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Mechanisms of Action of Lumbar Supports

A Systematic Review

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Study Design. A systematic review and meta-analysis of studies on the putative mechanisms of action of lumbar supports in lifting activities.

Objective. To summarize the evidence bearing on the putative mechanisms of action of lumbar supports.

Summary of Background Data. A restriction of trunk motion and a reduction in required back muscle forces in lifting are two proposed mechanisms of action of lumbar supports. Available studies on these putative mechanisms of action of lumbar supports have reported contradictory results.

Methods. A literature search for controlled studies on mechanisms of action of lumbar supports was conducted. The methodologic quality of the studies was assessed. The evidence for the two proposed mechanisms of action of lumbar supports was determined in meta-analyses.

Results. Thirty-three studies were selected for the review. There was evidence that lumbar supports reduce trunk motion for flexion–extension and lateral bending, with overall effect sizes of 0.70 (95% confidence interval [CI] 0.39–1.01) and 1.13 (95% CI 0.17–2.08), respectively. The overall effect size for rotation was not statistically significant (0.69; 95% CI −0.40–4.31). There was no evidence that lumbar supports reduce the electromyogram activity of erector spinae muscles (effect size of 0.09; 95% CI −0.41–0.59) or increase the intra-abdominal pressure (effect size of 0.26; 95% CI −0.07–0.59).

Conclusion. There is evidence that lumbar supports reduce trunk motion for flexion–extension and lateral bending. More research is needed on the separate outcome measures for trunk motion before definite conclusions can be drawn about the work conditions in which lumbar supports may be most effective. Studies of trunk motion at the workplace or during specified lifting tasks would be especially useful in this regard. [Key words: biomechanics, low back pain, lumbar support, meta-analysis, review] **Spine 2000;25:2103–2113**

Low back pain occurs very frequently and is one of the most costly health problems affecting industry and society. Low back disorders are one of the major reasons for work disability[55,63] and sick leave.[18,55] In the Netherlands in 1991 the total (direct and indirect) cost for back pain represented 1.7% of the gross national product.[58] In the United States, the total costs for back pain were estimated to be $27.9 billion in 1990,[12] which represented approximately 0.5% of the gross national produce.

In an attempt to reduce the incidence and consequences of back pain in industry, many prevention programs have been introduced.[25] Lumbar supports are frequently used in industry, and they increasingly receive attention in the scientific literature. Besides their use as a preventive measure, lumbar supports are also used in the treatment of patients with back pain. Several putative mechanisms of action of lumbar supports have been proposed. One hypothesis is that the use of a support may positively affect trunk motion. The support may either physically obstruct extreme postures, or it may improve body postures through tactile feedback (reminder function). Excessive trunk motion, especially axial rotation, is often assumed to be the cause of a back injury,[3,40] and the prevention of excessive motion would therefore lead to a reduction in the risk of low back pain. Another hypothesis is that less back muscle force may be required to extend the trunk when wearing a support, because of an increase in the intra-abdominal pressure (IAP) without a concomitant increase in abdominal muscle activation. This would yield less muscle loading, less muscle fatigue, and less compressive loading on the lumbar spine. Both reduced muscle fatigue[6] and reduced compressive loading[46] may result in a decrease of the risk for low back pain. The same mechanism may result in a higher maximal lifting capacity of the person wearing a lumbar support. Using a lumbar support may also make the workers feel more secure and make them inclined to lift heavier loads. This could increase the risk of low back injuries.

Available reviews argue that, partly because of conflicting results, no definite conclusions on the mechanism of action of lumbar supports can be drawn.[3,40,44,46] The objective of this review is to evaluate the evidence for the two hypothetical mechanisms of action of lumbar supports with the use of a systematic literature search and by combining the results of individual studies in a meta-analysis. Even if the results are contradictory, it should be possible to draw conclusions based on the results of the meta-analysis.

■ Methods

A search of MEDLINE (1966–1997), EMBASE (1988–1997), and Psychlit (1984–1997) was conducted (key words used: back, spine, orthotic devices, protective devices, biomechanics). No language restriction was used. References of relevant publications were screened for additional studies.

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Table 1. Criteria List for the Methodologic Assessment of Controlled Studies on the Mechanisms of Action of Lumbar Supports

Criteria*	
A	Randomization of the order belt/no belt
B	Wash-out period
C	Description of outcome assessment
D	Reproducibility of outcome assessment
E	Blinding of outcome assessment
F	No missing values or description of missing values
G	Appropriate analysis
H	Description of study population
I	Description of lumbar support
J	Adequate reporting of most important results

* All items were scored yes/no. A copy of the operationalization of the items can be obtained from the first author on request.

The following inclusion criteria were used: 1) The study should have a design in which the same subjects were tested with and without lumbar support. Studies without a prospective study design were excluded. 2) The study should include healthy human subjects. Studies with only patients with back pain were excluded, because posture and movements can be influenced by back symptoms, which in turn may alter the effect of lumbar supports. 3) Outcome measures should include one or more of the following: electromyographic activity; intra-abdominal pressure (IAP); and parameters on trunk motion, maximum lifting capacity, perceived exertion, or subjective maximum acceptable weight of lift (MAWL). 4) Interventions should consist of any lumbar support (orthotic corset, weight-lifting belt, and elastic support). Studies of thoracic supports were excluded.

