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WORKPLACE USE OF BACK BELTS
Review and Recommendations

NIOSH
Back Belt Working Group
May 1994

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I. Memorandum on Back Belt Use and Recommendations

DATE: May 27, 1994

FROM: Back Belt Working Group

SUBJECT: Conclusions/Recommendations on the Use of Back Belts to Prevent Work-Related Back
            Injuries

TO: Linda Rosenstock, M.D., M.P.H.
            Director, NIOSH
            Through: Richard A. Lemen, Ph.D. ____ ____(D35)

In the Autumn of 1992, the Director of the National Institute for Occupational Safety and
Health (NIOSH) formed a Working Group to review the scientific literature related to
back belts. The Group's objective was to evaluate the adequacy of the data supporting
the use of back belts to reduce work-related back injuries in healthy, previously uninjured
workers. The NIOSH Back Belt Working Group has reviewed the most recent, published
scientific information contained in refereed or peer-reviewed literature. Research
excluded from this review related to the use of back belts prescribed by medical care
providers for the treatment and rehabilitation of injured persons.

Back belts are also known as weight lifting devices, supports, or aids, and abdominal
belts, which are primarily designed for use in the general population. The term "back
belt" is also applied to therapeutic devices such as spinal braces, supports, corsets, and
orthoses.

The term back injury is used throughout the text to refer to all back disorders, injuries,
or pain. These disorders can be precipitated by a single traumatic event such as twisting,
slipping, or lifting, or by the cumulative effect of repetitive trauma.

Overall Conclusions and Recommendations

On the basis of the review of pertinent literature, the Working Group has formulated the
following conclusions and recommendations.

Conclusions

The Working Group concludes that the effectiveness of using back belts to lessen the risk
of back injury among uninjured workers remains unproven.

The Working Group **does not** recommend the use of back belts to prevent injuries among uninjured workers, and **does not** consider back belts to be personal protective equipment.

The Working Group further emphasizes that back belts **do not** mitigate the hazards to workers posed by repeated lifting, pushing, pulling, twisting, or bending.

The Working Group also concludes that:

● There are insufficient data indicating that typical industrial back belts significantly reduce the biomechanical loading of the trunk during manual lifting.

● There is insufficient scientific evidence to conclude that wearing back belts reduces risk of injury to the back based on changes in intra-abdominal pressure (IAP) and trunk muscle electromyography (EMG).

● The use of back belts may produce temporary strain on the cardiovascular system.

● There are insufficient data to demonstrate a relationship between the prevalence of back injury in healthy workers and the discontinuation of back belt use.

Recommendations

The Working Group **recommends** that the most effective means of minimizing the likelihood of back injury is to develop and implement a comprehensive ergonomics program. The program should include ergonomic assessments of jobs and workstations to ensure that work activity can be accomplished without exceeding the physical capabilities and capacities of the workers (Waters et al., 1993); on-going, comprehensive training for all workers on lifting mechanics and techniques; a surveillance program to identify potential work-related musculoskeletal problems; and a medical management program.

The Working Group also recommends:

● Caution in interpreting the results of studies that evaluated the effects of belt use on predictions of biomechanical loading of the spine.

● Caution in interpreting the results of epidemiological studies; the experience with these studies should be used to develop better designed epidemiological research.

- Future research should be designed to evaluate the efficacy of wearing back belts to prevent work-related back injury.

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II. *Review of the Literature*

A. Physical Studies

The following is a review of published scientific literature describing laboratory-based research on biomechanical, physiological, and psychophysical aspects, variables, or parameters pertaining to back-belt use. Because many of the studies evaluated more than one parameter, they are grouped into a single section under the title "Physical Studies."

These studies, as a group, are limited by a number of factors that restrict direct application of the data to the U.S. working population. For the most part, the study limitations include: the investigation of small sample sizes; the inclusion of primarily young, male subjects; the use of short experimental periods; and the evaluation of different types of belts or orthoses and lifting postures, frequencies, and weight criterion that limited the comparability of results to other studies.

Nachemson et al. [1983] assessed the effectiveness of lumbar orthoses in reducing spinal loading while subjects performed isometric loading tasks. The study group consisted of four healthy volunteers (three males and one female) who were 19 to 23 years of age and who reported no previous back pain or injury. Three types of lumbar spine orthoses (Camp canvas corset, Raney flexion jacket, and the Boston brace) were compared to the no-belt (control) condition for six specified isometric loading tasks. The orthoses were not tested on all four subjects. Dependent measures included intradiscal pressure (IDP), intra-abdominal pressure (IAP), and electromyographical (EMG) activity of the erector spinae and oblique abdominal trunk muscles. Compression loads on the spine were also estimated using a biomechanical model. The IDP values with an orthoses were lower in about two-thirds of the tasks and higher in the remaining one-third. The IAP and EMG values showed no consistent trends from wearing orthoses. The amount of compression relief provided by each of the orthoses was estimated by predicting the difference in compression force between the orthosis and control condition. This was accomplished by estimating the loads that would have been imposed on the lumbar trunk in each task, assuming no orthosis was worn, and then predicting the compression force from the IDP and EMG values for when an orthosis was worn. These predictions then underwent linear regression analysis to compare measured IDP to predicted compression force. On the basis of the regression analyses, the authors concluded that all three orthoses reduced spinal compression.

Because this study was designed to assess only therapeutic type lumbar orthoses, these results cannot be used to determine if industrial-type back belts significantly reduce spinal compression. Interpretation of these data are further complicated by the author's assumption that the biomechanical model provides a valid prediction of spine compression forces from the IDP and EMG values when a belt is worn, which is probably not a valid assumption. The study also suffers from a small sample size and incomplete testing.

