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The Effect of Lumbar Belt on the Variability of Spine and Pelvis Coordination during Repetitive Lifts in Male Athletes with Chronic Nonspecific Low Back Pain: Cross-sectional Study

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Original Article

Abstract

Introduction: Optimizing strategies to reduce the negative effects of lifts on low back pain (LBP) have attracted the attention of researchers. One of the practical strategies to deal with the effects of loads on the spine is lumbar belts. The aim of this study was to investigate the effect of lumbar belts on the coordination variability of spine and pelvis during repetitive lifts in male athletes with non-specific chronic LBP.

Materials and Methods: Twelve male athletes with chronic LBP participated in the study voluntarily. Participants with and without belts lifted the box for one minute at a frequency of 10 times per minute, and cinematic information based on the three-segment model of spine was recorded using a motion capture system equipped with 10 cameras. Coordination and coordination changes for these segments were calculated using a modified vector coding (VC) method. To compare the collected data, if normal, paired t-test was used in SPSS software and in variability data, statistical parametric mapping (SPM) method was used in MATLAB software with the significance level of $P \leq 0.05$.

Results: A significant difference was observed for the coordination of the pelvic segment to the lower back (LB) segment [concentric phase ($P \leq 0.035$), eccentric phase ($P \leq 0.043$)]. On the other hand, no significant difference was reported between using and not using belts for the coordination of the lumbar segment to the lower trunk segment ($P = 0.545$), lower trunk segment to the upper trunk segment ($P = 0.440$), and the variability of all calculated couples.

Conclusion: According to the findings, using the belt may optimize the transfer of motion from the distal segment to the proximal segment, which can reduce the pressure on the waist and prevent injury and pain in the lumbar region. Therefore, it is recommended that athletes with LBP use a belt when lifting heavy loads in order to transfer movement from the distal to the proximal segment correctly.

Keywords: Chronic non-specific low back pain; Lift; Coordination variability; Belt; Spine

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Introduction

Picking up and carrying objects is a daily necessity. We lift and carry objects frequently, which can cause low back pain (LBP) due to compressive and shearing forces on the lumbar spine. LBP is a common musculoskeletal disorder experienced by 70%-80% of people at least once in their lives (5, 6). Non-specific chronic LBP is the most common cause of LBP (7). This term is used when the source of pain cannot be determined. The pain is produced by various physical, anatomical, occupational, behavioral, and psychological factors (9). Most injuries that lead to chronic LBP are related to training volume and improper kinematics. Inappropriate lifting techniques such as excessive flexion, shear force, and compressive force on the spine, along with repeated

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pressure, reduce the contraction power of muscle fibers and proprioception, leading to a change in lift kinematics (10). Therefore, understanding the biomechanics of lifting is crucial for optimal muscle development and reducing injuries related to this movement (11).

There have been few studies on the kinematics of pelvis and spine during lifting for both healthy individuals and those with LBP. Some studies found no significant difference in joint coordination and variability between waist-thigh and thigh-knee during fiber movement for individuals with chronic LBP compared to healthy individuals (12). Additionally, it was found that more flexion of the lumbar spine during lifting was not a risk factor for the onset of LBP or differentiating people with and without LBP (13). Other studies have reported changes in upper and lower spine movement during walking (14), running (15), rowing (16), and deadlifting (17) in participants with chronic LBP, but these studies considered the spine as a single segment.

The results of recent studies suggest that the lower and upper parts of the spine can move differently at the same time (18-20). Studies on athletes with and without chronic LBP during rowing showed that those with chronic LBP could not adapt their coordination pattern with increasing rowing intensity, and the transfer of motion from the hip to the upper thoracic (UT) spine stopped at the junction of the spine with the pelvis (16). Furthermore, studies on patients with chronic LBP who had changes in the kinematics of the spine during walking showed that the movement in the frontal plane in the lower back (LB) joint and the symmetry of the movement in the transverse plane in the lower thoracic (LT) joint were reduced compared to the control group (21). Therefore, recent research suggests that it is better to examine the spine as three separate organs rather than as an organ (22).

Most studies on spine and hip kinematics use linear analysis methods, but recent preference is for non-linear methods such as continuous relative phase (CRP) and vector coding due to the details they provide on the coordination pattern and variability of coordination between joints or segments (23). Vector coding may be easier to interpret than relative phase angles and since it provides more intuitive information in a clinical environment, it can effectively be used to quantify relative movement patterns between spinal segments (24).