Methodologic Assessment. All studies were scored according to the methodologic criteria listed in Table 1. These criteria are based on generally accepted principles of intervention research, and similar criteria have been used in previous reviews concerning therapeutic interventions for low back pain.[21–23] Possible scores were yes/no. The criteria are described in more detail in a separate Appendix, which is available from the first author on request. Items concerning internal validity were: (A) randomization, (B) a fixed washout period, (C) outcome assessment, (D) reproducibility reported, (E) blinding of outcome assessment, (F) description of missing data or no missing data, and (G) correct analysis of the data. The other items (H, I, J) covered quality of reporting. Two reviewers assessed the methods of the studies independently, and disagreement was solved in a consensus meeting.

Data Extraction and Meta-Analysis. Data extracted from the original papers were: the number of subjects, the number of missing values, and the mean and standard deviation (SD) or confidence interval (CI) of outcome measures of subjects with and without a lumbar support or the mean and SD or CI of the difference between conditions with and without lumbar support. Because outcome measures within the same category (*e.g.*, trunk motion) differed between studies, effect sizes and in particular the Hedges's *g* were calculated before results of individual studies were statistically combined.[50] The Hedges's *g* is the difference between the means of the outcome measure in the two intervention groups or testing conditions, divided by the average population SD. The effect size thus expresses the magnitude of an effect as the number of SDs. As a rule of thumb, effect sizes less than 0.4 represent a small effect, 0.4–0.8 a medium-sized effect, and more than 0.8 a large effect.[8] Because heterogeneity of the studies was expected, due to variety in outcome measurements, study populations, and lumbar supports tested, the random effects model was used for combining the effect sizes for the meta-analysis.[51] Studies were weighted using the variance in effect size at issue. A statistical test for homogeneity was conducted.[51] If the data were not homogeneous, subsequent analyses with specific subsets of studies were performed to search for study characteristics that could account for the heterogeneity.

For investigating the hypothesis concerning an effect of lumbar supports on trunk motion, the outcome measures considered were vertebral displacement, the maximum range of motion (ROM), and the observed ROM in specified lifting tasks in the sagittal, transverse and lateral planes. Regarding the hypothesis about a reduction of back muscle force, the outcome measure considered most relevant was the electromyogram of erector spinae muscles. Intra-abdominal pressure was also considered as an outcome measure for this hypothesis, because it was assumed that an increase in IAP would lead to a decrease in electromyogram of erector spinae muscles and subsequently to a reduction in back muscle force. However, the correlation between IAP and electromyogram is under debate,[46] and IAP was therefore considered to be a less relevant outcome for this hypothesis than electromyogram of erector spinae muscles. Other, less important outcomes that could indicate a reduction in back muscle force were maximal lifting capacity, intradiscal pressure, and spinal shrinkage. To investigate whether workers may be inclined to lift heavier loads when using a lumbar support, subjective outcome measures were considered, such as the maximum acceptable weight of a lift, perceived exertion, and perceived discomfort due to lifting.

The effects of a specific type of support on different outcome measures within one study are not independent. In addition, because in most studies different types of supports were tested by the same subjects, the effects of different types of supports are not independent either. For this reason, only one outcome measure for one particular support was used per study in each pooled estimate of effect. In the meta-analyses on reduction in trunk motion, the outcomes concerning lumbar motion were thought more relevant than outcomes on thoracic motion. If both outcomes were available, only the lumbar outcomes were included in the meta-analysis. If more than one support was tested in a study, the effect size for a weight-lifting belt was chosen for statistically combining the results of electromyogram and IAP, because this type of lumbar support was most commonly tested in these studies. For combining the results on trunk motion, the effects of lumbosacral corsets were chosen for the same reason. If these belts were not tested and data on more than one support were available, the support most resembling a weight-lifting belt or lumbosacral corset was chosen. A subgroup analysis for elastic lumbar supports was performed, because these supports are commonly used in industry and are importantly different from rigid supports.

The influence of the methodologic items on the reported effect size was assessed by calculating the mean effect size of studies that scored less than four items and studies that scored more than four items positive of the seven methodologic items separately. Differences in the mean effect size between studies that scored less than four and more than four items positive were tested for statistical significance with Student's *t* test. If a statistically significant difference in effect size was observed between these groups of studies, only studies that scored more than four items positive were used in the meta-analysis.

Results

Thirty-three studies were identified that met our selection criteria.[4,5,7,11,13,15–17,19,20,24,26–34,36–39,42,43,45,49,52,53,60–62] There was initial disagreement between the reviewers on 77 (17%) of 462 items scored in the methodologic assessment of the studies. Disagreement was mostly due to reading and interpretation errors and was solved in a single consensus meeting. The studies scored from one to six positive items of the seven items for internal validity. The number of validity items scored positive per study is shown in Tables 2 and 3. A validity score of four or more items positive was found for 8 (24%) of the 33 studies. No statistically significant difference in the mean effect size was found between studies that scored less than four or four or more validity items positive. Therefore, all studies were included in the meta-analyses. The most prevalent shortcomings were (A) that the procedure was not randomized or the randomization was not described, inadequate analysis of the data (G), and the absence of an assessment or description of the reproducibility (D). Many studies used a computerized outcome measurement that could not be influenced by the investigators. Therefore, they scored positive on the item on blinded outcome assessment (E).

