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Effects of a belt on intra-abdominal pressure during weight lifting

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ABSTRACT

HARMAN, E. A., R. M. ROSENSTEIN, P. N. FRYKMAN, and G. A. NIGRO. Effects of a belt on intra-abdominal pressure during weight lifting. *Med. Sci. Sports Exerc.*, Vol. 21, No. 2, pp. 186–190, 1989. Intra-abdominal pressure (IAP) has been widely hypothesized to reduce potentially injurious compressive forces on spinal discs during lifting. To investigate the effects of a standard lifting belt on IAP and lifting mechanics, IAP and vertical ground reaction force (GRF) were monitored by computer using a catheter transducer and force platform while nine subjects aged 28.2 ± 6.6 yr dead-lifted a barbell both with and without a lifting belt at 90% of maximum. Both IAP and GRF rose sharply from the time force was first exerted on the bar until shortly after it left the floor, after which GRF usually plateaued while IAP either plateaued or declined. IAP rose significantly ($P<0.05$) earlier with than without the belt. When the belt was worn, IAP rose significantly earlier than did GRF. Both with and without the belt, IAP ended its initial surge significantly earlier than did GRF. Variables significantly greater with than without a belt included peak IAP, area under the IAP vs time curve from start of initial IAP surge to lift-off, peak rate of IAP increase after the end of its initial surge, and average IAP from lift-off to life completion. In contrast, average rate of IAP increase during its initial surge was significantly lower with the belt. Correlations are presented which provide additional information about relationships among the variables. Results suggest that the use of a lifting belt increases IAP, which may reduce disc compressive force and improve lifting safety.

IAP, RESPIRATORY MECHANICS, FORCE PLATFORM, GROUND REACTION FORCES, ESOPHAGEAL TRANSDUCER

Most disc compressive force during lifting has been attributed to tension in the erector spinae muscles which serves to oppose spinal flexion and accelerate the upper body and load (1,2,5,13). Although there has been some dissenting opinion (8,11), it has been widely hypothesized that intra-abdominal pressure (IAP) during lifting reduces the spinal compressive forces by creating an essentially rigid compartment which aids in resisting spinal flexion, thereby lessening tension in the erector spinae muscles necessary to effect a lift (3,4,12–14). IAP has been estimated to reduce spinal disc compressive forces by up to 40% (6,10,12,14).

High IAPs have been recorded during weight lifting (7,10). Both Olympic and power lifters have used lifting belts for many years, yet virtually no research has been directed toward examining whether and by what means the belts might be effective for increasing IAP, reducing injury, or improving lifting capacity. One abstract (9) showed higher mean IAP during the squat weight lifting exercise with than without a belt, with no statistical evaluation reported. Magnitude of IAP has been found to correlate positively with amount of weight lifted (7). The present experiment was undertaken to determine whether wearing a belt during lifting increases IAP, possibly reducing spinal disc compressive force for a given weight lifted or allowing more weight to be lifted at a given disc compressive force. High-speed computerized data collection was used in order to obtain more information about IAP changes during lifting than has been reported previously.

METHODOLOGY

Exercise examined. The dead lift (Fig. 1) was chosen since it is recognized as an exercise that places considerable stress on the lower back muscles. It also simulates the lifting of heavy objects in a work environment. The dead lift is effected by gripping a barbell resting on the floor with both hands and raising the weight until the body is upright with the barbell suspended from the arms. To standardize the lift, subjects were instructed to begin with bent knees, to maintain a straight back, and to effect the lift by concurrently straightening the knees and extending the back.