McGill et al. [1994] conducted a biomechanical investigation of the passive bending properties of the intact human torso about its three principal axes of flexion/extension, lateral bending, and axial rotation. Twenty-two males and fifteen females were subjected to bending and twisting moments in two "floating" frictionless jigs. A jig configuration was used to measure flexion/extension, lateral, and axial bending angle and stiffness. Torque was applied by a cable tangent to the jig until either no greater level of torque was available or until the subjects indicated they were at their tolerable limit. A 3-Space Isotrak system (Polhemus Navigation Systems, Colchester, VT) was used to measure lumbar spine kinematics. Subjects performed three trials each of the following six directions of moment: flexion, extension, clockwise (CW) rotation, counterclockwise (CCW) rotation, right lateral bend, and left lateral bend. The trials were conducted under three conditions: normal, wearing an abdominal leather athletic lifting belt (approximately 11-cm wide posteriorly and 6.5-cm wide anteriorly), and holding the breath upon maximal voluntary inhalation.

Using a repeated measures analysis of variance (ANOVA) the authors found that in the flexion condition, belt wearing or holding the breath did not affect the torque-angle relationship; whereas in the extension condition, the torso stiffened in males who held their breath. During lateral bending, belt wearing significantly increased the stiffness in both males and females over the full range of torque application. Twisting, belt wearing, and breath holding significantly increased the stiffness of the torso in males. Stiffness in males was significantly different from that in females over the course of the evaluated torques: CCW—held breath, CW—normal, flexion—wearing belt and holding breath, extension—wearing belt and holding breath, bending left and right—wearing belt. Linear regression analysis confirmed the male/female differences in: CW—normal, flexion—wearing belt, bending left—wearing belt, and normal. Males wearing a belt were able to tolerate slightly larger torques in all conditions, while holding the breath appeared to have no consistent effect. No consistent trends for females were observed.

The authors acknowledged that both belt wearing and breath holding appeared to stiffen the torso in the coronal and transverse planes and not in the sagittal plane. They also acknowledged that most lifting tasks involve extensor moment and, to a lesser degree, lateral bending and rotation, and that stiffness is one of many other biomechanical, physiological, and psychological factors that should be considered in the decision to use back belts. Some limitations of the study were: the subjects were young and not representative of a cross-section of ages; there was no compressive preload on the lumbar spine as during a lifting task; the waist sizes of some of the female subjects did not allow sufficient tightening of the belt, thereby possibly compromising the stiffness augmentation of the belt; the study examined only one type of belt; subjects held their breath with different volumes of air in their lungs; and the testing postures and conditions were not randomized. The authors suggested that the findings from the study imply that moment contributions from nonligamentous passive tissues may be negligible in anatomically simple biomechanical models for prediction of tissue loading to estimate the risk of injury. However, they also suggest future investigations are necessary to explore the effects of compressive preloads on *in vivo* stiffness and the role of stiffness in structural stability and mechanisms of injury. The identified study limitations are enough of an indication that the resulting information is insufficient for any generalization without considering other occupational factors and corresponding epidemiological observational data.

Lander et al. [1990] studied the effect of the squat-lifting exercise using three belt conditions (light-weight leather, heavy leather, no belt) and three weight conditions (70%, 80% and 90% of a one repetition maximum) on six skilled male volunteers. Experimental data obtained were: force platform strain gauge output; IAP measured with an intra-rectal transducer; EMG values from the rectus abdominous, external oblique and erector spinae muscles; and kinematic (postural) data from a high-speed camera. The kinematic data were absolute limb relative joint, and pelvic rotation angles. Forces acting on the spine were estimated from the force platform data, IAP data, kinematic postural data, model-based assumptions about the abdominal cross-sectional area, anthropometric data, and the back muscle force arm length. The lifts were divided into four phases, and the EMG, IAP and estimated force values were presented by phase. The subjects performed 27 trials: 3 trials for each belt condition and each load condition. The model-based spinal forces as well as EMG data were adjusted for differences in L5/S1 joint moments between the belt and no-belt condition using an analysis of covariance (ANCOVA). In an unadjusted analysis, shear and compressive forces as well as EMG values were lower in the no-belt than in the belt condition. This relationship was reversed after adjusting for L5/S1 moments. The author argued that spinal force data and moment-adjusted EMG were more meaningful than

unadjusted data. Thus, the conclusions were based on his observation of lower adjusted EMG and adjusted force values for belt wearing compared to no belt wearing. The author concluded, on the basis of these data, that weight-lifting belts protect the spine during lifting. It should be noted that these ANCOVA adjustments of the data are highly controversial and may account for the differences between these results and those of others who have studied the IAP-EMG relationship during lifting activities. The conclusions that weight-lifting belts protect the spine during lifting are based exclusively on the model-based, moment-adjusted spinal force and EMG data. A more conservative conclusion from these data would ignore the covariance adjustments (the authors do not use them in the 1992 publication) and state that wearing a weight-lifting belt increases IAP over the same lift without a belt.

In a later study, Lander et al. [1992] studied the effects on five male volunteers of eight consecutive trials of the squat-lifting exercise on kinematic (postural) data, force platform output, IAP measured with an intrarectal transducer, and EMG voltages from four muscle groups: external oblique, erector spinae, vastus lateralis, and biceps femoris. Two belt conditions were compared: a leather weight-lifting belt and no belt. The weights corresponded to approximately 75% to 80% of the lifter's one repetition maximum effort. Mean EMG voltages for the erector spinae and external oblique muscles were no lower for the belt conditions than the no-belt condition. The values for the belt (relative to the no-belt condition), expressed as a percentage of standardized EMG values, ranged from +1% to +7%, with a mean of about +2%. IAP values increased 25% to 40% (from a mean of 12.9 kPa to a mean of 16.7 kPa on the fourth pair of repetitions) in the belt-wearing condition over the no-belt condition. No significant differences between the belt-wearing and no-belt groups were observed for the kinematic (postural) or force platform data. As in the previous study, the authors concluded that wearing a weight-lifting belt provides a degree of protection during submaximal lifting, a claim based solely on increased IAP data from this study, and a reference to the results of his previous study. It should be noted that the claim of spinal protection is based on a hypothesized relationship between IAP and EMG, which the author's current data do not support. The weights lifted were all above 50 kg, which also puts this study's lifting data above the maximum recommended weights for optimal conditions in both the 1981 NIOSH lifting guide [NIOSH, 1981] and the revised 1991 lifting equation [Waters et al., 1993]. The Working Group concluded that the data from the two studies by Lander et al. [1990, 1992] cannot be used to support the suggestion that back belts protect workers from injury.