Changes in Body Posture or Movements

In Table 2 the 13 studies that reported on trunk motion are listed. In these, investigators measured the maximal range of motion (ROM) of the trunk,[5,28,32,38,42,45,60] the observed range of motion during specified tasks,[13,20,31,34] or the range of angular movement of spinal disks.[11,39,45] In eight of the 13 studies, researchers reported a reduction in trunk motion in at least one of the planes of motion due to wearing a support. Three groups reported inconsistent results,[32,39,45] and two reported that no effect of a support on trunk motion was observed.[20,34]

The study of Marley and Duggasani[34] was excluded from the meta-analysis, because the outcome measure used (displacement angle of the hip) was not considered similar enough with the other studies. Thus, 12 studies were included in the meta-analyses. Figure 1 shows the results for the restriction of flexion–extension, lateral bending, and rotation separately. For two planes of motion (flexion–extension and lateral bending) a statistically significant overall effect was found, with an overall effect size of 0.70 (95% CI: 0.39–1.01) for flexion–extension and 1.13 (95% CI: 0.17–2.08) for lateral bending. The overall effect on rotation was not statistically significant (0.69; 95% CI: −0.40–1.78).

The results of the studies included in the meta-analysis for flexion–extension were statistically homogeneous. In the analyses for lateral bending and rotation, they were heterogeneous. Possible reasons for the heterogeneity were differences in type of lumbar support and outcome measure. To assess the influence of the type of lumbar support on heterogeneity and to determine whether there were important differences in effect between elastic and rigid supports, a subgroup analysis was performed. Heterogeneity was still present within subgroups with only rigid or elastic lumbar supports. The effect sizes for rigid supports were 1.07 (95% CI: −0.09–2.24) for lateral bending and 0.29 (95% CI: −0.35–0.93) for rotation. The effect size for flexion–extension (0.70; 95% CI: 0.39–1.01) was already based on rigid belts only. Elastic supports were studied in four studies.[5,13,15,31] Combined effect sizes of these studies were 1.01 (95% CI: 0.10–1.92) for flexion–extension, 0.84 (95% CI: 0.24–1.43) for lateral bending, and 1.81 (95% CI: −0.22–3.84) for rotation.

Subsequently, the influence of differences in outcome measure was assessed. In the analyses for lateral bending and rotation, heterogeneity was still present within subgroups with the same outcome measure, and the effect sizes were not importantly different between the subgroups (data not shown).

Reduction in Back Muscle Force

Electromyogram or Intra-abdominal Pressure as Outcome Measurement. Twelve studies reported data on electromyogram measurements.[7,13,17,19,26,27,29,33,37,42,43,61] Characteristics of these studies are shown in Table 3. In most of these, investigators measured electromyogram of erector spinae and internal or external oblique muscles. Results of the studies were contradictory: Four groups reported a reduction of electromyogram of back muscles by one of the supports tested,[13,19,27,33] three could not find any consistent result,[29,43,61] and four found no effect on electromyogram.[7,17,26,37] In one study only electromyogram of the abdominal muscles was measured and a decrease in electromyogram was reported in subjects wearing a lumbar support.[42]

In four of the above-mentioned studies, investigators measured the electromyogram of back muscles and IAP simultaneously.[17,26,27,37] Reported results in all four showed an increase in IAP, but electromyogram in the erector spinae muscles consistently decreased in only one.[27] In seven studies, investigators measured IAP but did not simultaneously record an electromyogram of the back muscles (Table 3),[15,16,24,43,42,52,62] Investigators in two of these studies reported an increase in IAP in subjects using lumbar supports,[16,52] in two studies they reported inconsistent results,[15,43] and three they found no effect of a lumbar support on IAP.[24,42,62]

Separate meta-analyses for studies on electromyogram of erector spinae muscles and on IAP were conducted. In the statistical pooling, only studies in which subjects performed a lifting task were included. Two studies with squat exercises were excluded from the meta-analysis, because no regular lifting tasks were studied.[26,27] There were insufficient data reported in three studies for the calculation of an effect size on electromyogram.[13,17,19] Thus, three studies on electromyogram and

