Original Research Article

Muscular Asymmetry is Positively Correlated with Lumbar Back Pain in Wrestlers

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ABSTRACT

Wrestling, one of the oldest combat sports, has had a notable history of lumbar spine injuries among their athletes. High rates of reported lumbar spine injury in wrestlers by a variety of sports organizations have yet to elicit the response of any direct formal research regarding specific injury mechanics. Training habits, along with competition behavior, must be evaluated, as data shows that injuries occur much more commonly in wrestling practice compared to other sports' practices. Muscle strains are typically the most common form of lumbar spine injury within wrestlers, and have been shown to induce lower back pain, inhibit movement, and evoke recurring injuries in the future. Previous research has rigorously analyzed general spine injuries along with lumbar spine injuries across all sports. There is a research gap around the biomechanical predictors of lumbar spine injury. No studies have focused specifically on the muscular risk factors that can lead to lumbar spine injury in wrestling. The purpose of this research is to uncover modifiable muscular biomarkers that can be shown to result in a higher chance of lumbar spine injury. It was hypothesized that muscular imbalance and instability will be the most identifiable risk factors associated with lumbar spine injury. This study analyzed a synthetic dataset of 1000 wrestlers' biomechanical markers and parameters. T-Test revealed that Lumbar Back Pain had a statistically significant difference in score of Trunk Asymmetry than those reporting no Lumbar Back Pain ($p < 0.0001$). The same was true for spinal erector muscle imbalance scores ($p < 0.0001$). Future studies are encouraged to evaluate athlete condition and markers over an extended period.

Keywords: Wrestling; Lumbar Spine; Lumbar Back; Lumbar Back Pain; Biomechanics; Biomarkers; Injury

INTRODUCTION

Wrestling is one of the most spine injury-prone collegiate sports, only falling slightly behind men's ice hockey (1, 2). Research consistently shows that the nature of wrestling positions leads to a significant number of spinal injuries within young athletes (3–6). Studies show that back injuries have a notable and positive association with prolonged back pain in the future (7). Lower back pain is a major issue amongst athletes and the general population worldwide (3, 5, 6). In 2020, lower back pain affected over 600 million people worldwide (5). Such back pain leads to a significantly decreased quality of life, ability to conduct basic movements, l*et al*one to compete in a competitive sporting environment (6). Previous studies have focused on specific biomechanical

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kinematics that led to injuries in wrestling contexts (7), however, there is little research done regarding spinal injuries in wrestlers: specifically, the lumbar spine.

Lumbar spine injuries in men's wrestling occur at an exceedingly higher incidence than any other male sport activities, apart from male ice hockey, according to the NCAA Injury Surveillance Program (1). Wrestling also showed a longer recovery time from a lumbar spine injury out of any other men's sport activities in the NCAA, with 21% of wrestlers restricted from sport participation for 7-21 days after injury (1). The most common form of lumbar spine injury across all sports was classified under the lower back strains category (1, 6).

It has been briefly demonstrated in studies that muscle imbalance, strain, and fatigability is a main biomarker of future back injury within athletes such as wrestlers and judoka (8). A review of collegiate wrestlers and judoka identified asymmetrical or reduced trunk muscle cross-sectional area –resulting from sport-specific asymmetrical movements– as a key muscular biomarker for future lumbar intervertebral disc degeneration (8).

There are a wide variety of studies focusing on biomarkers leading to such injuries in more traditionally popular sports such as basketball, football, and hockey. However, no research includes direct and intentional focus on these same biomarkers in wrestlers. Few studies have analyzed specific modifiable biomechanical risk factors that predict lumbar spine injuries in wrestlers (8). There is a specific research gap on biomechanical markers that may lead to lumbar spine injuries in wrestling.

Given the high prevalence of lumbar injuries and the repetitive spinal stresses unique to wrestling, there is a strong need to identify modifiable muscular risk factors that contribute to these injuries. Therefore, the purpose of this research is to analyze biomechanical markers in wrestling to identify modifiable muscular risk factors associated with lumbar spine injury and lumbar back pain. Specifically, lumbar muscles will be analyzed for any possible indicators that may lead to lumbar back pain (LBP).

Based on previous research and knowledge already established on this topic, it was hypothesized that muscular imbalance will be the most identifiable risk factor associated with lumbar back pain.

METHODS AND MATERIALS

Synthetic data from 1000 wrestlers (Age 20.5 ± 2.5 yrs; Height 175 ± 22.2 cm; Weight 75.75 ± 36.15 kg) was utilized for this study. The wrestlers had generated physical traits, surface muscular electromyography (EMG), and prior lumbar spine injury incidence. Lumbar spine flexion and extension, trunk rotation and asymmetry index, left and right spinal erector muscle EMG, muscular imbalance, and total spinal load were all analyzed and evaluated.

