Spinal unloading after abdominal exercises

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Abstract

Background. Intervertebral discs are exposed to compressive forces, which produces fluid loss. This loss decreases disc height, spinal length and consequently overall stature. The loss of stature has been associated with spine loading and low back pain. Abdominal exercises increase intra-abdominal pressure and unload the spine. The purpose of this study was to identify if abdominal exercises may produce acute spinal unloading compared to a known unloading position.

Methods. Nine subjects performed a loading protocol and an unloading protocol on three experimental sessions. The loading protocol consisted of three sets of military press, while three unloading protocols were: three sets of regular abdominal exercises, three sets of abdominal exercises performed in an inclined board or an unloading resting posture.

Findings. Abdominal exercises showed a greater recovery (mean (SD)) (regular = 87.8 (20.4)%; inclined = 70.1 (14.5)%) in comparison to the resting position (Fowler = 33.6 (14.1)%), although no significant differences were found between abdominal exercises in stature recovery (P = 0.07).

Interpretation. Abdominal exercises may be introduced between sets of resistance training to decrease the negative effect of compressive forces imposed during such highly stressing activities. Further studies are required to confirm the proposed underlying mechanisms.

Keywords: Low back pain; Spinal unloading; Spinal shrinkage; Abdominal exercises

1. Introduction

The vertebral column is exposed to a variety of mechanical forces during daily live activities (Adams et al., 1994). These forces are distributed along the spine through an efficient system of loading absorption and dissipation. This system is composed of vertebrae, ligaments, muscles and intervertebral discs (Adams and Hutton, 1985). The intervertebral discs work as a visco-elastic system that absorbs and distribute forces acting in the spine. When submitted to compressive forces the collagen fibers of the annulus fibrosus are deformed radially expelling fluid from the nucleus pulposus of the discs (Adams and Hutton, 1985). The expelled fluid causes the discs to lose height, which reduces spinal length and, consequently, subject’s stature (Reilly et al., 1984). On the other hand, when compressive forces are removed or reduced, the intervertebral discs reabsorb fluid regaining height (Reilly et al., 1984), and eventually restoring subject’s stature. A few authors have reported that a reduction in the intervertebral space causes loading of other structures which are not well designed for such purpose (e.g. facet joints – Adams et al., 1994, 1990). In addition, this reduction can also cause soft tissues problems (e.g. spinal impingement – Adams and Dolan, 1995). The variation in the spinal length is related to the magnitude of the imposed loads (Althoff et al., 1992; Tyrrell...


et al., 1985) and has been used as a non-invasive method to measure the spinal stress. A precision stadiometer has been used to measure these changes (Rodacki et al., 2001; Van Dieen et al., 1994).

Skeletal muscles around the vertebral column are also important load absorbers and stabilizers of the spine (Kavcic et al., 2004). Increased strength of trunk flexors and extensors muscles are thought to raise intra-abdominal pressure and to decrease spinal loading (Aspden, 1988; Morris et al., 1961), which may reduce the occurrence of back problems (Lee et al., 1999). Specifically, trunk flexor muscles weakness may fail to provide adequate intra-abdominal pressure and may cause reduced spinal stability, which is associated with low back pain (Cholewicki et al., 1999). Thus, it seems that increasing the strength of trunk flexors may be effective to unload the spine and prevent injury (Lee et al., 1999). This concept has guided clinical and physical activity protocols designed to prevent and/or reduce back problems (McGill, 1998).

In order to understand the chronic result of trunk flexor muscle exercises to the spine, it is necessary first to understand the effect of immediate changes, i.e. if series of abdominal exercises can acutely unload the vertebral column. A number of studies have shown that abdominal exercises are able to increase spinal stability (Cholewicki et al., 1999) and unload the spine (Aspden, 1988; Daggfeldt and Thorstensson, 2003). Hodges et al. (2001) showed in vivo that an increased intra-abdominal pressure produces an extensor moment around the spine, but its significance to the spine and intervertebral disc is still to be determined.