Apparatus. Subjects lifted Olympic style barbells and weight plates while standing on a model LG6-1-1 AMTI (Newton, MA) 0.6 by 1.2 m force platform. The weight plates at either end of the bar rested on surfaces adjacent to and level with the top of the force platform. A switch (model PE-30, Tapeswitch Corporation, Farmingdale, NY) transmitted a voltage signal when the barbell was lifted off the ground. A hand-held switch used as an event marker allowed the experimenter to signal when

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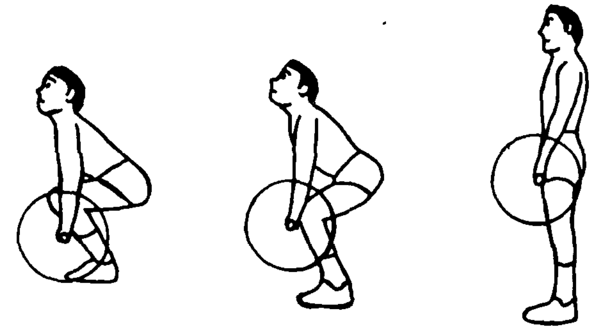

Figure 1—The dead lift exercise movement. Weight plates are drawn as if transparent to allow body position to be seen.

the subject had reached the endpoint of the lift. IAP was measured using a Millar model SPC 350 Mikro-Tip catheter pressure transducer (Millar Instruments, Houston, TX) inserted nasally. The transducer is optically isolated and incorporates a strain gauge pressure sensor with frequency response flat to 10 kHz. A control unit (model TCB 500) produces, according to switch position, either calibration voltages corresponding to 0.00, 2.67, and 13.33 kilopascals (kPa) or a 0.15 V·10 kPa^{-1} (0.2 V·100 mm Hg^{-1}) signal reflecting pressure at the catheter tip. Voltage signals from the pressure transducer control unit, force platform, and event marking switches were fed into an Infotek (Anaheim, CA) AD200 analog-to-digital (A/D) converter board mounted in a Hewlett-Packard (Lexington, MA) 310 microcomputer. Voltage input to each channel was sampled and digitized at 200 Hz. Processed data were transferred to a VAX 780 mainframe computer for statistical analysis using BMPD (Los Angeles, CA) programs.

Experimental procedure. The experiment was conducted in accordance with the policy statement of the American College of Sports Medicine (*Med. Sci. Sports* 10:ix–x, 1978) and U.S. Army regulation AR 70-25 on use of volunteers in research, which require that human subjects give free and informed voluntary consent before participation.

The subjects were one female and eight male volunteers who had varying degrees of noncompetitive weight lifting experience and were physically active but not engaged in organized sports. On the first test day, information was collected on the subject's age, height, and weight. Instructions were given on catheter insertion and lifting procedures. Each subject's one repetition maximum (RM) lifting capacity in the dead lift was determined. Descriptive statistics on subject age, height, body mass, and one RM lift are shown in Table 1. The one RM lift averaged 1.85 times body weight.

Before the lifting trials, the testing apparatus was calibrated by computer-sampling the pressure transducer control unit while it was set at 0.00 kPa and 13.33 kPa (100.0 mm Hg) calibration pulses and by sampling that vertical ground reaction force (GRF) channel of the force platform with no mass and with a 200 kg mass resting on its surface. Factors derived from the calibration were used to mathematically transform A/D converter output to standard units of pressure and force.

A minimum of 2 d following the one RM test, and after warming up with lighter weights, each subject lifted 90% of his or her one RM weight once while wearing and once again while not wearing a weight lifting belt (Fig. 2). Subjects were randomly assigned to lift first with or first without the belt. The belt was similar to those widely used by individuals engaged in weight training for general conditioning, sports training, and bodybuilding. It differed from a competition weight lifting belt, which is a maximum of 10 cm wide. The belt was buckled snugly and worn with the wide part against the lifter's back.

All subjects were familiar with the dead lift exercise and had been thoroughly coached to ensure that they would lift according to standard technique. Observation verified that all lifts were within the required form. Pilot testing had shown that critical measures of lift performance were repeatable for individuals. Test-retest reliabilities were above 0.9 for peak IAP and GRF and were 0.8–0.9 for key lift timing variables, average IAP and GRF, and area under the IAP and GRF curves.