In vector coding, the coordination of relative movement between two joints is determined by the coupling angle or corresponding vector angle. This can be classified as in-phase (movement in the same direction) or anti-phase (movement in the opposite direction), with dominance of the proximal or distal part (22). Optimal force transmission occurs with a distal-to-proximal extension sequence in the pelvis, LB, and UT spine (16). Deviation from neutral spine alignment during loading can increase demands on other segments and risk of overuse injuries and LBP in the future (25, 26).

The use of weight-lifting belts is a possible strategy to reduce negative effects of lifts on LBP, and is the necessary equipment for athletes to protect the back from injuries (27). The belt strengthens the back and deep muscles of the body by creating proper pressure in the abdomen, and causes coordination of muscles and joints during the lifting movement (28). In biomechanics, studies have investigated the effects of weight-lifting belts on spine forces, intra-abdominal pressure, stability, and muscle strength (29). However, little research has been done on the coordination and variability of spine and hip coordination in male athletes with non-specific chronic LBP. Therefore, the aim of the present study was to investigate the effect of using weight belts on the variability of spine and hip coordination in the repetitive lifting of male athletes with non-specific chronic LBP.

Materials and Methods

This semi-experimental cross-sectional study involved male power lifters or bodybuilding students of Kharazmi University, Tehran, Iran, with non-specific chronic LBP, who were selected on a voluntary basis using available sampling. The sample size of 12 people was estimated on G*Power software version 3.1.9.4 (University of Dusseldorf, Dusseldorf, Germany) with an effect size of 0.8 and test power of 0.8. The research was conducted in 2019 at Javad Mowafaqian Neurorehabilitation Center of Sharif University of Technology, Tehran, with full respect to research ethics.

In this study, patients with chronic non-specific LBP were included if they had pain lasting for at least six months or had a history of recurrent LBP attacks, and if no specific cause for their pain was identified by the medical staff. Pain intensity was measured using a visual analog scale (VAS), and those with a score of greater than 2 (30) were included in the study. Patients were evaluated by an experienced physiotherapist for exclusion criteria, which included serious spinal injury, neurological or vestibular dysfunction, history of spinal surgery, and inability to perform functional tasks (31).

Before the test, participants were briefed on procedures. They completed the Oswestry Functional Disability Questionnaire and signed consent forms. Ethical approval was granted by the Institutional Review Board (IRB) of Kharazmi University. Kinematic data were recorded using the Vero2.2/Vicon motion capture system with 10 cameras based on the three-segment biomechanical model of the spine at a sampling rate of 200 frames per second after calibration. Anthropometric dimensions of the subjects were measured to record kinematic data using the motion analysis system. Markers were installed on the subject's body based on the marking model of the lower limb cluster and the three-segment model of the spine, and 5 markers were installed on the box (Figure 1).

Figure 1. Location of markers according to the three-segment model of the spine

To prepare for the test, each participant performed selected stretching movements and a 5-minute warm-up on an ergometer cycle at a self-selected speed with moderate resistance. The laboratory protocol began with the subjects standing in a T-like position with their arms and elbows open in a static position. During the test, each effort was divided into three phases: lifting, standing pause, and lowering. The participants were randomly divided into two groups using a lottery. One group lifted and lowered a box ten times with a frequency of 10 times per minute (15% of body weight) for one minute while wearing a belt on the first day, while the other group did not wear a belt. After 24 hours, the same amount of loading was performed by the first group without a belt and the second group with a belt, and kinematic data were recorded. An electronic metronome provided an audible cue to begin each lift and descent. After recording the data, creating a time series and labeling the markers, and eliminating the distances between the paths, the markers were registered in Nexus software version 2.8.1 (Vicon Nexus, Oxford, UK).