A promising way to gain insight about the effect of such exercises is to compare stature variation between series of trunk flexor exercises and a resting position (e.g. Fowler’s position). The Fowler’s position (lying down in a supine posture) has been shown to be an effective procedure to promote acute spinal unloading (Healey et al., 2005) and effects of any physical activity performed before the experimental session. After this resting period, subjects were positioned in the stadiometer and the first stature measurement was taken. Then, subjects were requested to perform three sets of 8 military press movements with 60% 1RM, in an attempt to cause a normalized spinal stress. Finally, subjects’ stature variation was measured in the stadiometer immediately before and after three experimental conditions: three series of regular crunch exercises in a flat surface (no inclination) with the knees flexed at 90° (ABS1); three series of regular crunch exercises in a 45° inclined board (knees flexed at 45° and feet supported) (ABS2); 4.5 min resting in the Fowler’s position (FOWL). In both crunch exercises subjects performed three sets of 20 movements. The time to perform each crunch movement was controlled using a digital metronome, which emitted an audio signal every 1.5 s (0.6 Hz) and helped participants to perform each movement in 3 s (1.5 s to flex and 1.5 s to extend the trunk) and to conclude the series in 60 s. At the end of each exercise series an interval of 30 s was imposed. This interval was also imposed at the end of the third series to allow participants to recover their normal breathing before the measurement was taken in the stadiometer. The total crunch exercise duration (exercise and intervals) equaled the period subjects remained resting in the Fowler’s position.

Military press exercises were performed in the sitting posture. Experimenters positioned the barbell at the shoulder level of the participant, which grasped the bar using an overhand grip, slightly wider than their shoulders and pressed the bar until arms were extended overhead. One minute interval between series was imposed and execution time was not controlled. Abdominal exercises were performed in a position similar to that assumed in the Fowler position, i.e. with the hips flexed at approximately 90°. The upper segments were folded across the chest whilst the upper body was lifted to an angle of approximately 30°. Subjects were instructed to initiate the movement from the Fowler’s position in order to reduce measurement variability. Subjects were deemed familiarized to the protocol when the standard deviation of stature measurements obtained in 10 consecutive assessments was equal or lower than 0.05 cm. Subjects were requested to step away from the equipment between each measurement and the whole familiarization with the device can be found elsewhere (Rodacki et al., 2001). In addition, one maximal repetition (1RM) value in the military press exercise was determined. The procedures performed to determine 1RM are described by Brown and Weir (2001). The order of experimental sessions was randomly assigned.

The experimental sessions followed the same procedures. At the beginning of each session, subjects rested in the Fowler’s position for 20 min to reduce circadian variations (Reilly et al., 1984; Healey et al., 2005) and effects of any physical activity performed before the experimental session. After this resting period, subjects were positioned in the stadiometer and the first stature measurement was taken. Then, subjects were requested to perform three sets of 8 military press movements with 60% 1RM, in an attempt to cause a normalized spinal stress. Finally, subjects’ stature variation was measured in the stadiometer immediately before and after three experimental conditions: three series of regular crunch exercises in a flat surface (no inclination) with the knees flexed at 90° (ABS1); three series of regular crunch exercises in a 45° inclined board (knees flexed at 45° and feet supported) (ABS2); 4.5 min resting in the Fowler’s position (FOWL). In both crunch exercises subjects performed three sets of 20 movements. The time to perform each crunch movement was controlled using a digital metronome, which emitted an audio signal every 1.5 s (0.6 Hz) and helped participants to perform each movement in 3 s (1.5 s to flex and 1.5 s to extend the trunk) and to conclude the series in 60 s. At the end of each exercise series an interval of 30 s was imposed. This interval was also imposed at the end of the third series to allow participants to recover their normal breathing before the measurement was taken in the stadiometer. The total crunch exercise duration (exercise and intervals) equaled the period subjects remained resting in the Fowler’s position.

2. Methods

2.1. Subjects

Nine physically active healthy male subjects (23.0 (3.0) years; 75.0 (5.0) kg; 175.1 (5.5) cm) volunteered to participate in this study. None of them presented low back pain or spine pathologies in the 12 months that preceded the study. University’s Ethical Committee approved the study and all subjects signed an informed consent form before participation.

3. Experimental protocol

Subjects reported to the laboratory on four occasions, which were conducted at least three days apart. In the first session, subjects were acquainted to the stadiometer in order to reduce measurement variability. Subjects were deemed familiarized to the protocol when the standard deviation of stature measurements obtained in 10 consecutive assessments was equal or lower than 0.05 cm. Subjects were requested to step away from the equipment between each measurement and the whole familiarization with the device can be found elsewhere (Rodacki et al., 2001). In addition, one maximal repetition (1RM) value in the military press exercise was determined. The procedures performed to determine 1RM are described by Brown and Weir (2001). The order of experimental sessions was randomly assigned.

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the lower part of the upper segment until the final position was achieved.