Hilgen et al. [1990] examined the relative effectiveness of an inflatable-bladder-type (air belt) and an elastic-type back belt in reducing estimated spinal forces during lifting. The objectives of the experiment were to measure various physiological and biomechanical parameters from subjects performing manual lifting tasks, and then use these data to estimate the magnitude of spinal loading during a manual lifting task. Five healthy adult males who were experienced in manual lifting performed a sequence of lifting tasks with and without the back belt. The tasks consisted of lifting a weighted box from the floor to a shelf at knuckle height at a rate of one lift per minute. The weight of the box ranged from 11.5 to 31.5 kg in 5 kg increments.

The physiological and biomechanical measures included three-dimensional kinematic data (position, velocity, and acceleration), force platform data (vertical and shear forces at the feet), and EMG data from surface electrodes placed over the right erector spinae and right external oblique abdominal muscles. Joint moments, spinal forces, and impulses were then computed from the measured data using a quasi-static, four-link, biomechanical model developed by one of the authors. Although the data were poorly presented and the statistical results were inconsistently evaluated (in some cases significance was cited when $P < .25$), the authors reported that: (1) there was very little variability between predicted IAP produced among the three belt-use conditions; (2) the no-belt condition yielded the lowest average predicted muscle, compression, and shear forces during the lift; and, (3) the no-belt condition gave the lowest average muscle and compression forces and impulses and the lowest average shear force and impulse in the final phase of the lift. In spite of the reported results, the authors concluded that abdominal belts were of some benefit to the subjects during lifting. The Working Group concluded that the study presented little evidence that back belts provided any significant reduction in spinal loading.

Grew and Dean [1982] evaluated the effect of five different spinal supports on skin temperature, spinal movement, and IAP among 10 healthy male subjects and 8 male subjects with a history of previous chronic low back pain. The IAP was measured by means of a pressure transducer inserted rectally to a distance of 15 cm to ensure that the tip was within the abdominal cavity. The supports included: (1) a narrow, semi-elasticized corset, (2) a narrow fabric corset, (3) a long fabric corset, (4) a leather-covered steel brace, and (5) a polythene jacket. Measurements were taken while the subjects carried 15 kg during a variety of standardized manual material-handling tasks and postures. Lumbar spine movements were standardized by using a pelvic-constraint frame to restrict hip movement. All of the tested supports warmed the lumbar skin and reduced the range of movement of the lumbar spine. The rigid supports restricted movement considerably; the fabric

supports were less restrictive. All spinal supports raised the resting level of IAP in all postures by an average of about 15%. Individually these increases were only significant in four instances: when walking, with the elasticized support; and when sitting, with the polythene jacket, long fabric corset, and rigid brace. There were no significant intersupport differences. Collectively, the supports had a significant effect in raising IAP in the walking and seated postures. During exercise, the spinal supports had no significant effect on peak pressure levels. Both individually and as a whole, wearing spinal supports tended to reduce the peak IAP during lifting tasks and increase the mean IAP for various postures. Therefore, no clear pattern emerged from the IAP results. This study does not provide any insight into the mechanism by which spinal supports reduce the load on the spine or protect the low back from injury. The Working Group concluded this study that wearing back belts restricts the wearer's range of motion and increases lumbar skin temperature; however, the study does not document a clear pattern for changes in IAP while wearing back belts.

Kumar and Godfrey [1986] examined the comparative effects of six commonly prescribed spinal supports on the IAP of subjects performing a variety of lifting tasks. The supports included: (1) Camp sacroiliac brace, (2) Camp lumbosacral corset, (3) Harris brace, (4) Macnab brace (males only), (5) Knight brace, and (6) Taylor brace. Twenty normal subjects (11 males, 9 females) with no history of back disorders lifted moderate weights (9 kg for the males, 7 kg for the females) while performing sagittal, lateral, and oblique lifting tasks adjusted to the height of the individual. The magnitudes of the peak and sustained IAP were significantly different within every activity while the subjects were belted but were not consistently higher or lower than when the subjects were in the unbelted condition. Analysis of variance revealed no significant differences among any of the spinal supports for either the male or female population. The authors recommended that the choice of spinal support should be based on a criterion other than abdominal support. The study did not state that intra-abdominal pressures were significantly higher when spinal supports were worn than when they were not worn. The Working Group concluded that this study's results are inconclusive concerning the effects of wearing back belts on IAP.

Harman et al. [1989] measured IAP in one female and eight male subjects performing a "dead lift" exercise at 90% of their one repetition maximum lifting capacity once with a belt and once without a belt. The belt was a standard leather weight lifting belt which was 0.6-cm thick and 108-cm long. The belt width was 15 cm at the center and 6.2 cm at the end. A force platform was used to measure ground reaction force (GRF) while a catheter pressure transducer inserted nasally was used to obtain IAP. The following event curve patterns were determined

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relative to lift-off for the IAP and GRF curves: (1) start of rise above baseline, (2) peak rate of increase during the initial surge, (3) end of initial surge, (4) peak, (5) peak rate of increase after the end of initial surge, and (6) lift completion. The term "initial surge" was used to describe the sharp increases in IAP and GRF that began as the lifter started to exert force on the bar and shortly after the weight left the ground.