Lumbar flexion and extension angles were measured using digital inclinometers following standardized lumbar range of motion (ROM) assessments. Measurements were taken in standing posture with the inclinometer placed over T12 and S1 vertebrae. The difference in angle was recorded during maximal forward flexion and maximal backward extension. Each measurement was repeated twice and averaged for accuracy.

Trunk rotation was evaluated by using a seated goniometry method, to minimize pelvic compensation. Wrestlers were instructed to rotate maximally to both sides whilst keeping their hips fixed. The resulting angle of rotation was measured using a goniometer placed on the shoulder along the axis of the spine.

Trunk asymmetry was based on differences of right and left trunk muscle strength, activation, along with rotational ROM. Higher values of trunk asymmetry index indicate greater imbalance. This metric is commonly derived from strength testing or imaging-based muscle measurements. Range of motion was derived through identical methods of trunk rotation. Surface EMG electrodes were placed over both sides of the lumbar erector spinae muscles to measure trunk muscle strength and activation. EMG signals were recorded during isometric trunk extension tasks. Average amplitude (mV) was used as the outcome measure.

Muscular imbalance index was calculated from the absolute difference between left and right erector spinae EMG amplitudes during the same tasks as Trunk Asymmetry Index. A larger muscular imbalance index indicates a higher discrepancy of side-to-side muscle activation, possibly showing indicators of neuromuscular and physical muscular imbalance.

Lumbar spine compressive load was estimated using inverse dynamics modeling. Kinematics were collected using a video capture system, and external force was recorded by force plates during lifting or sport specific movements. Musculoskeletal models on the OpenSim software were used to calculate joint reaction forces, from which the lumbar compressive loads were extracted in Newtons (N).

A binary variable representing previous lumbar spine injury was included in the synthetic dataset, with approximately one third of simulated wrestlers classified as having a prior injury. Reported lumbar back pain (LBP) was also modeled as a binary outcome variable within the dataset for analytic comparison.

Data was analyzed with Python (v3.x) in Google Colab (Google LLC, Mountain View, CA, USA), resulting in descriptive statistics, Pearson correlative tests, and graphical representation of relationships between biomarkers and lumbar spine injury within the data. Pandas, Numpy, Os, Seaborn, and Matplotlib. pyplot were all imported into Colab as libraries. T-tests and Pearson Correlation Tests were imported into Colab from Scipy.stats. Pearson correlation coefficients were applied to evaluate relationships among trunk asymmetry, muscular imbalance, and reported lumbar spine injury. During Pearson tests, standardized residuals showed no influential outliers, and variable distributions were approximately normal. Correlation strength was interpreted using Cohen's thresholds ($r = 0.10$ small, 0.30 moderate, 0.50 large). Differences in group values were identified as statistically significant if p-values (resulting from T-Tests) were less than the value of 0.05. No procedures were utilized to normalize or validate data. Because this study relied exclusively on computationally generated synthetic data and did not involve real human participants, this research did not require IRB approval or equivalent ethics committee. No personally identifiable information existed within the dataset.

RESULTS

The purpose of this study was to identify modifiable biomechanical markers associated with reported lumbar back pain (LBP) in wrestlers. Specifically, trunk asymmetry, muscle imbalance, spinal load, and prior lumbar injury were evaluated in relation to reported LBP. Descriptive statistics for demographic and exposure variables are shown in Table 1. Biomechanical parameters are summarized in Table 2.

All data, whether general or biomechanical, was recorded and organized into two tables. Table 1 consists of general information (age, height, weight, etc.), and Table 2 consists of specific biomechanical measurements and evaluations (Trunk rotation (°), Lumbar Flexion (°), Trunk Asymmetry Index, Muscle Imbalance Score, etc.). Analysis through T-Test reveals a statistically significant difference of the Trunk Asymmetry Index between LBP groups. Specifically, the LBP group had a significantly higher score than the No LBP group, as shown in Figure 1 ($p < 0.0001$). T-Test also revealed a statistically significant difference between Muscle Imbalance Score and LBP groups. LBP groups had significantly higher scores than the No LBP group, as shown in Figure 2 ($p < 0.0001$).

Analysis through Pearson correlation tests revealed correlations between Reported LBP and Trunk Asymmetry, Reported LBP and Muscle Imbalance, as well as Reported LBP and Previous Lumbar Injury. Reported LBP shows a weak correlation with Trunk Asymmetry Index under Cohen's Thresholds (Pearson correlation: $r = 0.29$). Reported LBP shows a weak correlation with Muscle Imbalance Index under Cohen's Thresholds (Pearson correlation: $r = 0.14$). Reported LBP shows a moderate correlation with Previous Lumbar Injury under Cohen's Thresholds (Pearson correlation: $r = 0.44$). All correlation values between the variables identified in Table 1 and Table 2 are shown in a heat map in Figure 3.