The kinematic data filter used was a fourth-order low-pass Butterworth filter with zero delay and a cut-off frequency of 6 Hz. Lift movement cycles were separated using the vertical position of the marker placed on the anterior superior iliac spine (ASIS) of the subjects. Kinematic data were extracted using the three-segment model of the spine, including pelvis, LB, lower trunk, and upper trunk, in ProCalc software version 2.1.2 (Vicon ProCalc, Oxford, UK) (25). The beginning of the lift movement and the end of the lowering of the box were determined by the separation and re-contact of the box with the force plate. The moments of the end of the lift and the beginning of the descent were determined using the linear displacement data of the Z axis and as a complement to the movement of the center of pressure (COP) (36). After using ProCalc software to calculate angles, the data from movement cycles were normalized by dividing them into two phases. The first phase began at the start of the eccentric phase and ended at the knee extension position, and was normalized to 50 points. The second phase began at the start of the concentric phase and ended at the end of the movement, with the maximum knee flexion also normalized to 50-time points. This ensured that all motion cycles were normalized to one hundred points. After data processing, three segments of the spine and pelvis were analyzed using the modified vector coding method in MATLAB software (MATLAB R2013b, Natick Inc., Massachusetts, USA). The coordination and variability of the segments were then shown as frequency and time series data in graphs.

Vector Coding Analysis: To calculate coordination, the modified vector coding method described by Needham et al. was used (25). Thus, to calculate the coupling angle at any moment (i) during the lifting cycle, using the angles of the proximal segment (p) and the distal segment (D), the coupling angle (y_i) was obtained from equation 1.

Equation 1 $$y_i = tan^{-1}\left(\frac{\theta_{D(i+1)}-\theta_{(Di)}}{\theta_{p(i+1)}-\theta_{(pi)}}\right) \times \frac{180}{\pi}$$

Then, equation 2 was used to correct the coupling angle in values between zero and 360 degrees.

Equation 2 $$y_i = \begin{cases} y_i + 360 \; y_i < 0 \\ y_i \; y_i \geq 0 \end{cases}$$

To calculate the average values of vertical ($\bar{x}$i), horizontal ($\bar{y}$i), and coupling angle at each moment (i), relations 3 and 4 were used, where n is equal to the number of lifting cycles to be calculated.

Equation 3 $$\bar{x}_i = \frac{1}{n}\sum_{i=1}^{n} cos\ y_i$$

Equation 4 $$\bar{y}_i = \frac{1}{n}\sum_{i=1}^{n} sin\ y_i$$

Then, the average coupling angle was also obtained from relations 5 and 6.

Equation 5 $$\bar{y}_i = tan^{-1}\left(\frac{\bar{y}_i}{\bar{x}_i}\right).\frac{180}{\pi}$$

Equation 6 $$\bar{y}_i = \begin{cases} \bar{y}_i + 360\,\bar{y}_i < 0 \\ \bar{y}_i\,\bar{y}_i \geq 0 \end{cases}$$

The average length of the coupling angle was calculated from equation 7.

Equation 7 $$\bar{r}_i = \sqrt{\bar{x}_i^2 + \bar{y}_i^2}$$

Finally, the variability was obtained using equation 8.

Equation 8 $$CAV_i = \sqrt{2.(1 - \bar{r}_i)}.\frac{180}{\pi}$$

In order to calculate coordination, the modified vector coding method of Needham et al. (25) was used. The output data of coordination and variability are numbers between zero and 360 degrees, which are divided into 8 intervals for interpretation. If the coordination numbers are between zero and 90 degrees, the coordination is in-phase and both segments move in the positive direction. The movement is up to 45 degrees with the dominance of the proximal segment and between 45 and 90 degrees with the dominance of the distal segment. In numbers from 90 to 180 degrees, the coordination is anti-phase and the movement of the proximal segment is in the negative direction, i.e., clockwise, and the movement of the distal segment is in the positive direction, i.e., anti-clockwise, and up to 135 degrees, the distal segment is dominant and after that, the proximal segment dominates. Again, from 180 to 270 degrees, the coordination is in-phase and both segments move in the negative direction, and up to 225 degrees, the proximal segment dominates, and from 225 to 270 degrees, the distal segment dominates. Finally, from 270 to 360 degrees, the re-coordination is of anti-phase type; that is, the movement of the proximal segment is in the positive direction and the movement of the distal segment is in the negative direction, and from 270 to 315 degrees, the movement is done with the dominance of the distal segment and from 315 to 360 degrees with the dominance of the proximal segment (25).