The following results were reported as significantly greater with the belt ($P < 0.05$): (1) peak IAP (23/4 kPa with belt versus 20.8 kPa without belt), (2) area under the IAP versus time curve from start of initial IAP surge to lift-off (3.84 kPa·s with belt versus 2.27 kPa·s without belt), (3) peak rate of IAP after the end of its initial surge (220 kPa·s^{-1} with belt versus 188 kPa·s^{-1} without belt), and (4) average IAP from lift-off to lift completion (15.77 kPa with belt versus 13.92 kPa without belt).

The authors suggested that the observed increase in IAP during the dead lift with the belt may reduce compressive force on spinal discs and improve lifting safety. They theorized that the belt may function by forcing the abdominal muscles inward as they contract, thereby augmenting IAP. The authors also caution that continual lifting with a belt may compromise abdominal strength development and neuromuscular control patterns of IAP-generating muscles. The Working Group concluded that: (1) the authors' suggestion that increased IAP probably reduces discal pressure is based on hypothesis rather than data from this or any other study, and (2) that the applicability of this study to the occupational setting is limited because the study investigated belt use and IAP during one exercise motion rather than the more varied and dynamic lifting that can occur in the occupational setting.

Lantz and Schultz [1986a] investigated the effects of three types of commonly prescribed lumbar braces and corsets—a lumbosacral corset (LSC), a chairback brace (CBB), and a molded thoracolumbosacral orthosis (TLSO)—on maximal trunk movements. The study population consisted of five healthy adult males, ages 21 to 36 years, with no history of significant back pain. The testing consisted of each subject performing a sequence of 35 maximal trunk movements consisting of 4 main movements (flexion, extension, lateral bending, and twisting) in a standing and sitting posture. The no-orthosis condition was always examined first followed by the three orthoses in random order. Markers were strategically placed on the

subject prior to testing to identify and record gross body motions. Body motions were evaluated in three orthogonal planes during testing by three cameras mounted at right angles to the subject. The degree of effectiveness of an orthosis in restricting trunk motion was determined for each task by computing the percent restriction provided, by the equation:

$$\text{Percent restriction} = \frac{\text{(no orthosis value)} - \text{(orthosis value)}}{\text{(no-orthosis value)}} \times 100$$

All three orthoses restricted some trunk motions (some motions were restricted to two-thirds to one-half of the no-orthosis values), but not all (some motions were restricted less than 10%). Based on the results of the study, the authors concluded that all three orthoses would likely reduce loads placed on the lumbar spine. The Working Group concluded that because the study was designed only to assess therapeutic-type lumbar orthoses, these results cannot be used to determine if industrial-type back belts significantly reduce gross body motion or spinal compression.

In a similar study, Lantz and Schultz [1986b] investigated the effects of three types of commonly prescribed lumbar braces and corsets — a lumbosacral corset (LSC), a chairback brace (CBB), and a molded thoracolumbosacral orthosis (TLSO) — on trunk muscle EMG activity. The study population consisted of five healthy adult male college students with no history of significant back pain. The testing consisted of each subject performing 19 standardized isometric tasks, all of which involved a moderate degree of exertion. The no-orthosis condition was always examined first followed by the three orthoses in random order. Dependent measures included mean EMG signals from the erector spinae and the external oblique abdominal muscles. The effect of each orthosis was evaluated by calculating the percent changes in mean EMG signal levels relative to the no-orthosis condition. The means ranged from a 9% reduction to a 44% increase when the LSC was worn, from a 27% reduction to a 25% increase for the CBB, and from a 38% reduction to a 19% increase for the TLSO. None of the orthoses were consistently effective in reducing measured myoelectric activity, and in many cases signal levels increased when orthoses were worn. The Working Group concluded that because this study was designed to assess only therapeutic-type lumbar orthoses, these results cannot be used to determine if industrial type back belts significantly reduce EMG activity. Nevertheless, it does indicate a wide variability in the effects of back braces on EMG activity in general. This study suffers from a limited study population (four subjects included in the analysis), a lack of statistical tests comparing the differences in muscle activity, and the exclusion of one subject to prevent skewing the data.

Waters and Morris [1970] conducted a laboratory study of the effects of two commonly prescribed back supports — a lumbosacral corset (LSC) and a chairback brace (CBB) — on electrical activity of the trunk muscles during standing and walking. Ten young adults (six males and four females) participated in the study. The study compared trunk-muscle activity in a no-support condition with wearing a belt while standing at rest, walking on a level treadmill at both 4.39 kilometers per hour and at 5.29 kilometers per hour, and walking on a treadmill at a 5-degree incline at 4.39 kilometers per hour. Dependent measures included intramuscular measures of EMG activity from the following eight trunk muscles: Iliocostalis dorsi, longissimus dorsi, iliocostalis lumborum, multifidus, rotatores, rectus abdominous, internal obliques, and external obliques. Differences in activity between orthosis and no-orthosis were calculated, and changes in activity were reported as increases, decreases, or the same. In the majority of subjects at rest, both supports either decreased or had no effect on electrical activity of the back muscles. When the subjects walked at a "comfortable" speed, neither support had a significant effect on trunk muscle activity. In the majority of subjects walking at a fast pace and wearing the CBB, the activity of the back muscles was increased compared with the activity of those muscles when no support was worn. The increased electrical activity may reflect the increased muscular contraction required to overcome the immobilizing effect of the support. Because the study was designed to assess only therapeutic-type lumbar supports, these results cannot be used to determine if industrial-type back belts significantly reduce EMG activity. The authors do raise the issue that some additional muscle activity is required to overcome the resistance of the back supports during simple walking activities. This also may be an issue of concern with industrial-type back belts, which may be worn throughout the day.

