study. BMJ (2009) 339:b3829.

(13) **Norman GR, Sloan JA, Wyrwich KW:** Interpretation of changes in health-related quality of life: the remarkable universality of half a standard deviation. Med Care 41 (2003) 582-592.

(14) **Pfingsten M:** Multimodal - Was ist das überhaupt? Manuelle Medizin 43 (2005) 80-84.

(15) **Risch S, Norvell N, Pollock M, Risch E, Langer H, Fulton M, Graves J, Leggett S:** Lumbar strengthening in chronic low back pain patients. Spine 18 (1993) 232-238.

(16) **Turk DC, Rudy TE:** Neglected topics in the treatment of chronic pain patients: relapse, noncompliance and adherence enhancement. Pain 44 (1991) 5-28.

Contact:
Anika Stephan
Kieser Training AG
Kanzleistraße 126
8026 Zürich
Switzerland
E-Mail: anika.stephan@kieser-training.com