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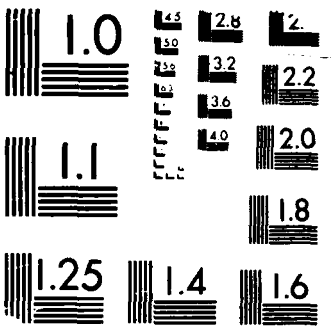

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SCIENTIFIC PAPER

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

Running head: Weight lifting belt and intra-abdominal pressure

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

ABSTRACT

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 plate while 9 subjects aged 28.2±6.6 yrs. 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 force usually plateaued while IAP either plateaued or declined. IAP rose significantly ($p<.05$) earlier with than without the belt. When the belt was worn, but not without it, IAP rose significantly earlier than did GRF. For both conditions, IAP reached plateau significantly sooner than did GRF. Variables significantly higher with than without a belt included peak IAP, area under the IAP vs. time curve from start of IAP rise to lift-off, peak rate of IAP increase after start of IAP plateau, and average pressure from lift-off to lift completion. In contrast, average rate of IAP increase before start of IAP plateau was significantly lower with the belt. Correlations provide additional information about relationships between variables. Results suggest the use of a lifting belt increases IAP, which may reduce disc compressive force and improve lifting safety. [illegible])

RESPIRATORY MECHANICS, FORCE PLATE, GROUND REACTION FORCES, ESOPHOGEAL TRANSDUCER, SUPPORT, SAFETY

INTRODUCTION

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 a rigid body compartment which aids in resisting spinal flexion, lessening tension in the erector spinae muscles necessary to effect a lift (3,4,12,13,14). Intra-abdominal pressure has been estimated to reduce spinal disc compressive forces by up to 40% (6,9,12,14).

High intra-abdominal pressures have been recorded during weightlifting (7,9). Both olympic and power lifters have used lifting belts for many years, yet virtually no research has been reported which examines the efficacy of belts for increasing intra-abdominal pressure, reducing injury or improving lifting capacity. One abstract (10) showed higher mean intra-abdominal pressure during the squat weightlifting exercise with than without a belt, with no statistical evaluation reported. Magnitude of intra-abdominal pressure has been found to correlate positively with amount of weight lifted (7). The present experiment was undertaken to determine if wearing a belt during lifting increases intra-abdominal pressure, 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 pressure changes during lifting than was obtained during any previous experimentation.

METHODOLOGY

Exercise examined

The dead-lift 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 with both hands a barbell resting on the floor 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 straight back and bent knees, and to avoid rounding the back or prematurely straightening the knees.

Apparatus

Subjects lifted Olympic style barbells and weight plates while standing on a model LG6-1-1 AMTI (Newton MA) .6 meter by 1.2 meter force plate. The plates at either end of the bar rested on surfaces adjacent to and level with the top of the force plate. 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 allowed the experimenter to signal again when the subject had reached the endpoint of the lift. Intra-abdominal pressure 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 2.667 and 13.333 kilopascals (kPa) or a .15 volt per 10 kPa (.2 volt per 100 mmHg) signal reflecting pressure at the catheter tip. Voltage signals from the pressure transducer control unit, force plate and event marking switches were fed into an Infotek (Anaheim CA) AD200 analogue-to-digital converter board mounted in a Hewlett-Packard (Lexington MA) 310 microcomputer. Signals from each channel were sampled at 200 Hz. Processed data was transferred to a VAX 780 mainframe computer for statistical analysis using BMDP (Los Angeles, CA) programs.

Experimental procedure

The experiment was conducted in accordance with the policy statement of the American College of Sports Medicine (MEDICINE AND SCIENCE IN 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 8 male and 1 female volunteers who had varying degrees of non-competitive 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 1 repetition maximum (RM) lifting capacity in the dead lift was determined. Descriptive statistics on subject age, height, body mass and 1 RM lift are shown in table 1. The 1 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 mmHg and 100 mmHg calibration pulses, and the force plate with no mass and with 200 kg resting on its surface. Factors derived from the calibration were used to mathematically transform A/D converter output to meaningful units of pressure and force.