Table 1. Subject Information Descriptive Statistics.

Measure	Mean	Std	Min	25%	50%	75%	Max
Age	20.51	1.68	18.00	19.00	21.00	22.00	23.00
Weight (kg)	77.97	10.35	39.60	70.90	77.90	85.10	111.90
Height (cm)	175.30	7.15	152.80	170.90	175.10	180.10	197.20
Competition Exposure (hr)	39.41	10.12	4.90	32.70	39.20	46.20	73.50
Practice Exposure (hr)	120.10	30.97	30.80	100.60	121.30	141.00	210.00
Reported LBP	0.34	0.48	0.00	0.00	0.00	1.00	1.00
Previous Lumbar Injury	0.34	0.48	0.00	0.00	0.00	1.00	1.00

Note: This table summarizes demographic and exposure characteristics of the wrestler dataset (n=1000). Measures include age, height, weight, and cumulative practice and competition exposure hours. Reported LBP and Previous Lumbar Injury are both identified as either 0 or 1 (0 = No; 1 = Yes).

Table 2. Subject Biomechanical Parameter Descriptive Statistics.

Measure	Mean	Std	Min	25%	50%	75%	Max
Lumbar Flexion (°)	50.13	7.82	25.70	44.50	49.90	55.40	77.10
Lumbar Extension (°)	25.25	5.05	10.80	22.00	25.00	28.50	39.60
Trunk Rotation (°)	40.47	9.93	18.80	34.10	40.40	47.20	85.20
Trunk Asymmetry Index	0.15	0.06	-0.04	0.10	0.14	0.19	0.32
Left Erector EMG (mV)	0.60	0.10	0.23	0.53	0.60	0.67	0.93
Right Erector EMG (mV)	0.58	0.10	0.23	0.51	0.58	0.64	0.91
Spine Load (N)	2201.00	297.20	1160.00	2018.00	2216.00	2405.00	3155.00
Muscle Imbalance Score	0.24	0.10	0.02	0.17	0.23	0.30	0.76

Note: This table presents descriptive values for lumbar range of motion, trunk rotation asymmetry, erector spinae EMG activity, and estimated spine loading of wrestlers (n=1000). These variables represent biomechanical predictors evaluated for their association with low back pain incidence among the wrestler cohort.

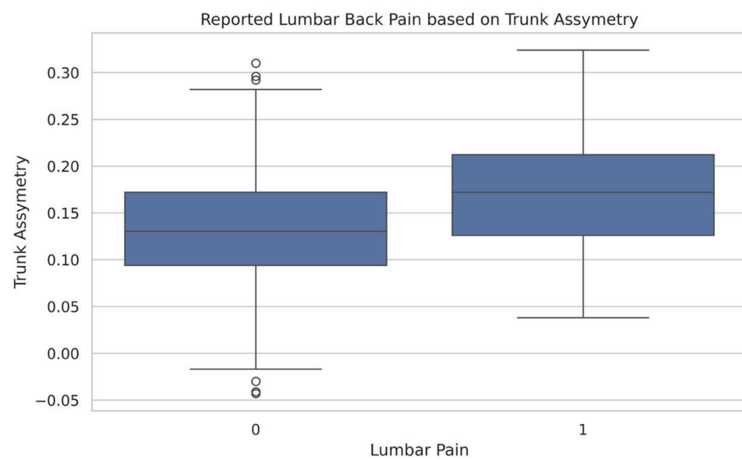

Figure 1. *Boxplot of Reported LBP vs. Trunk Asymmetry (n=1000) (0=no 1=yes). Wrestlers reporting lumbar back pain showed higher median trunk asymmetry and greater consistency compared to those without pain.*