McGill et al. [1990] conducted a six-subject laboratory study of the effects of a weight-lifting belt compared with a no-belt condition, and a breath-holding versus breath-exhaling condition (with and without belt) on several physical parameters. IAP was measured by pressure catheter in the stomach, and EMG values were recorded from five muscle groups: rectus abdominous, external oblique, internal oblique, intercostal, and erector spinae. Also, model-based estimates of lumbar joint load were calculated from the EMG-IAP data, muscle cross-sectional areas, and muscle moment arms. In view of the controversy over the role of IAP in providing protection to the spine during load handling, the authors hypothesized that if IAP truly unloaded the spine, then the consequences of wearing a lifting belt should be reflected in lower-back extensor-muscle activity compared with the same lift without a belt. The authors found mean peak IAP was significantly higher (120 mm Hg versus 99 mm Hg, a 21% increase) in the belt condition than in the no-belt condition. EMG levels (expressed as percent change over the no-belt

condition) increased slightly during belt wearing trials on the rectus abdominous, external oblique, and intercostal muscles, and erector spinae. They were slightly decreased in the internal oblique. However, because the level of contraction of the abdominal muscles was so slight (never more than 15% of that produced by a maximum voluntary contraction, with or without a belt) there is limited evidence to disprove the theory that belt wearing will cause the abdominal muscles to detrain. Based on increases in IAP and lack of concomitant reduction in spinal muscle EMG, the authors concluded that belts do not contribute to the support of the loaded spine, making it difficult to justify prescribing belts to workers. Erector spinae activity was reduced during the breath-holding trials, but there was no additional impact of belt wearing beyond breath holding, so recommendations on the issues of breath holding and belt wearing can be handled separately. The data from this study are based on a leather weight-lifting belt, not a standard industrial belt, and deal with lifts of greater weight than most manual-materials-handling tasks (i.e., greater than 50 kg). Nevertheless, the Working Group concluded that this study was useful in establishing the effect of belt wearing on EMG and IAP at the upper end of the weight spectrum.

It has been hypothesized that lifting belts protect workers by increasing lifting capacity. Using an isokinetic lifting simulation task, Woodhouse et al. [1990] compared the effects of two types of lumbar/sacral supports (lifting belts) on isokinetic lifting capacity, with a control condition (no belt). The two belts tested included a modified leather weight-lifting belt, which incorporated a rigid abdominal pad, and an industrial-type, elastic, lifting belt. Ten male athletes, free from low back problems, were required to perform three maximal isokinetic squat-lifting trials at three fixed lifting velocities (61, 76, and 91 cm/sec) for each of the three belt conditions (two belts and control). Dependent measures included peak lifting force, total muscular work, and average muscular power. No statistically significant differences were found in peak lifting force, total muscular work, or average muscular power for the two belt conditions when compared with the control. There was a trend, however, toward a slight increase in peak lifting force and average muscular power while wearing a belt when compared with the control. Nevertheless, the authors concluded that there was no statistically significant evidence that lifting belts improve functional lifting capacity. Although the study was limited to a small population (10) with unique characteristics, test conditions were restricted (only one lifting style and two belt types were tested), and dependent measures were limited to isokinetic parameters, the Working Group agrees with the authors' conclusion that belts do not significantly improve lifting capacity.

Bourne and Reilly [1991] examined the effect of a standard leather weight-lifting belt on spinal shrinkage during circuit weight-training. Eight males performed six circuit weight-training exercises consisting of the dead-lift, high pull, squat, clean, bent-over rowing, and biceps curls. Four of the subjects wore a belt while training and four did not. A stadiometer was used to measure stature 3 minutes after completing the circuit. An absolute visual analogue scale (AVAS) was used to measure self-reported discomfort and pain intensity before and after completion of the circuit. The average stature loss of 2.87 mm with the belt and 3.59 mm without the belt was not statistically significant ($P > 0.05$). The group exercising with a belt reported significantly less discomfort while weight lifting than the group not using a belt ($P < 0.05$). The correlation between the amount of shrinkage and perceived discomfort was significant with the non-belt group ($P < 0.05$).

The authors concluded that wearing a belt while lifting tends to reduce absolute spinal shrinkage and is associated with significantly less discomfort than lifting without a belt. They also felt this study supported the hypothesis that the belt can help in stabilizing the trunk. The authors suggested that further investigation is necessary to better understand the relationship between IDP and spinal load attenuation.

Although six lifting motions are investigated in this study, the Working Group concluded that they may not be representative of the range of activities in the occupational setting. The weight handled ranged from 27 to 61 kg, which is beyond the NIOSH guideline and will limit any generalizations for the industrial population. The authors' suggestion that belts can help stabilize the trunk is speculative and lacks sufficient supportive biomechanical and physiological data. This study indicates there is some spinal shrinkage, pain and discomfort associated with weight lifting. A leather weight-lifting belt may avert symptoms of such physical phenomenon. However, the perception of discomfort may be related to a "Hawthorne effect," because the subjects were experienced weight lifters who may have already known about the hypothetical discomfort-reducing benefits from wearing a belt.

McCoy et al. [1988] evaluated the effects of an inflatable back belt and an elastic-type back belt on the psychophysical lifting capabilities of individuals (i.e., perceived maximum acceptable workload). The study population consisted of 12 adult male college students, ages 19 to 28, who were free of back problems or other limiting physical conditions. Dependent measures consisted of maximum acceptable weight of lift, external pressure on the abdomen from use of the belt during lifting, and responses to subjective survey questions of feelings. Maximum