Descriptive statistics were used to describe the mean and standard deviation (SD) of data. The normality of data distribution was checked using the Shapiro-Wilk test. The collected data were compared using paired t-test in SPSS software (version 24, IBM Corporation, Armonk, NY, USA) and statistical parametric mapping (SPM) method in MATLAB software. $P < 0.05$ was considered significant. All calculations were done in MATLAB software.

Results

16 people who met the inclusion criteria were purposefully selected for the study. 4 individuals declined participation due to coronavirus disease 2019 (COVID-19) concerns. After recruitment, 12 subjects participated. Table 1 displays the demographic characteristics of the participants.

Table 1. Demographic characteristics of subjects

Variable	Mean ± SD
Age (year)	22.38 ± 3.74
Weight (kg)	87.13 ± 4.21
Height (m)	1.76 ± 0.06
BMI (kg/m^2)	23.50 ± 1.38
Duration of sports activity (year)	3.28 ± 1.02
Duration of chronic nonspecific low back pain (year)	14.13 ± 10.20

BMI: Body mass index; SD: Standard deviation

The Shapiro-Wilk test indicated normal distribution for measured indices in all coordination patterns. Table 2 shows paired t-test results for the pelvic to lower lumbar segment (LB). Coordination and variability for lower lumbar to LT segment (LB/LT) and LT to UT segment (LT/UT) in sagittal plane were not significant and were not shown in the table. Significant difference in spine and pelvis coordination pattern was observed.

Table 2. Paired t-test results in concentric and eccentric phases

Phase	Belt use	Interval (degree)	Coordination index	P value
Concentric	Yes	0-45	-6.75 ± 8.29	0.020*
	No			
	Yes	225-570	-2.75 ± 1.53	0.035*
	No			
Eccentric	Yes	0-45	-7.50 ± 2.88	0.014*
	No			
	Yes	180-225	-5.00 ± 2.94	0.043*
	No			
	Yes	270-315	3.50 ± 2.08	0.044*
	No			

*Significant at P < 0.05 level
Data are reported as mean ± standard deviation (SD)

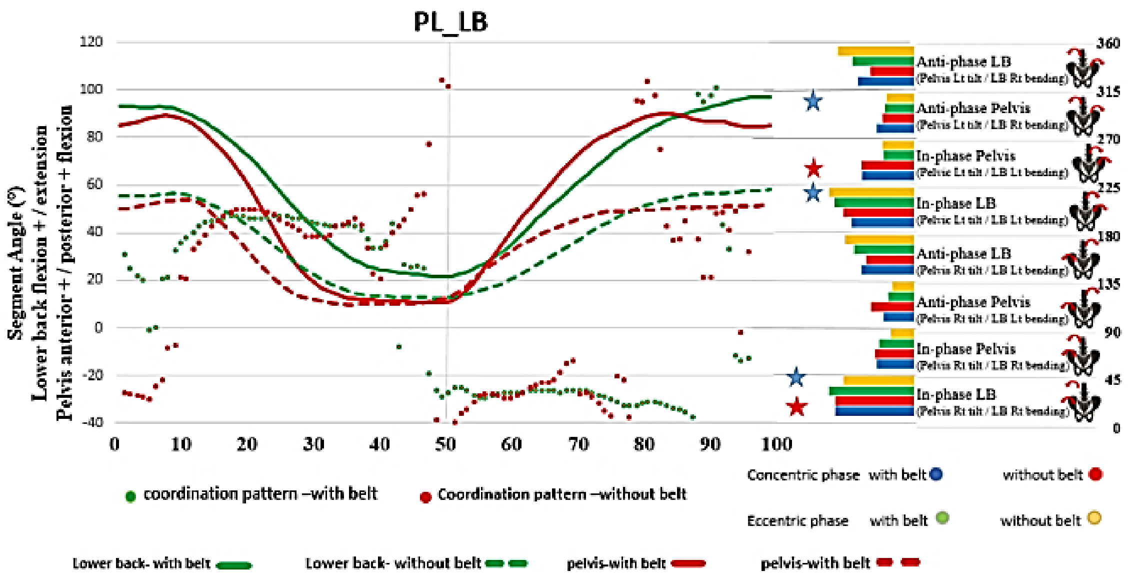

Figure 2. Kinematic view and kinematic coordination of the spine and pelvis in the sagittal plane

The coordination pattern of the spine and pelvis was compared between male athletes with non-specific chronic LBP in a state with a belt and without a belt during repetitive lifting. Significant decreases were observed in the concentric phase between 0 and 45 degrees in-phase with the dominance of the proximal segment (LB) (P = 0.020), and between 225 and 270 degrees in-phase with the predominance of the distal segment (pelvis) (P = 0.035) (Figure 2).