GRF, IAP, and the event marker were monitored throughout the lifts by the computer. Subjects rested between the two lifts until they felt fully recovered. Before the lifting bouts, subjects inserted the catheter pressure transducer into a nostril and down the esophagus until it descended just below the diaphragm. Position of the catheter tip was determined by having the subjects sniff repeatedly during insertion. A change from below to above atmospheric pressure signaled that the tip had passed below the diaphragm.

RESULTS

Figure 3 is a plot if IAP and GRF data points collected during one subject's dead lift, with event times

TABLE 1. Subject descriptive statistics (mean ± SD).

Subjects	8 males, one female
Age	28.2 ± 6.6 yr
Body mass	77.4 ± 8 kg
Dead lift one RM	1,403 ± 265 N

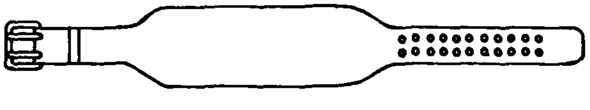

Figure 2—The weight lifting belt drawn to scale. Fabricated of 0.6 cm thick leather, it was 108 cm long, 15 cm wide in its center section, and 6.2 cm wide in its end sections. The belt was worn with its buckle centered over the navel.

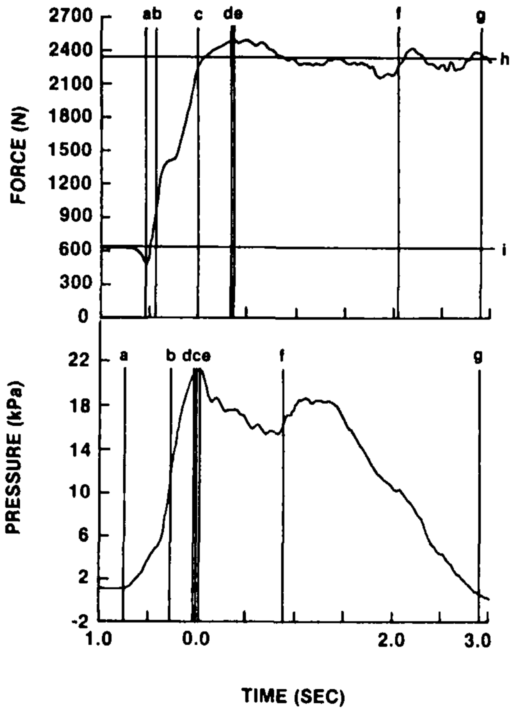

Figure 3—**GRF and IAP during a dead lift (with the belt).** ***Vertical lines*** **indicate for each curve times of a) start of initial surge, b) peak rate of increase during initial surge, c) departure of weight from ground, d) end of initial surge, e) peak magnitude, f) peak rate of increase after initial surge, and g) lift end: lifter standing erect holding weight.** ***Horizontal lines*** **indicate h) body plus bar weight and i) body weight.**

TABLE 2. Event times relative to bar lift-off (mean ± SD).

Event	Time of Event (s)	
	No Belt	Belt
Start of GRF rise	−0.31 ± 0.15	−0.38 ± 0.16†
Start of IAP rise	−0.34 ± 0.17	−0.56 ± 0.20*†
Peak GRF	1.06 ± 0.75	0.79 ± 0.67
Peak IAP	0.45 ± 0.37	0.42 ± 0.46
End of GRF IS	0.31 ± 0.16†	0.33 ± 0.16†
End of IAP IS	0.20 ± 0.06†	0.14 ± 0.13†
Peak GRF IS rate	−0.10 ± 0.14	−0.10 ± 0.16
Peak IAP IS rate	−0.08 ± 0.12	−0.09 ± 0.09
Peak post-IS GRF increase rate	1.85 ± 0.59	1.76 ± 0.59
Peak post-IS IAP increase rate	1.59 ± 0.63	1.09 ± 0.58
Lift completion	2.41 ± 0.41	2.43 ± 0.36

IS = initial surge.

* Significant ($P < 0.05$) difference between belt and no-belt conditions.