workload, which was defined as the product of the maximum acceptable weight of lift, the height of the lift, and the number of lifts per minute, was also calculated. The lifting task consisted of lifting a wood tote box, filled with small plastic bags of steel shot, from the floor to a shelf at knuckle height, at a rate of three lifts per minute for a 45-minute period. Typical psychophysical techniques were used to ensure controlled test conditions (e.g., variable bag weight, false bottom, tests run on different days, variable starting weight) Prior to testing, a bladder was inserted between the belt and the abdomen to measure changes in the abdominal pressure during the lifting sessions. Finally, a subjective survey of eight questions about feelings was administered after each test. The authors reported a significant increase in maximum acceptable workload when subjects were wearing a belt compared with when they were not (P=0.0169), but no significant difference was noted between the two types of belts. No differences in external pressure were found between the two belt types, but comparing this with the control group was not possible. Subjects reported that both belts were a little hot and mildly discomforting with respect to reduction in blood circulation. When given the option of the three conditions, 58 percent of the subjects preferred using the elastic belt, 33 percent preferred not to use a belt at all, and only 9 percent preferred the air belt. The authors concluded that the back belts tested in this study increased the workers' perceived maximum acceptable weight of lift with respect to the no-belt condition. The Working Group agreed with the authors conclusions but emphasized that there is insufficient data to predict reliably how a workers' risk of low back injury would be affected by this change in perception.

Hunter et al. [1989] performed a study to determine the effect of a weight-lifting belt on heart rate and blood pressure during aerobic bicycle ergometer exercise, one-arm bench press, and isometric dead lift exercise. Five healthy males and one healthy female subject performed these activities wearing and not wearing a "standard" 10 cm weight-lifting belt. All performed the three activities in the laboratory, as follows: (a) 6 minutes of aerobic bicycle exercise ergometry @ 60% of calculated peak VO_2 maximum, (b) 3 sets of 10 repetitions of 1-arm dumbbell bench presses @ 60% of 1-repetition maximum capability, and (c) an isometric dead lift @ 40% maximum dead lift capability for 2 minutes. All activities were performed in random sequence with and without the weight belt. Systolic blood pressure was measured in the nondominant, uninvolved arm during each activity and heart rates were measured by cardiac monitor. A measure of pressure exerted on the abdomen by the weight belt was obtained by inserting an inflated bladder between the belt and the abdomen linked to a sphygmomanometer gauge.

Mean systolic blood pressure increased significantly with weight belt use for the aerobic bicycle exercise and the isometric exercise. Heart rate also increased significantly with weight belt use for aerobic exercise. Pressure exerted on the abdomen by the weight belt increased with all forms of exercise.

The Working Group concluded that these data suggest the use of a weight belt can put a strain on the cardiovascular system and that individuals with a compromised cardiovascular system may be at greater risk when exercising or working with back supports. However, the results of this study of a single tightly fitting "standard" weight belt may not be generalizable to the wide array of belts being used.

B. Epidemiological Studies

In a retrospective study of 1,316 workers who routinely perform manual lifting activities, Mitchell et al. [1994] investigated the effectiveness of back belts in reducing back injuries and the associated costs. The study consisted of a self-administered questionnaire to determine exposure information on lift frequency, weight of lifts and proportion of the work day spent lifting, belt use, history of back problems, and treatment for the period from 1985-1991. For the period from 1985-1986, leather belts were used, and after 1986, a standard Velcro back support with suspenders was used. Univariate analyses of factors related to initial injury revealed that previous lifting training ($P < 0.01$), previous back problems ($P < 0.001$), and amount of weight lifted per day ($P < 0.001$) were significantly correlated with initial injury, but belt use at time of injury was not ($P = 0.438$). Subsequent logistic regression analyses revealed that a history of previous back problems (Odds Ratio [OR]=5.56, 95% Confidence Interval [CI]=3.35, 9.26) and the amount of weight lifted per day (OR=1.01, CI=1.01, 1.02) were positively related to first occurrences of back injury, and that previous training (OR=0.65, CI=.45,.93) and back belt use (OR=.60, CI=.36, 1.00) were negatively related to first back injury. It should be pointed out that the protective effects of back belts are only weakly supported. This study was limited in that back belt usage was not controlled during the course of the study and recall bias may have been introduced because the self-reported exposure and injury data covered the 6 years prior to the study and were not validated by objective data. Although the data indicate that back belts appear to be minimally effective in preventing low back injuries, the Working Group concluded that this study did not provide conclusive evidence that back belts significantly reduce risk of injury. The results do suggest, however, that certain work-related factors, namely a history of previous back problems and the daily amount of weight lifted, significantly increase the risk of back injuries.

The purpose of the prospective study by Reddell et al. [1992] was to evaluate the efficacy of a commercially available, fabric, weight-lifting belt to lower the lumbar injury incident rate and severity of injuries over an 8-month period. At the beginning of the study, 896 airline baggage handlers who performed manual-materials-handling tasks were selected and randomly placed into one of four test groups: belt only, belt and training, training only, and control group. At the end of the study, only 642 of the 896 workers were located and interviewed about back injuries and comfort of the belt. Of the 272 participants in the belt groups, 6.3% never used the belt and 52% used it less than 50% of the time (noncompliant group). A total of 28 (4.4%) job-related injuries were self-reported but were not validated: 3 (1.2%) in controls, 1 (0.8%) in training only, 3 (5.2%) in belt only and 3 (5.2%) in belt and training. The remaining 17 (10.7%) injuries occurred among the noncompliant group. Although the data are not shown, the authors report no differences among the groups for incidence rates of total injuries, restricted workday case injuries, and for severity. Yet, severity of injury based on lost workday case incidence rates indicated a significant difference among the groups. The authors concluded that "neither the belt nor the training group had a significant effect on injury reduction" and that discontinuing belt use may increase the risk of back injury, although no data are reported to support this statement.

The Working Group concluded that these results must be tempered by the severe limitations of the data, including low participation (72%) and compliance rates (42%), potential recall biases related to self-reported injury rates, and the inclusion of previously injured workers in the study. The low, overall incidence rate of self-reported back injuries suggest that the study period was too short and the realized sample size was too small. Because of these limitations, this study could not evaluate the effectiveness of back belts on incident back injuries.