Observing the coordination patterns of the spine and pelvis with and without a belt during the eccentric phase, it was found that coordination was in-phase with proximal (LB) dominance from 0-45 degrees (P = 0.014) and significantly reduced from 180-225 degrees (P = 0.043). Meanwhile, between 270-315 degrees, there was an increase in anti-phase resynchronization with distal (pelvis) dominance (P = 0.044) (Figure 2).

Figure 3 shows the kinematic view and kinematic coordination of the LB to the lower thoracic on the site page.

Figure 4 shows the kinematic view and the LT to UT kinematic coordination in the sagittal plane.

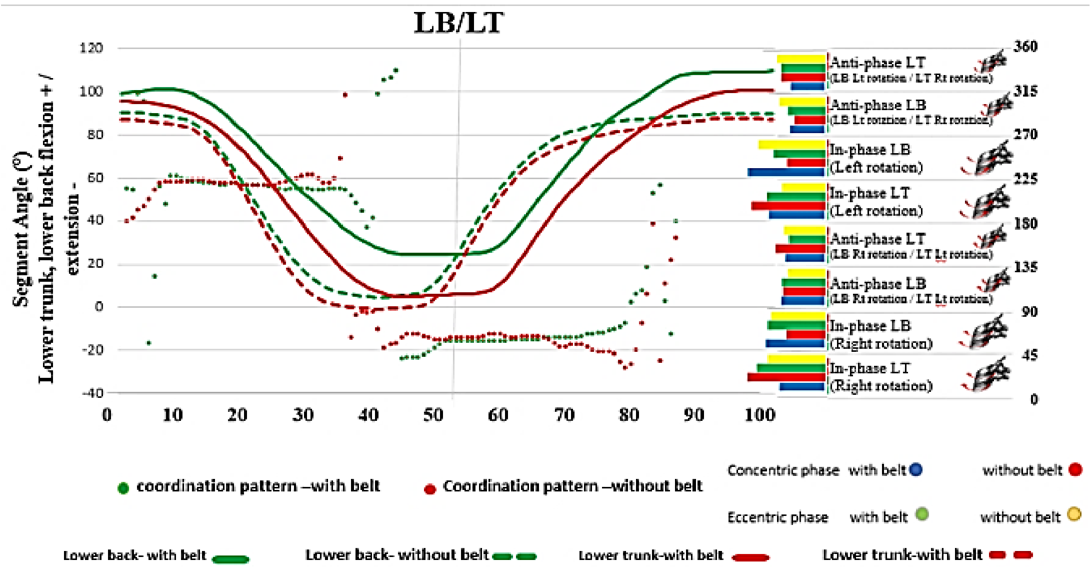

Figure 3. Kinematic view and kinematic coordination of the lower back (LB) to the lower thoracic in the sagittal plane