Table 2. Description of Studies on Trunk Motion

Authors [Validity score*]	Conditions	Subjects	Test Procedure	Outcome Measures	Result According to Authors
Buchalter et al[5] [3]	I No belt II Raney jacket III Camp corset IV TLSO V Elastic support	Healthy 33 (sex ?)	From upright position, free motion in three planes	Maximum ROM	II–V: reduction in range of motion
Fidler & Plasmans[11] [1]	I No belt II Canvas lumbosacral corset III Raney flexion jacket IV Baycast jacket V Baycast spica	Healthy 5 ♂	Radiographic film in max. flexion and extension	Segmental sagittal movement of lumbar spine (from L1–L2 to <L5–S1)	II–V: restricted sagittal movement Considerable variation among individuals.
Granata et al[13] [3]	I No belt II Elastic support III Leather weightlifting belt IV Fabric belt with rigid posterior support	Healthy 15 ♂	Lifting from knee height to upright position, both symmetrical and asymmetrical with 14 and 23 kg	EMG Trunk and pelvis motions during lifting activities Trunk moments Spinal loading (modeled)	II: reduced EMG of erector spinae and increased EMG in internal oblique muscles; reduced observed peak trunk motion in all planes; increased peak pelvic flexion, reduced spinal load. III: no effect on EMG or spinal load; reduced peak trunk lateral bending and flexion; increased peak pelvic flexion. IV: no effects on EMG or spinal load; peak trunk motion reduced only in lateral bending. Large variation among individuals.
Grew & Deane[15] [2]	I No belt II Semielastic corset with rigid anterior section III Narrow fabric corset IV Long fabric corset with steel posterior strengthening V Leathered covered steel brace VI Polythene jacket	LBP patients 8 (sex ?) Healthy 10 ♂	Movement to limit of comfort: flexion, circumduction, extension, lateral bend Different activities; lying, standing from lying, walking, ascending and descending stairs, sitting, lifting between high and low shelves, lifting with flexed hips and straight legs, lifting with flexed hips and knees, holding weight, lifting from the side	Lumbar spinal motion IAP Skin temperature	II–IV: increased lumbar skin temperature; reduced motion of the lumbar spine; increased IAP by walking and sitting; no effect during other activities
Jonai et al[20] [3]	I No belt II Pelvic belt	Healthy 12 (sex ?)	Analysis of trunk motion during normal working day	Observed ROM in flexion/extension, lateral bending, and rotation Max. angular velocity	Decrease in max. angular velocity in flexion No consistent effect on max. angular velocity in flexion/extension, rotation, or lateral bending or on observed ROM
Lantz & Schultz[28] [2]	I No belt II Lumbosacral corset III TLSO IV Chairback brace	Healthy 5 ♂	Flexion, extension, right and lift twisting, right and left lateral bending, both standing and sitting	Maximum ROM	II–IV: restricted gross body motion
Lavender et al[31] [4]	I No belt II Elastic support	Healthy 8 ♂, 8 ♀	Lifting box from floor to elbow height, symmetrical and 45 and 90 asymmetry. Weight 20% of max. isometric lifting strength. Seven lifts at each asymmetry level with foot movements, and seven lifts without moving foots.	Observed trunk motion during lifting activities	Reduction in trunk motion in lateral plane and transverse plane. No effect in sagittal plane.
Lumsden et al[32] [1]	I No belt II Lumbosacral corset III Chairback brace	Healthy 10 ♂	Rotating trunk standing, straddling . bicycle seat, and walking at three speeds	Axial rotation	II: effect varied unpredictably III: reduced axial rotation while straddling bicycle seat and standing. Increased axial rotation during walking.
Marley & Duggasani[34] [3]	I No belt II Elastic support	Healthy 8 ♂	Lifting box from floor to 76 cm (squat lifting style encouraged). Weights 7 or 14 kg; 3, 6, and 9 lifts/min.	Trunk motion Perceived exertion Cardiovascular parameters	Increase in blood pressure. No effect on other cardiovascular parameters, trunk motion, or perceived exertion.

Table 2. (Continued)

Authors [Validity score*]	Conditions	Subjects	Test Procedure	Outcome Measures	Result According to Authors
McGill et al[38] [3]	I No belt II Leather weightlifting belt	Healthy 22 ♂, 15 ♀	Lateral bending, flexion-extension with pelvis and lower body rigid. Resisting bending forces	Bending angle with increasing torque	Belt wearing stiffens torso in lateral bending and axial rotation, not in flexion/extension.
Miller et al[39] [1]	I No belt II Lumbosacral corset III Jewett brace IV TLSO	LBP patients n = 7 Healthy n = 7	Radiographic film in flexion and extension	Lumbosacral motion (S1–L4)	II: no effect III and IV: reduced motion at L3–L4 and L4–L5 level, but not at L5–S1
Norton & Brown[45] [1]	I No belt II Chairback brace III Lumbosacral corset IV Goldwaith V Williams VI Abbott VII Jewett VII Plaster jacket IX Rigid Taylor X Flex. Taylor XI Reenf. Taylor	Healthy ♂ (N = ?)	Standing, bending, and sitting	L5–S1 interspace Force produced by brace on back Lumbosacral motion	II–XI: inconsistent effects
Wasserman & McNamee[60] [2]	I No belt II Lumbosacral corset	LBP status ? 6 ♂, 2 ♀	Rotating shoulders to a standardized position while seated	Twist angle of vertebral column (L3–T10)	Reduction of rotation

* The number of validity items scored positive. A copy of a more detailed methodologic assessment can be obtained on request from the first author.
TLSO = thoracolumbosacral orthosis; ROM = range of motion; EMG = electromyographic activity; IAP = intra-abdominal pressure; LBP = low back pain.

seven on IAP were included in the meta-analyses (Figure 2). No statistically significant overall effect of lumbar supports on electromyogram (0.09; 95% CI −0.41–0.59) or IAP was observed (0.26; 95% CI: −0.07–0.59). Both analyses were statistically homogeneous.

Other Outcome Measurements Related to Back Muscle Force

In three studies the effect of lumbar supports on muscle strength and endurance was determined.[7,49,53] In two of these studies, researchers found no effect of a lumbar support on muscle strength or endurance,[7,49] and in the other they reported an increase in force production in men wearing a lumbar support.[53] Intradiscal pressure was measured in one study and no consistent effect of any type of support could be demonstrated.[43] In two studies spinal shrinkage was measured, and investigators found no effect of supports on spinal shrinkage.[4,33]

Overall, an outcome that might influence back muscle force was measured in 20 studies (Table 3). Assuming that a increase in IAP without a concomitant decrease in electromyogram of the back muscles does not reduce the back muscle force, investigators in 7 (35%) of the 20 studies reported an effect that could possibly lead to a reduction of the back muscle force.

Subjective Outcome Measures

Results of five studies showed outcomes that could indicate that workers are inclined to lift heavier loads while wearing a lumbar support. The MAWL was assessed in three studies,[30,36,49] and perceived exertion,[34] discomfort,[4] or intensity of the task[7] in an additional three studies. In only one study on MAWL did researchers report an increase for subjects wearing a lumbar support.[36] Bourne and Reilly[4] reported less perceived discomfort for subjects wearing a support.[4] The other groups studying MAWL or other subjective outcome measures reported no effect of a support. The results of the six studies on subjective outcome measures were statistically combined. No statistically significant overall effect of lumbar supports on subjective outcomes was found (effect size: −0.002; 95% CI: −0.41–0.41).