† Significant ($P < 0.05$) difference between IAP and GRF timing.

indicated by vertical lines. Each lift took 2–3 s to complete. It can be seen that, before lift-off, IAP and GRF increased steeply. The term "initial surge" will be used to describe the sharp increases in IAP and GRF that began as the lifter started to exert force on the bar and usually continued until shortly after the weight left the ground. GRF usually plateaued shortly after its initial surge, while IAP plateaued or declined.

Various individual curve patterns were exhibited. Computer processing determined times at which the following events occurred 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 ends of the initial IAP and GRF surges were taken, respectively, as the times after which IAP failed to increase at least 0.40 kPa (3.0 mm Hg) within 0.20 s and after which GRF failed to increase at least 40 N within 0.20 s. These criteria were selected because they identified surge ends which appeared reasonable upon visual inspection of the curves. The event times are listed in Table 2, where a negative sign means that an event occurred before lift-off. IAP rose significantly ($P<0.05$) earlier with than without the belt. When the belt was worn, IAP rose significantly earlier than did GRF. Both with and without the belt, IAP ended its initial surge significantly sooner than did GRF.

Table 3 shows IAP magnitude, area under the IAP vs time curve, and IAP rate of change. The mean for peak IAP is very similar to that previously reported for dead lifts without a belt (7). Variables significantly greater with than without a belt included peak IAP, area under the IAP vs time curve from start of initial IAP surge to lift-off, peak rate of IAP increase after the end of its initial surge, and average IAP from lift-off to lift completion. Interestingly, average rate of IAP increase during its initial surge was significantly lower with the belt. The earlier IAP rise with the belt cannot fully explain this phenomenon since *peak* rate of IAP increase during its initial surge, which is unaffected by total rise time, was also lower with the belt, though not significantly so. Those variables that did not differ significantly between the belt and no-belt conditions were area under the IAP vs time curve from lift-off to lift completion, peak rate of IAP increase during its initial surge, and average IAP from start of its initial surge to lift-off. Of the eight IAP variables, six were higher with than without the belt, though two of the differences did not reach significance. The belt clearly increases IAP during weight lifting.

Table 4 shows GRF magnitude and area under the GRF vs time curve (impulse). There were no significant differences between the belt and no-belt conditions. Peak GRF averaged about 11% above body plus bar weight. Whenever GRF was above body plus bar weight during a lift, the center of mass of the lifter-bar system had to accelerate upwards. When GRF equaled body plus bar weight, the center of mass had to either remain stationary or move upward at a constant speed. When GRF was less than body plus bar weight, the center of mass had to decelerate, as it had to toward the end of a lift as the weight was brought to a stop.

Table 5 lists some correlations of interest. Peak IAP, which always occurred after lift-off, correlated well with

TABLE 3. IAP magnitude IAP · time area, and IAP rate of change (mean ± SD).

	No Belt	Belt
Peak IAP (kPa)	20.8 ± 3.6	23.4 ± 4.3*
IAP · time area: start to lift-off (kPa · s)	2.27 ± 1.7	3.84 ± 2.0*
IAP · time area: lift-off to end (kPa · s)	34.5 ± 11.0	38.6 ± 8.7
Peak rate of IAP IS (kPa · s^{-1})	1,516 ± 552	1,432 ± 596
Average rate of IAP IS (kPa · s^{-1})	40.9 ± 15.0	33.9 ± 8.7*
Peak rate of post-IS IAP increase (kPa · s^{-1})	188 ± 75	220 ± 98*
Average IAP: start to lift-off (kPa)	6.71 ± 3.3	7.02 ± 2.9
Average IAP: lift-off to end (kPa)	13.92 ± 3.1	15.77 ± 2.9*

1.00 kPa = 7.50 mm Hg.
IS = initial surge.
* *Significant ($P < 0.05$) difference between belt and no-belt conditions.*

TABLE 4. GRF variables (mean ± SD).