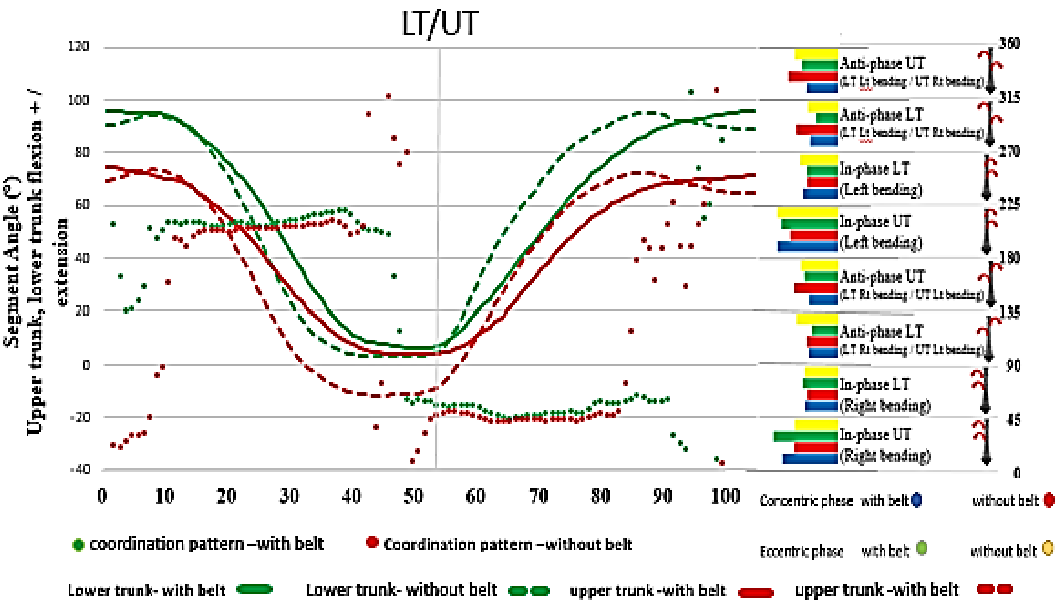

Figure 4. Kinematic view and kinematic coordination of lower thoracic (LT) to upper thoracic (UT) in the sagittal plane

According to the paired t-test using the SPM method, there was no significant difference in segment coordination variability between the two situations with and without a belt. The variability points did not reach the significance level of 0.05 (dashed line) (Figure 5).

Discussion

The aim of this study is to investigate the effect of weightlifting belts on spine and hip coordination variability in male athletes with non-specific chronic LBP. Due to a lack of uniformity in test protocols and implementation methods, we cannot directly compare these results to similar studies. Therefore, we tried to compare the results of research that investigated coordination patterns in the spine and pelvis with the present study. Pelvis/LB coordination patterns in repeated lifts in the sagittal plane indicate that in the concentric phase between 0 and 45 degrees, the in-phase coordination pattern is associated with waist predominance as the proximal segment. However, using a belt significantly reduces waist predominance, and instead, the pelvis moves forward more at the beginning of the phase, with pressure distributed more on the lower segment. Back injuries may be caused by the weakness of stabilizing role of the pelvis and excessive activity of the back area in injured individuals (37). Therefore, reducing pressure distribution in the LB can potentially reduce the risk of injury among athletes.

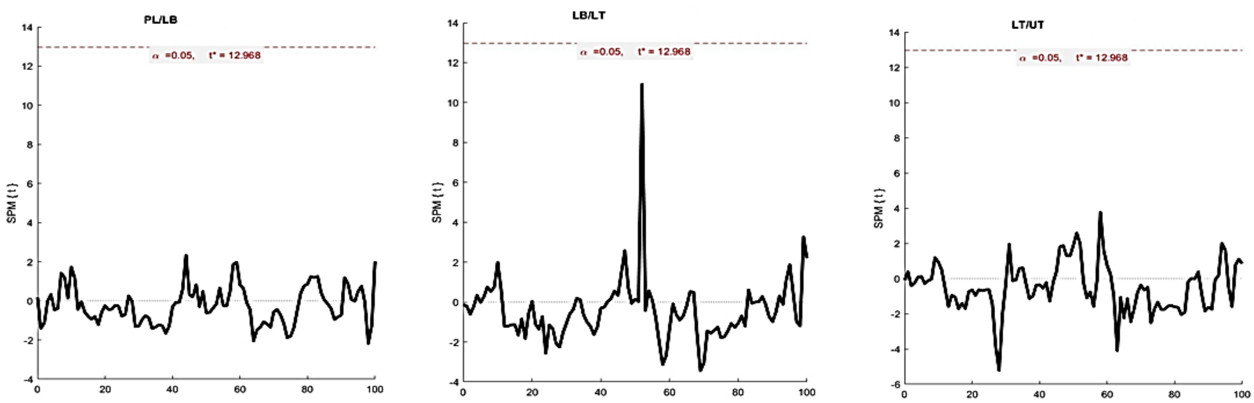

Figure 5. Statistical parametric mapping (SPM) analysis for coordination variability in the sagittal plane

In this study, it was found that wearing a belt significantly reduced the pelvis/LB coordination pattern during the concentric phase between 225 and 270 degrees. This reduction was observed when compared to the condition where the belt was not worn, with dominance of the distal segment (pelvis). The results were consistent with the research findings of Ghiasi et al. (37). They concluded that the pelvis played a supportive role in transferring movement from the distal to the proximal segment by reducing the movement of the lumbar region, which is associated with more pressure distribution in the lumbar segment. Significant decrease in the coordination pattern during the eccentric phase between 0 and 45 degrees was observed when the belt was tightened. This decrease was in the form of in-phase with the dominance of the proximal segment (LB) (37). The study concludes that by bringing the weight closer to the body and using the force of the spinal straightening muscles, the upper body movement prevails during movement and therefore, reduces the possibility of injury.