A minimum of two days following the 1 RM test, and after warming up with lighter weights, each subject lifted 90% of his 1 RM weight once while wearing, and again while not wearing a six inch wide weight lifting belt. The order of the belt and no-belt lifts was randomized. Force, intra-abdominal pressure and the event marker were monitored throughout the lifts by the computer. The event marker signal stayed high while the weight rested on the floor. When the weight left the floor (lift-off) the marker signal dropped to a low level. When the lifter reached the upright position the experimenter's button push brought the event marker high again. 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 signalled that the tip had passed below the diaphragm.

RESULTS

Figure 1 is a plot of intra-abdominal pressure and vertical ground-reaction force data points collected during a typical dead-lift, with times of bar lift-off and lift completion indicated by vertical dashed lines. Each lift took 2-3 sec to complete. It can be seen that before lift-off, pressure and force increased steeply. Force usually plateaued shortly after lift-off while pressure plateaued or declined. Various individual curve patterns were exhibited. Computer processing determined the following times relative to lift-off for the pressure and force curves: 1) start of rise above baseline 2) peak rate of increase before start of plateau 3) start of plateau 4) peak 5) peak rate of increase after start of plateau and 6) lift completion. The event times are listed in table 2, where a negative sign means an event occurred before lift-off. In general, pressure began to rise 1/3 to 1/2 sec before lift-off, reached its steepest rate of increase about 1/10 sec before lift-off, plateaued about 1/5 sec after lift-off and peaked 1/4 sec thereafter. Ground reaction force followed a similar pattern but reached plateau a bit earlier and peaked somewhat later than did pressure. Pressure rose significantly ($p<.05$) earlier with than without the belt. When the belt was worn, but not without it, pressure rose significantly earlier than did ground reaction force. For both conditions pressure reached plateau significantly sooner than did force.

Table 3 shows intra-abdominal pressure magnitude, area under the pressure versus time curve and pressure rate of change. The mean for peak pressure is very similar to that previously reported for dead-lifts without a belt (7). Variables significantly higher with than without a belt included peak pressure, area under the pressure versus time curve from start of pressure rise to lift-off, peak rate of pressure increase after start of the pressure plateau and average pressure from lift-off to lift completion. Interestingly, average rate of pressure increase before start of the pressure plateau was significantly lower with than without the belt. The earlier pressure rise with the belt cannot fully explain the phenomenon since <u>peak</u> rate of pressure increase before start of the pressure plateau was also lower with the belt, though not significantly so, and peak rate is unaffected by total time of rise. Those variables that did not differ significantly between the belt and no-belt conditions were area under the pressure versus time curve from lift-off to lift completion, peak rate of pressure increase before the start of pressure plateau and average pressure from start of pressure rise to lift-off.

Of the eight pressure variables, six means were higher with than without the belt, though two of the differences didn't reach significance. Clearly, a belt increases intra-abdominal pressure during weight lifting.

Table 4 shows ground reaction force magnitudes and areas under the force versus time curves (impulses). There were no significant differences between the belt and no-belt conditions. Peak force averaged about 11% above body plus bar weight. During a lift, whenever ground reaction force is above body plus bar weight the center of mass of the lifter-bar system accelerates vertically. When ground reaction force equals body plus bar weight the center of mass moves upward at a constant speed. If ground reaction force is less than body plus bar weight then the center of mass decelerates, as must occur towards the end of a lift as the weight is brought to a stop.

Table 5 lists some correlations of interest. Peak pressure, which always occurred after lift-off, correlated well with average pressure after lift-off and area under the pressure versus time curve after lift-off, indicating that pressure peaks were reflective of the magnitude of the entire curve and were not irregular transients. Graphs of both pressure and force versus time show that peaks did not generally rise much above the level of curve plateaus. Peak pressure correlated well with peak pre-plateau rate of pressure increase, indicating that individuals achieving higher peak pressures did so by generating pressure at a faster rate. This effect was more consistent when the belt was worn. Peak pre-plateau rates of pressure and force increase correlated well with each other when the belt wasn't used and only moderately when the belt was employed, indicating that use of the belt somehow weakened the association of force and pressure rate of change. On the other hand, the fact that there was a higher correlation when the belt was worn between area under the pressure versus time curve after lift-off and peak force shows that the belt heightened the association between force and area under the pressure versus time curve after the weight left the ground. Time at which peak pre-plateau rate of increase occurred correlated well between force and pressure, indicating good temporal association of the speeds of pressure and force augmentation.

DISCUSSION

The use of a standard lifting belt during dead lift exercise clearly increases intra-abdominal pressure, probably reducing compressive force on spinal discs and improving lifting safety. A belt is likely to similarly affect IAP 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 during contraction.