Discussion

Limitations of the Review

A potential limitation of this systematic review, and of most reviews in general, is the completeness of the literature search. It is possible some relevant published studies were missed that had other key words or unclear abstracts. Furthermore, not all studies are indexed in the bibliographical databases used. In fact, most studies were identified by screening the references of already identified studies. It is very possible that studies were missed that were not included in these reference lists. In addition, because the review was limited to published studies, it may be biased toward positive findings, because of publication bias.[9]

There is no evidence-based consensus on which criteria should be used for the methodologic assessment of studies at this moment. Although the criteria used are included in most other available checklists,[41] the criteria are, to some extent, arbitrarily chosen.

In all studies a design was used in which the same subjects were tested with and without lumbar support. In the original studies paired data-analyses were used. In the meta-analysis this was impossible, because the mean difference between conditions was not reported in all

Table 3. Description of Studies on EMG Activity, IAP, or Other Outcome Measures Related to Back Muscle Force

Authors [Validity Score*]	Conditions	Subjects	Test Procedure	Outcome Measures	Result According to Authors
Ciriello & Snook[7] [4]	I No belt II Nylon weightlifting belt	Healthy 13 ♂	Lifting and lowering box from floor to 76.2 cm for 4 hrs with MAWL, 4.3 lifts/min 5 sets of 10 repetitions of isokinetic extensions (baseline and after 4 hrs lifting)	EMG median frequency slope EMG median frequency Perceived intensity of task Maximum isokinetic endurance	No effect on any of the outcome measurements
Granata et al[13] [3]	I No belt II Elastic support III Leather weightlifting belt IV Fabric belt with rigid posterior support	Healthy 15 ♂	Lifting from knee height to upright position, both symmetrical and asymmetrical with 14 and 23 kg	EMG Trunk and pelvis motions during lift Trunk moments Spinal loading (modeled)	II: reduced EMG of erector spinae and increased EMG in internal oblique muscles; reduced observed peak trunk motion in all planes; increased peak pelvic flexion, reduced spinal load. III: no effect on EMG or spinal load; reduced peak trunk lateral bending and flexion; increased peak pelvic flexion. IV: no effects on EMG or spinal load; peak trunk motion reduced only in lateral bending. Large variation among individuals.
Hilgen et al[19] [4]	I No belt II Airbelt III Elastic support	Healthy 5 ♂	Lifting box from floor to knuckle height, 1 lift/min, 10 lifts with 5 random weights of 11.5 kg to 31.5 kg.	EMG erector spinae and external oblique muscles	II: reduced EMG in stooped phase of lift, not in initial phase of lift III: no statistically significant effect
Lantz & Schultz[29] [3]	I No belt II Lumbosacral corset III TLSO IV Chairback brace	Healthy 5 ♂	9 tasks (standing, flexing, and bending while holding 1-kg weight, resisting twist, etc) both standing and sitting	EMG erector spinae and oblique abdominal muscles.	II–IV: no consistent effect
Magnusson et al[33] [4]	I No belt II Elastic lumbar support	Healthy 5 ♂, 7 ♀	Repetitive lifting of 10 kg from floor to 72 cm. Two lifts/min for 5 min. Immediate height change when donning or doffing support EMG erector spinae muscles	Spinal shrinkage No effect on spinal shrinkage Increase in spinal height when donning the support	Reduction of EMG
Waters & Morris[61] [3]	I No belt II Chairback brace III Lumbosacral corset	Healthy 6 ♂, 4 ♀	Standing and treadmill walking with three intensities	EMG erector spinae and abdominal oblique muscles Step frequency	II and III: decrease or no effect on EMG at rest, no effect during walking, increased EMG at high speed walking (II); No effect on step frequency
Hemborg et al[17] [3]	I No belt II Nonelastic flexible support of thermoplastic material (syrlon) III Leather weightlifting belt	LBP patients 20 ♂ Healthy 10 ♂	Lifting from floor to upright position with 0, 10, 25 kg, using back and leg lifting style, syrlon support only (patients) Lifting with 55 kg using leg lifting style, both syrlon and weightlifting belt (healthy subjects)	EMG IAP	II and III: no effect on EMG; Increased IAP
Lander et al[27] [3]	I No belt II Light leather weightlifting belt III Heavy leather weightlifting belt	Healthy 6 ♂	Squat exercise with 70 to 90% of 1RM, 3 trials with each weight	EMG IAP	II and III: Increased IAP; Decreased EMG in erector spinae muscles and external oblique muscles
Lander et al[26] [4]	I No belt II Leather weightlifting belt	Healthy 5 ♂	Eight repetitions of squat exercise with 8RM	EMG IAP	Increased IAP No effect on EMG erector spinae or external oblique muscles
McGill et al[37] [3]	I No belt II Leather weightlifting belt	Healthy 6 ♂	Lifts on lifting machine, while holding breath and with continuously expiring	EMG IAP Dynamic hand forces	Slightly increased IAP No effect on EMG
	II Nepalese patuka (5m long piece of cloth worn around waist)	10 ♂		Lumbosacral compression force	Decrease in lumbosacral compression force in 2 of 10 postures