Coordination patterns between 180 and 225 degrees in eccentric phase decreased significantly with belt use, particularly in the proximal segment. This may affect distal couplings more than proximal during the beginning and middle of the phase in the sagittal plane, resulting in reduced pressure distribution and injury potential in athletes with chronic LBP. These findings were consistent with Romanazzi et al.'s study on closed chain movements in strength training (38).

During the eccentric phase, an increase in anti-phase coordination was observed with the dominance of the distal segment, specifically the pelvis between 270 and 315 degrees. Anti-phase coordination increased significantly with lumbar flexion and posterior tilt of the pelvis, which can be related to the end of the eccentric phase when the athlete leans on the hip to transfer flexion to lumbar extension. This pattern results in a better lumbopelvic rhythm, easier movement transfer to the spine, and less pressure on the lumbar spine (37).

Studies show that during pyramidal loading, there is poor transfer of movement from the distal to the proximal segment in the sagittal plane, which can lead to damage in the distal couplings. Wearing a belt during the eccentric phase may reduce pressure on the LB and prevent injuries (39). Coordination between segments during lifts was not significant, and inflexibility of the chest segment can hinder lifting low-mass objects (40). Patients with LBP may try to transfer the load to the thoracic region, and wearing a belt can be an obstacle to this transmission (41).

The statistical analysis of segment coordination variability in SPM showed no significance, possibly due to the small number of subjects and the complexity of the variable. Coordination variability in the sagittal plane lift movement decreased at the end of the concentric phase and the beginning of the eccentric phase, indicating motor adaptation for reduced flexibility and contributing to lifting cycle stability (42). However, LB/LT coordination variability increased at the end of the concentric phase and the beginning of the eccentric phase in the deadlift movement, possibly due to the functioning of the nervous system and its feedback (42).

In both conditions, with and without the belt, the variability of LT/UT coordination decreased in the middle of the deadlift's concentric phase. It can be concluded that fatigue and load affect coordination variability, which is a necessary strategy for repetitive tasks. The reduction of variability can also be considered a type of motor adaptation to control movement and an explanation for the reduction of flexibility (43, 44).

Limitations

One limitation of this study is the lack of similar research in Iran and other countries, which makes it difficult to compare hypotheses and interpret findings. Another limitation is the small sample size, as the spread of COVID-19 prevented the evaluation of more samples. However, power analysis shows that this did not affect the validity of the reported results.

Recommendations

It is suggested to investigate the effect of using weight belts on the variability of spine and pelvis coordination in the repetitive lift of healthy athletes with chronic LBP along with intra-abdominal pressure measurement and focusing on the central stabilizing muscles of the body and proprioception of the spine area. Moreover, in the present research, male bodybuilders were considered as a group. Therefore, it is suggested to compare men and women separately in future studies.

Conclusion

The study highlights the importance of weight belts in reducing the variability of spine and hip coordination during repetitive lifting for male athletes with chronic LBP. The use of a belt facilitates the proper transfer of movement from distal to proximal segments, potentially preventing LBP.

Acknowledgments

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Authors' Contribution

Study design and ideation: Ali Abbasi
Getting financial resources for the study: Ali Abbasi
Scientific and executive support of the study: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia
Data collection: Hamed Fadai, Sheida Shurabadi, Mostafa Sajedinia
Analysis and interpretation of the results: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia
Specialized statistics services: Ali Abbasi
Manuscript preparation: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia
Specialized scientific evaluation of the manuscript: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia
Confirm the final manuscript to be submitted to the journal website: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia
• Maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments: Hamed Fadai, Ali Abbasi, Sheida Shurabadi, Mostafa Sajedinia.

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Conflict of Interest

Authors have no conflict of interest.

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