The phenomenon of earlier pressure 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 pressure magnitude and area under the pressure versus time curve were higher with the belt, the pre-plateau rate of pressure increase was lower. Apparently the earlier rise of pressure with the belt allowed IAP 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 intra-abdominal pressure may not be strengthened as much as they would if no belt were used in training. In addition, neuromuscular control patterns of pressure 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 intra-abdominal pressure than if he 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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TEXT TO FIGURES

Figure 1. Ground reaction force and intra-abdominal pressure during a dead lift. Vertical dashed lines indicate times of weight lift-off and lift completion (full upright body posture).

Table 1. Subject descriptive statistics (Mean±SD)

subjects	8 males, 1 female
age	28.2±6.6 years
body mass	77.4±8 kg
dead-lift 1 RM	143.±27 kg

Table 2. Event times relative to bar lift-off (Mean±SD)

Event	Time of event (sec)	
	No Belt	Belt
start of force rise	-.31±.15	-.38±.16 ‡
start of pressure rise	-.34±.17	-.56±.20 ‡ *
peak force	1.06±.75	.79±.67
peak pressure	.45±.37	.42±.46
start of force plateau	.31±.16 ‡	.33±.16 ‡
start of pressure plateau	.20±.06 ‡	.14±.13 ‡
peak pre-plateau rate of force increase	-.10±.14	-.10±.16
peak pre-plateau rate of pressure increase	-.08±.12	-.09±.09
peak post-plateau rate of force increase	1.85±.59	1.76±.59
peak post-plateau rate of pressure increase	1.59±.63	1.09±.58
lift completion	2.41±.41	2.43±.36

* significant (p<.05) difference between belt and no-belt conditions

‡ significant (p<.05) difference between pressure and force timing

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peak post-plateau rate of pressure increase	1.59±.63	1.09±.58
lift completion	2.41±.41	2.43±.36

* significant ($p<.05$) difference between belt and no-belt conditions

\# significant ($p<.05$) difference between pressure and force timing

Table 3.

Intra-abdominal pressure magnitude, time area and rate of change (Mean±SD)

1.00 kPa = 7.50 mmHg

		No Belt	Belt	
peak pressure	(kPa)	20.8±3.6	23.4±4.3	*
pressure•time area: start to lift-off	(kPa•sec)	2.27±1.7	3.84±2.0	*
pressure•time area: lift-off to end	(kPa•sec)	34.5±11.0	38.6±8.7	
peak pre-plateau rate of press. incr.	(kPa/sec)	1516±552	1432±596	
avg. pre-plateau rate of press. incr.	(kPa/sec)	40.9±15.0	33.9±8.7	*
peak post-plateau rate of press. incr.	(kPa/sec)	188±75	220±98	*
average pressure: start to lift-off	(kPa)	6.71±3.3	7.02±2.9	
average pressure: lift-off to end	(kPa)	13.92±3.1	15.77±2.9	*

* - significant ($p<.05$) difference between belt and no-belt conditions

Table 4. Ground reaction force variables (Mean±SD)

		No Belt	Belt
peak force	(N)	2229±345	2229±306
impulse: force start to lift-off	(N•sec)	354±185	432±198
impulse: lift-off to end	(N•sec)	4904±1299	4948±1269
peak pre-plateau rate of force incr.	(N/sec)	71382±15258	69482±19156
peak post-plateau rate of force incr.	(N/sec)	56464±26677	45984±24578
peak force as % over body + bar weight	(%)	10.5±2.5	10.9±4.3
average force: start to lift-off	(N)	1154±173	1123±155
average force: lift-off to end	(N)	2001±303	2005±304

* - significant ($p<.05$) difference between belt and no-belt conditions

Table 5. Selected significant ($p<.05$) correlations

	No-belt	Belt
Peak pressure with:		
Peak pre-plateau rate of pressure increase	.69	.84
pressure•time area: lift-off to end	.71	.83
Average pressure: lift-off to end	.83	.88
Area under the pressure versus time curve - lift-off to end with:		
Peak force	.58	.80
Peak pre-plateau rate of pressure increase with:		
Peak pre-plateau rate of force increase	.87	.49
Time of peak pre-plateau rate of pressure increase with:		
Time of peak pre-plateau rate of force increase	.83	.86