### 3.1. Stature loss measurement

Absolute stature loss was calculated as the difference between measurements taken before and after military press exercises. A period of 90 s was imposed in the standing posture to allow soft tissue accommodation (Foreman and Linge, 1989). Absolute stature recovery was estimated as the difference of measurements taken after military press exercises and after one of the three experimental conditions (i.e. two crunch exercises and resting position). Stature changes were reported as percentages of the initial values (before military press exercises).

Stature changes were measured with a precision stadiometer, which allows verifying small variations in subject’s spinal length, which have been described as the cumulative changes that occur in the intervertebral disc height (Fowler et al., 2005; Reilly et al., 1984). A full description of the device and detailed procedures may be found elsewhere (Rodacki et al., 2001). In short, the stadiometer consists of a rigid frame, inclined 15° backwards with respect to the vertical. Subjects were positioned standing upright in the device with their natural posture with the body weight divided between the feet. The contour of both feet was drawn in the plantar support of the device to avoid postural adjustments. A number metallic rod was positioned against the back (fourth cervical vertebra, seventh thoracic vertebra, fourth lumbar vertebra, middle sacral crested) to allow subjects to be positioned and repositioned in the stadiometer with no postural adjustments. The position of the head was also controlled by a modified glasses with two laser devices (class two, wave length 630–680 mm, and maximum output <1 mW) aiming the top board of the stadiometer. The weight of the device designed to control the head position was negligible. An elastic tape fixed the glasses on the head and helped to prevent glasses movements. Vertical and horizontal control of the head was made by aligning the laser lights with two small reference points (2.0 mm), placed on the top board of the stadiometer. After all adjustments, a calibrated linear variation digital transducer (Solatron DC50, model RS 646-511, 0.05 mm resolution) was positioned above the subjects’ heads and the rod of the transducer driven by gravity to the head apex. The point of contact of the transducer in the head was marked to improve measurement precision (see Fig. 1).

### 3.2. Statistical analysis

After normality test (Kolgomorov–Smirnov), a two-way ANOVA for repeated measures was applied. Tukey post-hoc test was used for multiple comparison purposes after significant *F*-values. Significance level was set at *P* < 0.05.

### 4. Results

The lower standard deviation of the measurements in the familiarization session indicates that the measurements were very consistent (Rodacki et al., 2001). The average SD in the familiarization session was 0.45 (0.11) mm.

The absolute stature measurements taken after the military press indicated that this exercise was effective to load the spine and to produce spinal shrinkage. The spinal shrinkage imposed after military press exercises was similar (*P* > 0.05) across experimental sessions (Fig. 2).

A significant difference in stature recovery was found between experimental conditions (*P* < 0.05). Both abdominal exercises (ABS1 and ABS2) produced significant stature recovery (*P* < 0.05) compared to the measurements performed after Fowler’s position (Fig. 3), although no differences were detected between abdominal exercises. However, there was a trend (non-significant, *P* = 0.07) towards a greater stature recovery in ABS1 compared to ABS2. In addition, Fowler’s position was also effective to produce stature recovery (*P* < 0.05) but to a lower extent than both abdominals exercises (*P* < 0.05).

Subjects were able to recover stature almost completely after crunch exercises when compared to their initial condition (i.e. before military press exercises; *P* < 0.05). Specifically, ABS1 had a mean recovery of 87.8 (20.4%), while ABS2 had an average of 70.1 (14.5%). There was no significant difference between exercises (*P* = 0.096). However,
4.5 min in Fowler’s position allowed a significantly lower stature recovery (33.6 (14.1)% ) when compared with the other two experimental conditions ( \( P < 0.0001 \) ) (Fig. 4).

5. Discussion

The purpose of this study was to determine whether abdominal exercises can promote spinal unloading and to compare stature recovery between these exercises with a resting position (Fowler’s position). The main finding of this study was that abdominal exercises were able to unload the spine. Abdominal exercises were also more effective to unload the spine than resting in the Fowler’s position for the same relative period of time.

The small standard deviation of the stature variation obtained in the familiarization session indicated the precision of our measurement after a relatively short training period (Rodacki et al., 2001). Our measurement variability (9%) is similar to that presented in the literature (e.g. Althoff et al., 1992) and indicates data reliability. There were also no differences in the magnitude of the changes produced by the loading protocol between sessions.