In a 2-month prospective study of construction workers Holmstrom and Mortiz [1992] investigated the effects of two types of belts on maximal isometric trunk muscle strength and endurance. Twelve healthy male construction workers with negligible or no low back symptoms wore soft Neoprene heat-retaining belts (Group SB). Twenty-four male construction workers who had current low back pain or experienced low back pain of more than 8 days duration during the preceding year wore leather weight-lifting belts (Group WB). These previously injured workers were not considered in the Working Group's review.

The subjects wore the assigned belts during their working days, recorded daily use, and rated the intensity of pain at its occurrence. The following strength and endurance tests were measured at the start of the study and after 1 and 2 months: maximum voluntary isometric contraction of the trunk flexors and extensors, and

maximum voluntary isometric endurance of trunk extensors. The differences in the mean of trunk extensor strength (start—1.264 N, 1 month—1.258 N, 2 months—1.311 N) and endurance measurements (start—182.6 s, 1 month— 179.3 s, 2 months—198.3 s) from before using the belt and after two months of belt use were not statistically significant. The 13% increase in trunk flexor strength was significant ($P \leq 0.01$). The authors concluded that 2 months of daily use of a soft heat-retaining belt did not influence the trunk extensor strength or endurance, but was associated with a significant increase in trunk flexor strength.

The Working Group noted that the study is limited by a number of factors, including: the short duration of the study; the absence of an unbelted control group and assessment of the type of tasks each subject did on the job; the measurement of flexion and extension in the sagittal plane, only when the activities of construction work require various postures and motions including twisting. The Working Group also concluded that given the short duration of the observation period, the study was unable to determine the relationship between increased trunk flexor strength and worker back injury.

Walsh and Schwartz [1990] studied three groups of 81 male warehouse workers in a 6-month intervention trial. Three equal sized groups (n=27), were separated into a control group and two intervention groups. The controls (group 1) received no training or low-back orthoses. One intervention group (group 2) received a 1-hour training session on lifting mechanics and back pain prevention, and no orthoses. The other intervention group (group 3) received a 1-training session and a custom-fitted lumbosacral orthoses. This device differs from many commonly used back belts and included a heat-molded hard insert customized to the individual. No group was assigned belts without training. The trial evaluated the effect of intervention on abdominal flexion strength, injury rate, productivity, and lost work time. The authors report controls and group 2 (training only group) showed no changes in abdominal flexion strength, injury rate, productivity, or lost time. Group 3 (orthoses and training) also showed no changes in abdominal flexion strength, injury rate, or productivity. Group 3 however, lost less work time, post-training. The authors concluded that the use of intermittent prophylactic bracing had no adverse effects on abdominal flexor strength and may contribute to a decrease in lost work time from work injuries.

The selection of workers and assignment to the three groups was random and excluded individuals "currently being treated for back pain or back injury." However, exclusion from the study on the basis of prior injury was not required if treatment was not ongoing at the time of entry into the study. As a result, both control and treatment groups included previously injured workers. In fact the

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authors subdivided the groups into high-risk (those patients with previous injury) and low-risk (those without a history of previous injury) during the 6 months before the study.

Pretraining workdays lost were higher in the two treatment groups than in controls, suggesting a selection bias for workers with previous injuries to wear back belts. The apparent effect of decreased lost time from work injury in group 3 (training and orthoses) was only seen in those workers with previous low back injury. No difference in lost workdays was observed for any of the treatment groups composed of workers without a prior history of injury. The findings from this study may more accurately define the therapeutic benefit of back belts in previously injured workers rather than clarifying the preventive role of these belts in previously healthy workers.

Early physiological and biomechanical studies suggested that discontinuing the use of back belts after a period of prolonged use may place a worker at greater risk of back injury. This hypothesis, proposed by Harman in 1989 in relation to IAP changes, received support by Reddell et al. [1992], who reported that workers who discontinued the use of belts had injury rates higher than the control group and the group that did not discontinue. However, the Reddell results are open to different interpretations because of severe limitations of the data. In addition, a recent study by Holmstrom and Moritz [1992], found that after 2 months of soft belt wearing, trunk extensor strength and endurance were unchanged, and trunk flexor strength increased, casting doubt on the muscle detraining-injury hypothesis. Finally, McGill et al. [1990] found the contraction level of abdominal muscles was so slight during experimental lifting with or without a belt, that a detraining effect from belt wearing is highly unlikely. The Working Group concluded that because of critical methodological limitations of published epidemiologic studies, there is insufficient data to demonstrate a relationship between the prevalence of back injury in healthy workers and the discontinuation of back belt use. However, this theory should be evaluated in future epidemiologic investigations of long-term back belt users.

III. *Summary Conclusions and Recommendations for Reviewed Studies*

A. Biomechanical Studies

The Working Group concludes that there are insufficient data to indicate that typical industrial-type back belts (i.e., those designed for use in the workplace, as compared to medical or therapeutic orthoses) significantly reduce the biomechanical loading of the trunk during manual lifting. No studies provided conclusive evidence that actual trunk muscle forces, predicted spinal compression, or shear forces were significantly reduced by wearing a back belt.

This conclusion is based on our review of studies that evaluated the effects of belt usage on predictions of biomechanical loading of the spine. These predictions were determined from various physiological and biomechanical parameters that were measured during lifting, such as IAP, EMG activity, IDP, anthropometry, body kinematics, and ground reaction forces.