	No Belt	Belt
Peak GRF (kN)	2.23 ± 0.35	2.23 ± 0.31
Impulse: GRF start to lift-off (N · s)	354 ± 185	432 ± 198
Impulse: lift-off to end (kN · s^{-1})	4.90 ± 1.30	4.95 ± 1.27
Peak rate of GRF IS (kN · s^{-1})	71.4 ± 15.3	69.5 ± 19.2
Peak rate of post-IS GRF increase (kN · s^{-1})	56.5 ± 26.7	46.0 ± 24.6
Peak GRF as % over body + bar weight (%)	10.5 ± 2.5	10.9 ± 4.3
Average GRF: start to lift-off (kN)	1.15 ± 0.17	1.12 ± 0.16
Average GRF: lift-off to end (kN)	2.00 ± 0.30	2.01 ± 0.30

IS = *initial surge.*

TABLE 5. Selected significant ($P < 0.05$) correlations.

	No Belt	Belt
Peak IAP with:		
Peak rate of IAP IS	0.69	0.84
IAP · time area: lift-off to end	0.71	0.83
Average IAP: lift-off to end	0.83	0.88
IAP · time area: lift-off to end with peak GRF	0.58	0.80
Peak rate of IAP IS with peak rate of GRF IS	0.87	0.49
Time of peak IAP IS rate with time of peak GRF IS rate	0.83	0.86

IS = initial surge.

average IAP after lift-off and area under the IAP vs time curve after lift-off, indicating that IAP peaks were reflective of the magnitude of the entire curve and were not irregular transients. Peak IAP correlated well with peak rate of IAP increase during the initial surge, indicating that individuals achieving higher peak IAPs did so by generating IAP at a faster rate. This effect was more consistent when the belt was worn. Peak rates of IAP and GRF increase during initial surge correlated well with each other when the belt was not used and only moderately well when the belt was employed, indicating that use of the belt somehow weakened the association of GRF and IAP rates of change. On the other hand, the belt increased the association between peak GRF and area under the IAP vs time curve after the weight left the ground. Time of peak rate of increase during initial surge correlated well between IAP and GRF, indicating good temporal association of the speeds of IAP and GRF augmentation.

DISCUSSION

A lifting belt like those commonly used in weight training clearly augments IAP during dead lift exercise, probably reducing compressive force on spinal discs and improving lifting safety. IAP is likely to be similarly affected by a belt during other lifts involving back extension against resistance. The belt may function by preventing protrusion of the abdomen and possibly by forcing the abdominal muscles to move inwardly as they bulge while contracting. A competition belt should have similar or even greater effect on IAP since, though narrower in the back than the belt used in the present study, it is often wider in the front where it presses against the abdomen.

The phenomenon of earlier IAP rise with than without the belt may be due to the close proximity of thighs and trunk during the bent-knees straight-back starting position of the lift, which tends to push abdominal tissue up against the belt. It is interesting that, while all measures of IAP magnitude and area under the IAP vs time curve were higher with the belt, the rate of IAP increase during initial surge was lower. Apparently the earlier rise of IAP with the belt allowed pressure to rise higher even though the rate of increase was less.

It should not be concluded that all weight lifting need be performed with a belt. If a lifter trains with a belt, the abdominal muscles which contribute to generation of IAP may not be strengthened as much as they would be if no belt were used in training. In addition, neuromuscular control patterns of IAP-generating muscles may develop differently when a belt is used in training. Thus, a lifter accustomed to using a belt who tries lifting without one may generate less IAP than if he or she had trained regularly with no belt. Training with a belt may thus not reduce vulnerability to injury during lifts without a belt. A conservative recommendation would be that a belt always be employed for maximal or near-maximal lifting and that someone who lifts regularly with a belt should be extremely cautious about lifting without one. Athletes or workers who want to train for an activity during which a belt is not worn may be well advised to do at least some of their training without a belt to both strengthen the deep abdominal muscles and develop a pattern of muscle recruitment needed to generate high IAP when a belt is not worn.

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