The forces applied during the three sets of military press exercises may have caused an acute deformation of the
elastic components of the disc (Keller et al., 1987) and an increase in intradiscal pressure (Adams and Dolan, 1995). Fluid loss is known to occur when the pressure inside the disc increases (Kraemer, 1985) and can be indicated as the major mechanism to account for the reduction in disc height (Botsford et al., 1994) and consequently in stature loss (Boocock et al., 1990; Reilly et al., 1984). On the other hand, stature loss occurring during the task was partially reversed by adopting an unloading position (Nachemson, 1981; Reilly et al., 1984). This recumbent position reduces gravity influence and decreases intradiscal pressure (i.e. osmotic swelling pressure) allowing the disc to regain its initial height. In addition, this position may have also changed the posture of the lumbar spine, decompressing the posterior portion of the annulus fibrosus and allowing greater influx of fluid than when sustaining its physiological curvature (Adams and Dolan, 1995). Adopting the resting position also promotes muscle relaxation, which may have reduced the compressive forces applied in the spine (Healey et al., 2005). These arguments have been used to explain stature gains and symptoms alleviation experienced by subjects suffering from low back pain while assuming this position for a relatively short period of time (Nachemson, 1981).

The large forces created during crunch exercises are believed to increase spinal compressive loading. Axler and McGill (1997) reported peak compressive forces acting in the lumbar vertebrae ranging from 1850 to 3530 N during trunk flexors exercises, which would tend to reduce disc height and spinal length. In fact, participants were able to recover intervertebral discs height, spinal length, and as a consequence, overall stature. A number of factors can be proposed in an attempt to clarify the underlying mechanisms.

First, the reader should have in mind the way healthy intervertebral discs respond to transient compressive stimulus. When a subtle load is applied, pressure inside the disc increases and tends to deform the walls of the annulus fibrosus, causing the disc to bulge (Koeller et al., 1984; Simon et al., 1985). However, fluid is relatively confined in the nucleus pulposus and there is insufficient time for the water content to migrate outwards very rapidly. Thus, loading is accommodated elastically by an instantaneous deformation of the fibers of the annulus fibrosus (i.e. fibrocolagen fibers), which requires minimal or no fluid loss (Van Dieen and Toussaint, 1993). Intervertebral disc recover its original shape on unloading (Kraemer, 1985). This important mechanism allows intervertebral disc to maintain longer its mechanical characteristics (dissipating/absorbing shocks) to resist to sudden or abrupt loads frequently applied during daily life activities. Although compressive forces during crunch exercises reach high values (Axler and McGill, 1997), the transient nature of the load (i.e. the short period in which the compressive force peaked) did not induce fluid loss.

The amount of water each disc can absorb is limited only by the extensibility of the corresponding annulus fibrosus and surrounding soft tissues (Adams and Dolan, 1995), which is closely influenced by the recumbent posture. During exercises the intervertebral disc alternates the internal pressure cyclically and extends the structures of the posterior aspect of the motion segment. Trunk flexion movement causes compressive forces in the anterior region of the intervertebral disc, while stretching forces are imposed on the posterior side of the intervertebral disc. Changes in posture during exercise may have caused variation in the internal pressure and in conjunction with water binding properties of the nucleus pulposus (osmotic...
swelling pressure) (Lindh, 1989) induced a greater fluid influx rate than when sustaining a static recumbent posture.

The fast stature recovery produced in response to trunk flexors exercises may have occurred as the result of increased intra-abdominal pressure, which exerts an extensor moment and tends to extend the spine (Daggfeldt and Thorstensson, 2003). Abdominal exercises seem to be effective to activate all muscles of the abdominal wall (Vera-Garcia et al., 2000), producing a braking action, increasing intra-abdominal pressure. Thus, increased intra-abdominal pressure may overcome or partially reduce, the compressive forces produced during trunk flexors exercises, allowing fluid absorption. In fact, intra-abdominal pressure has been advocated as an important component to unload the spine. Unfortunately, the study performed Axler and McGill (1997) did not consider the intra-abdominal pressure in their model and peak compressive forces may have been overestimated.

We did not find differences in stature recovery between abdominal exercises. However, abdominal exercises performed in the plane presented a trend to produce greater stature recovery than when this exercise is performed in an inclined board. Some authors have suggested that inclined or inverted positions are not very effective to activate all muscles of the abdominal wall (Vera-Garcia et al., 2000). Abdominal exercises seem to be an interesting strategy to unload the spine after high compressive loads. In addition, these exercises seem to be more effective that common unloading postures (Fowler’s position).

6. Conclusions

Abdominal exercises seem to be an interesting strategy to unload the spine after high compressive loads. In addition, these exercises seem to be more effective than what has been reported as an important component to unload the spine. Unfortunately, the study performed Axler and McGill (1997) did not consider the intra-abdominal pressure in their model and peak compressive forces may have been overestimated.

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References