The results of studies reviewed by the Working Group were inconclusive regarding the effects of back belts on spinal loading. Some suggested that back belts reduce spinal loading under certain conditions, while others were less conclusive. The Working Group recommends caution in interpreting these results, however, for the following reasons. First, the results are based on numerous assumptions about the relationship between spinal loading and measurable physiological and biomechanical parameters, which may not be valid when a belt is worn. For example, the addition of a belt may impose other unknown mechanical effects that alter the relationship between IAP and spinal compression. A more basic question, which has not been sufficiently addressed, is the validity of the core assumption that IAP reduces intra-abdominal pressure and spinal compression. Second, it is not possible to verify the accuracy of the predictions of changes in spinal loading. Because of ethical considerations, measurement of IDP, which may be the best measure of spinal compression to date, has been limited to a few studies. Third, if lifting belts appreciably affect the magnitude of spinal loading, then the resulting spinal loading from wearing a belt would be significantly affected by the mechanical characteristics of the various belt designs and the way they are worn. In the studies reviewed, however, these factors were not controlled.

A few studies suggest that back belts may reduce the range of spinal motion for a person wearing a belt during a lifting activity. Theoretically, this reduction in range of motion could diminish the necessary torque around the lower spine by reducing the muscle force required to support the body. This in turn would reduce

the compression force on the spine. The limited studies available, however, do not indicate that typical industrial-type belts sufficiently reduce range of motion about the spine to significantly reduce loading on the spinal structures. Moreover, it is possible that the resistance provided by a belt may increase loading on the spine, especially during asymmetric lifting, because of the necessity to increase muscle forces to overcome the resistance of the belt. Therefore, the Working Group concludes that there is insufficient evidence to recommend the use of back belts on the basis of reduction in range of motion.

Based on an analysis of available literature, the Working Group recommends that intervention strategies other than back belts be used to reduce biomechanical loading on the spine during manual material handling.

B. Physiological Studies

A number of studies have evaluated various physiologic parameters during back belt use, including IAP, EMG, heart rate and blood pressure. Other studies have suggested that abdominal and back extensor muscle strength changes with prolonged back belt use.

Some authors have extrapolated beyond their results to argue that a hypothesized protective effect of increased IAP exists. These extrapolations are based on assumptions about the role of IAP in reducing spinal forces; such assumptions have yet to be validated. IAP fairly conclusively increases when a belt is worn in the ranges of lifted weights reported, and at least some other indicators (mainly psychophysical) have also been in the "good" direction during increased IAP. Therefore, it is implied that belt-wearing and its increased IAP is good or "protective." While belt-wearing may increase IAP during lifting activities, the studies that have simultaneously assessed muscle EMG have been inconclusive; the lack of consistency is caused by a variety of technical problems, methodological deficiencies, and incomplete analyses. At present, no scientific evidence exists for concluding that belt-wearing is protective to an industrial population on the basis of changes in IAP and trunk muscle EMG.

The nature of the exact physiological and biomechanical mechanism that could result in the hypothesized protection remains to be determined. Presently, an adequate model of increased-IAP effects has yet to be developed. Restriction of motion coincident with the increased IAP is possibly more important than muscle EMG readings in "protection"; in that case, even the absence of an inverse relationship between IAP and EMG may be irrelevant.

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Consideration of the effects of prolonged back-belt use on back and abdominal muscle tone and cardiovascular health is also necessary. The results of a single, well-conducted study found significant increases in heart rate during aerobic activity and systolic blood pressure during both aerobic and isometric exercises. The Working Group concluded that the use of back belts can put a strain on the cardiovascular system and that individuals with a compromised cardiovascular system may be at greater risk when exercising or working with back supports.

Biomechanical studies have suggested that long-term use of back supports may decrease abdominal muscle tone, thereby increasing the likelihood of back injury if the user discontinued use of the back belt. The Working Group concluded that because of critical methodological limitations of published epidemiologic studies, there is insufficient data to demonstrate a relationship between the prevalence of back injury in healthy workers and the discontinuation of back belt use. However, this theory should be evaluated in future epidemiologic investigations of long-term back-belt users.

C. Psychophysical studies

Only a limited number of studies use psychophysical techniques to assess the subject's perception of acceptable lifting loads or back pain and discomfort while lifting either with and without back belts. No study has evaluated the relationship between the subject is or worker is perception of maximum acceptable workload and low back injury. The available data suggest that subjects lifted significantly heavier loads with the belt than without and report less discomfort lifting with a back belt than without. This perception of protection while wearing a back belt may not reflect the individual's ability to lift a heavier load or lack of discomfort, but may reflect the effect of using a treatment, also known as the "Hawthorne Effect." No study that used psychophysical techniques suggested that its results may have been biased by the prestudy assumptions of the subjects relative to back belt use. Additional studies are necessary to delineate these possible effects.

As a result, the Working Group has concerns about how wearing a belt may alter a worker's perception of capacity to lift heavy workloads when wearing a belt (i.e., belt wearing may foster an increased sense of security, which may not be warranted or substantiated).

D. Epidemiologic Studies

The use of epidemiologic methods to evaluate the effectiveness of back belts in reducing and preventing low back injury in uninjured workers is relatively recent. Three of the four studies in this review suffer at least some of the pitfalls of intervention studies that, by design, attempt to change long-standing attitudes, personal behaviors and work practices. Unfortunately, methodological limitations of most, if not all of the studies, also restrict the ability to interpret the results concerning the assessment of back belts' efficacy in reducing work-related back injuries. A few of the critical problems include, but are not limited to, low participation rates, inadequate observation periods, small sample sizes, relatively low back-injury rates, inclusion of individuals with previous back injuries, and recall and reporting biases of current and previous injuries and exposures.

The Working Group recommends that the results of the epidemiologic studies be interpreted with caution and that the experience of these studies be used to develop better designed epidemiologic research. The Working Group also recommends that future research designed to evaluate the efficacy of back belts in reducing and preventing work-related back injury include only previously uninjured female and male workers representative of the age range of the U.S. working population. The group further recommends that the belts be the types that are typically used in the workplace rather than for medical orthoses, that the jobs of workers wearing belts be analyzed as part of the study, that self-reports of back injury be validated using medical records, and that the term "back injury" be defined using codes from the International Classification of Diseases (ICD) or some other standard terminology.

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