AUTHORS' STATEMENT

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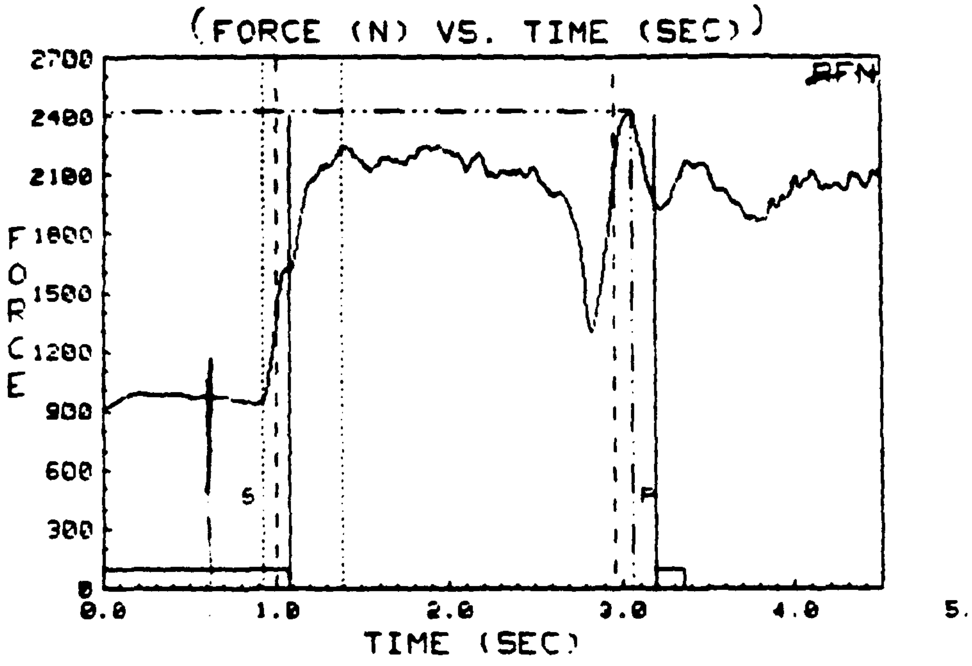

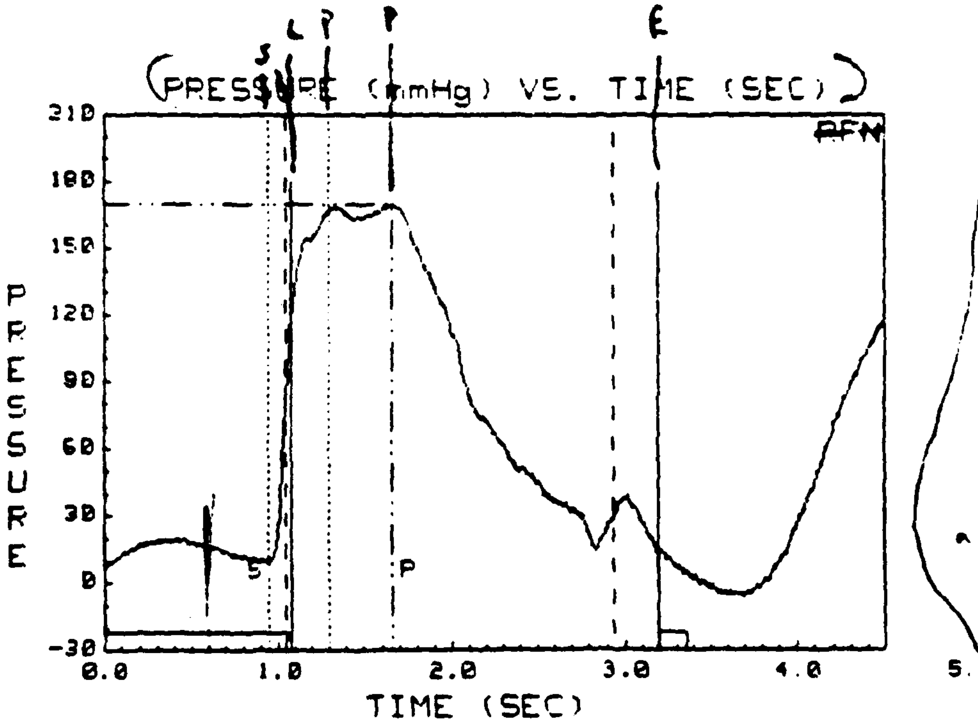

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