Table 3. Continued

Authors [Validity Score*]	Conditions	Subjects	Test Procedure	Outcome Measures	Result According to Authors
Morris & Lucas[42] [3]	I No belt II Inflatable corset	Healthy 10 ♂	Pulling against a fixed resistance in upright position and 30, 60, 90° flexed	EMG of abdominal and intracostal muscles IAP Intra-thoracic pressure	Decrease in EMG of abdominal and intracostal muscles Increase in resting IAP, but not in peak IAP Slight increase in intra-thoracic pressure
Nachemson et al[43] [1]	I No belt II Camp canvas corset III Raney flexion jacket IV Boston brace with 0, 15, and 30° lumbar extension	Healthy 1 ♂, 3 ♀	Resisting flexion, extension, twist, and lateral bend and weight-holding tasks while standing relaxed and upright	EMG of erector spinae and abdominal oblique muscles Intradiscal pressure IAP	II–IV: no consistent effect on IAP, EMG, or intradiscal pressure
Harman et al[16] [4]	I No belt II Leather weightlifting belt	Healthy 8 ♂, 1 ♀	Dead lift with bent knees and straight back, 90% of 1RM	IAP	Increased IAP
Kumar & Godfrey[24] [3]	I No belt II Camp sacroiliac corset III Camp lumbosacral corset IV Harris brace V Macnab brace VI Knight brace VII Taylor brace	Healthy 11 ♂, 9 ♀	Sagittal, lateral, and oblique stoop lifting, from ground to knee, ground to hip and ground to shoulder level; same level side to side weight transfer, at ground, knee, hip, and shoulder level. All exercises with 9 kg (♂) or 7 kg (♀)	IAP	II–VII: no effect on IAP
Woodhouse et al[62] [2]	I No belt II Weightlifting belt III Weightlifting belt with rigid pad IV Elastic support	Healthy 9 ♂	Lifting box from squat to standing position, 90% of 1RM	IAP L5–S1 kinetics (peak force/shear force) Lifting strategies and lifting speed	II–IV: no effect on any of the outcome measures
Grew & Deane[15] [2]	I No belt II Semielastic corset with rigid anterior section III Narrow fabric corset IV Long fabric corset with steel posterior strengthening V Leathered covered steel brace VI Polythene jacket	LBP patients 8 (sex ?) Healthy 10 ♂	Movement to limit of comfort: flexion, circumduction, extension, lateral bend Different activities: lying, standing from lying, walking, ascending, and descending stairs, sitting, lifting between high and low shelves, lifting with flexed hips and straight legs, lifting with flexed hips and knees, holding weight, lifting from the side	Trunk motion IAP Skin temperature	II–IV: increased lumbar skin temperature; reduced motion of the lumbar spine; increased IAP by walking and sitting; no effect during other activities.
Shah[52] [1]	I No belt II Nepalese patuka (5m long piece of cloth worn around waist)	Healthy 10 ♂	Standing, flexion, extension, bending, rotating, walking, climbing stairs, lifting 10 kg, doko lift, walking, climbing stairs, and standing with doko	IAP Lumbosacral compression force	Increase in IAP Decrease in lumbosacral compression force in 2 of 10 postures
Bourne & Reilly[4] [3]	I No belt II Leather weightlifting belt	Healthy 8 ♂	Six common weight-training exercises. Three sets of 10 repetitions at 10RM.	Spinal shrinkage Perceived discomfort and pain	No effect on spinal shrinkage Less perceived discomfort with belt
Reyna et al[49] [3]	I No belt II Soft, heat-retaining neoprene belt	Healthy 9 ♂, 13 ♀	Lumbar extension machine Lifting box from knuckle level to shoulder level, from floor to knuckle level, from floor to shoulder level, both one or four repetitions, with increasing weight	Isolated lumbar extensor strength MAWL	No effect on MAWL or isolated lumbar muscle strength
Sullivan & Mayhew[53] [6]	I No belt II Leather weightlifting belt III Elastic support	Healthy 30 ♂, 30 ♀	Static leg lift: simulated lifting activity in partial squat (back straight, knees bent), pulling upward	Isometric muscle force production	II: no effect III: increased produced force for males only

* The number of validity items scored positive. A copy of a more detailed methodologic assessment can be obtained on request from the first author.
TLSO = thoracolumbosacral orthosis; MAWL = maximum acceptable weight of lift; EMG = electromyographic activity; IAP = intra-abdominal pressure; LBP = low back pain; RM = repetition maximum.

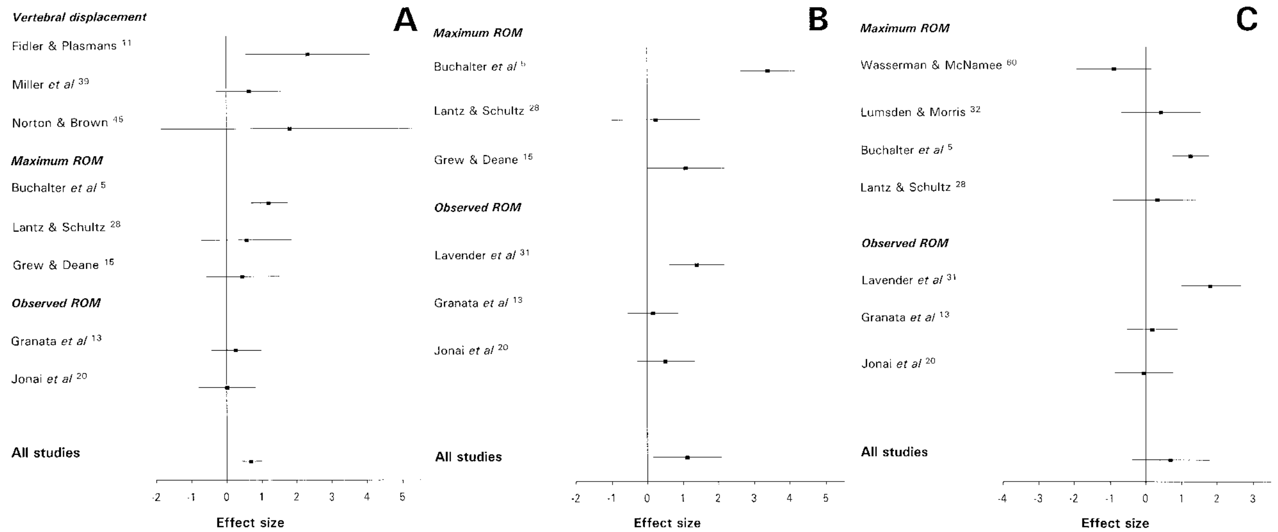

Figure 1. Meta-analysis of the effects of lumbar supports on trunk motion during flexion–extension (**A**), lateral bending (**B**), and rotation (**C**).

studies, but rather the mean and SD for each condition. A paired analysis is more efficient than comparing two means. Therefore, some of the effects that were statistically significant in the original study were not significant in the meta-analysis presented in this article. Furthermore, it is possible that the overall effects would have had smaller CIs if a paired meta-analysis had been feasible.

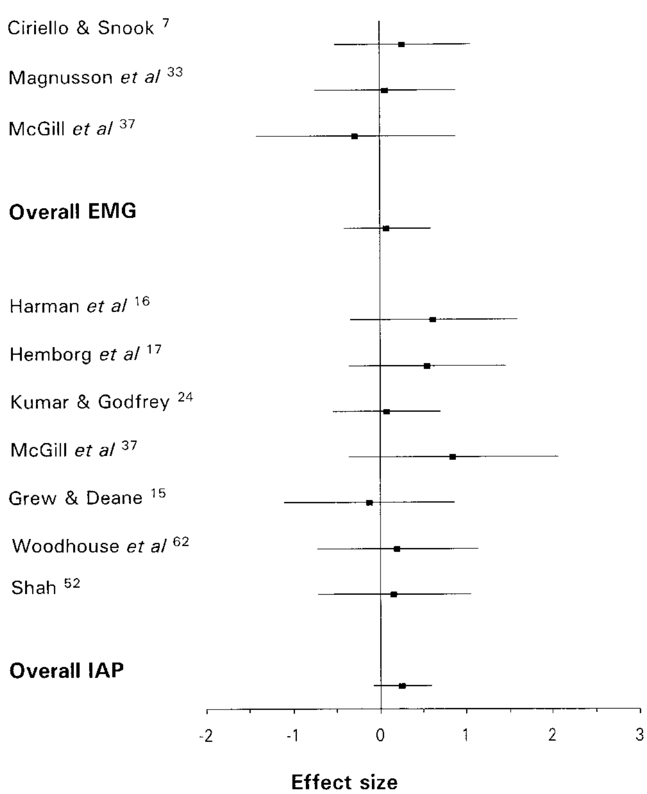

Figure 2. Meta-analysis of the effects of lumbar supports on electromyographic activity of erector spinae muscles and on intra-abdominal pressure (IAP).

In almost any meta-analysis, the decision to statistically combine the results of studies can be questioned. In this meta-analysis, it was decided to combine three different outcome measures on trunk motion. The authors chose to do this, because the objective was to test the hypothesis that lumbar supports affect trunk motion, and all three outcome measures represent an aspect of trunk motion. However, by combining these outcome measures no conclusions can be drawn about which aspect of trunk motion is affected or about the (clinical) relevance of the effect. Those who disagree with this decision may want to disregard the overall estimates of effect and pay attention only to the effects of lumbar supports in subgroups with the same outcome measure.

Methodologic Assessment

The methodologic assessment showed that most studies on mechanisms of action of lumbar supports did not have a valid randomization procedure or description of the randomization and an adequate data analysis. Furthermore, the reproducibility of the outcome measurements was seldom determined and described. Future articles on this subject could easily be improved if more attention is paid to these features. No systematic differences in mean effect size were observed between studies that scored less than four or four or more items positive of the seven internal validity items. This indicates that studies with a lower score were not more likely to report an effect of lumbar supports than studies with a higher score. Therefore, all studies were included in the meta-analyses.

Mechanisms of Action

Change in Body Posture or Movements . A restriction of trunk motion was observed in all three planes of motion, and the overall estimate of effect was statistically significant for lateral bending and flexion–extension. In a subgroup analysis for elastic and rigid supports, it was found that both types of support restrict trunk motion. There was considerable heterogeneity in the meta-analyses on lateral bending and rotation. Likely sources for this heterogeneity are the outcome measure and the type of lumbar support. Subgroups of studies using the same outcome measure were formed. The overall estimates of effect for lateral bending and rotation were not importantly different between the subgroups. Furthermore, differences in outcome measures alone could not explain the heterogeneity in results. Another potential source for heterogeneity is the type of lumbar support. However, heterogeneity was still present within the subgroups with rigid or elastic supports only. It is likely that the heterogeneity in the analyses for lateral bending and rotation was due to a combination of differences in outcome measure and type of support. It should be noted that, because the meta-analyses of all studies and the subgroup analyses on rigid belts included only belts resembling a lumbosacral corset as much as possible, it may be that completely different types of support (*e.g.*, a thoracolumbosacral orthosis or a flexion jacket) have other effects on trunk motion.

Aside from the heterogeneity of the results between studies, it should be noted that a large variation was present in results among subjects within the original studies. In a small number of studies, even an increase in lumbosacral motion was observed in some of the subjects when they were wearing a lumbar support.[32,39,45,60]

The results of the current meta-analysis indicate that lumbar supports decrease trunk motion. In theory, a reduction of trunk motion could be beneficial in the prevention of low back pain, because it may decrease both the net muscle moments and the stresses acting on the internal structures of the spine due to extreme joint angles. Spinal rotation has been reported to be a risk factor for low back pain.[35,47] Furthermore, fatigue failure of posterior spinal structures may occur at large flexion angles in repetitive lifting for long periods, specifically in individuals whose spinal segments are stiffer than average.[10] Therefore, a reduction of spinal rotation and of the flexion angle may lead to a reduced risk of back injuries. In practice, however, it remains to be seen whether a restriction in trunk motion by lumbar supports indeed has a beneficial effect on the risk of back injury, because, so far, contradictory results have been reported on lumbar supports in the prevention of back pain.[1–3,15,25,48,54,56,57–59]

Reduction in Back Muscle Force. Investigators reported inconsistent results on the effects of lumbar supports on outcomes possibly related to the back muscle force. Although the role of IAP in the reduction of spinal compression is inconclusive,[46] it was decided to include IAP in the review. In the meta-analysis, no statistically significant effect of supports on electromyogram of erector spinae muscles or IAP was observed. Other reviews concluded that no conclusive statement could be made on the effects of lumbar supports on electromyogram or IAP, because the available studies failed to show consistent results.[3,40,46] The results of the current meta-analyses, however, are very homogeneous and indicate that lumbar supports may not influence electromyogram or IAP. Therefore, the authors conclude that the hypothesis that lumbar supports decrease the back muscle force by means of a decrease in electromyogram of back muscles or an increase in IAP is not supported by the available evidence.

Subjective Outcome Measures. No overall effect of lumbar supports was observed on the maximum acceptable load and other subjective outcomes. This is reassuring, because critics of lumbar supports are afraid that workers may have a false feeling of security when wearing a lumbar support. They could be tempted to lift heavier loads with a support, although the spinal load is not diminished. This potentially adverse effect of lumbar supports does not seem to take place.

■ Conclusion

The hypothesis that lumbar supports decrease the back muscle force by means of a decrease in electromyogram of back muscles or an increase in IAP is not supported by the results of the meta-analyses presented in this article. Neither is there evidence that workers would be inclined to lift heavier weights when wearing a lumbar support. The only hypothesis that could be confirmed was that lumbar supports affect trunk motion. However, no definite conclusions can be drawn about the clinical relevance of this effect. At this moment, there is no evidence for the effectiveness of lumbar supports in the prevention of back pain in industry, because clinical trials on the effect of lumbar supports on the incidence of back pain report contradictory results.[3,25,56] More research is needed on the effects of lumbar support on the separate outcome measures for trunk motion before definite conclusions can be drawn about work conditions in which lumbar supports may be most effective. Studies of trunk motion at the workplace or during specified lifting tasks would be especially useful in this regard.

■ Key Points

- A systematic review of the literature on mechanisms of action of lumbar supports was conducted.
- No evidence was found that lumbar supports influence back muscle electromyogram or intra-abdominal pressure.
- There was evidence in the literature that lumbar supports restrict trunk motion, especially for flexion–extension and lateral bending.

• Future studies of trunk motion in the workplace or during lifting tasks are needed to examine the conditions under which lumbar supports are most effective.

Appendix

Operationalization of Criteria List

(A copy of the operationalization of the criteria list can be obtained on request from the corresponding author).

(A) Yes, if age, gender, back pain status, and work type or global fitness status of the study population were reported.

(B) Yes, if the order of conditions was determined randomly. Methods for randomization should be adequate (*e.g.*, use of random number Table). No, if method of randomization was not described. Order allocation by means of date of birth for instance is also scored no.

(C) Yes if subject had a fixed rest period between conditions.

(D) Yes, if the type of corset or belt was described sufficiently to replicate the study procedure.

(E) Yes, if the test procedure, the test equipment, and outcome measurement were described sufficiently to replicate the study. The test procedure and equipment should also be appropriate for assessing the main outcome measure.

(F) Yes, if reproducibility of the test procedure is described and if the test is sufficiently reproducible ($\kappa > 0.4$ for categorical data and intraclass correlation coefficient; test–retest reliability, Pearson's coefficient; >0.60 for continuous data).

(G) Yes, if outcome assessment was blinded. Also, yes if blinding is not relevant for the particular outcome measure, because the investigator is unable to influence the outcome measurement (*e.g.*, computerized registration of outcome).

(H) Yes, if no values were missing or if all missing values were described and not more than 20% of the observations were missing values (reason for missing value, in which condition is the value missing and for which outcome measure).

(I) Yes, if a period effect is determined. If there is a period effect, further testing should determine whether there is period–treatment interaction (carryover). If there is period–treatment interaction, only data from the first period should be used in the analysis. Otherwise, a paired analysis should be conducted.

(J) Yes, if for the most important outcome measures the frequency, percentage or mean and SD or CI is reported or if individual patient data are reported.

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