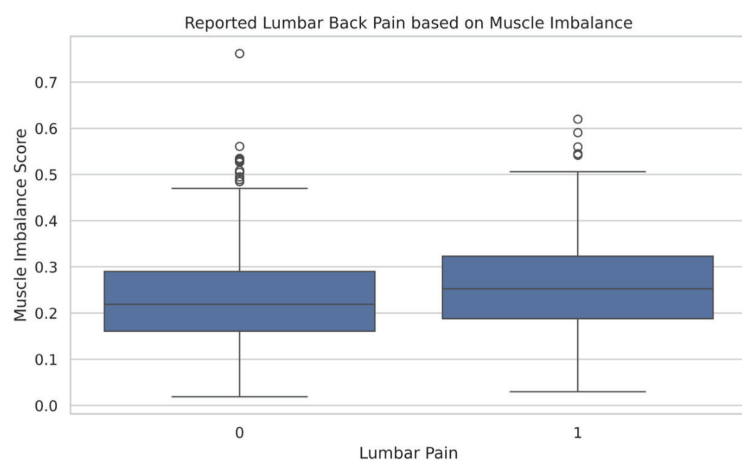

Figure 2. *Boxplot of Reported LBP vs. Muscle Imbalance (n=1000) (0=no 1=yes). Wrestlers with lumbar back pain demonstrated slightly higher muscle imbalance scores, though differences between groups were less distinct.*

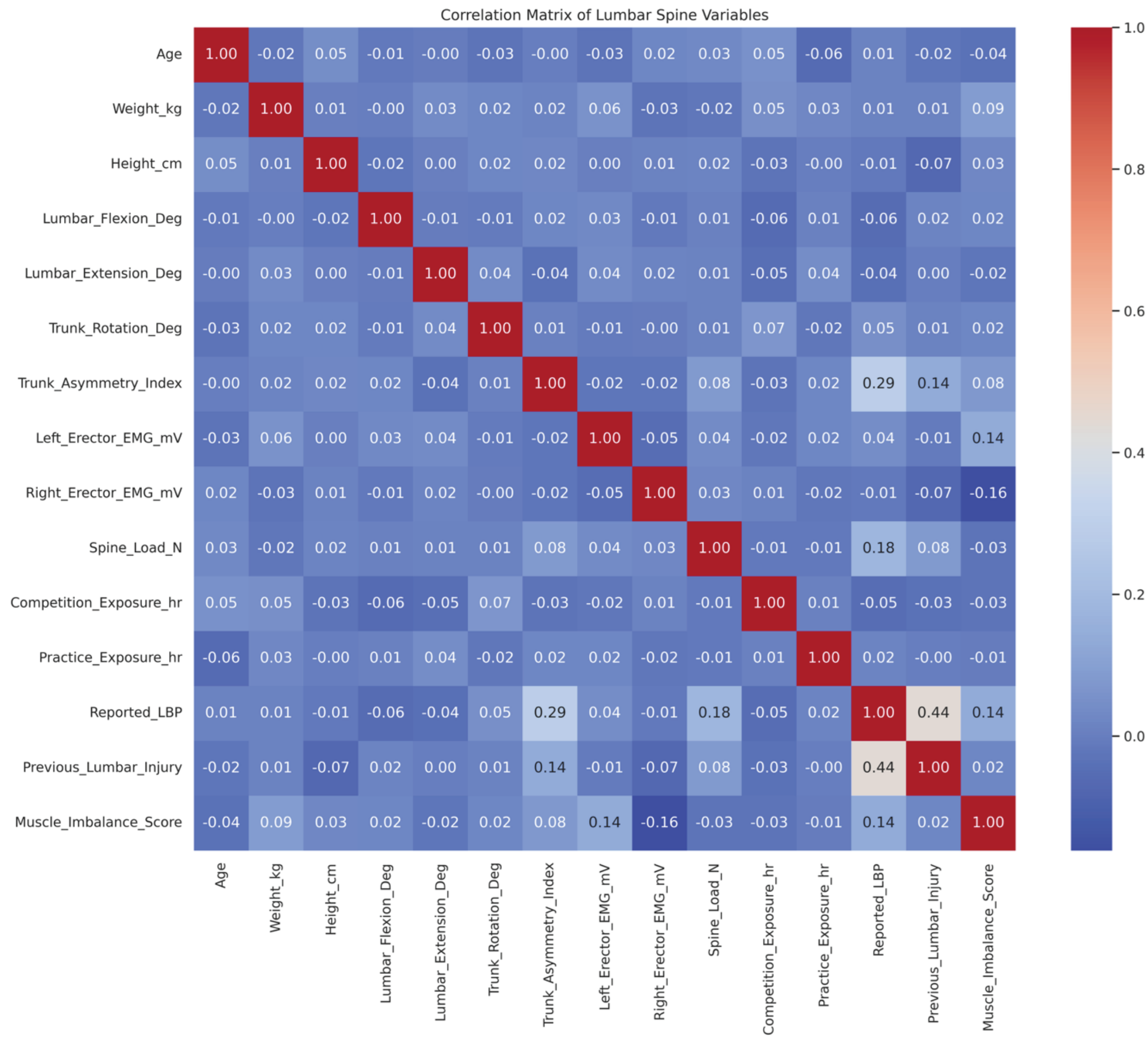

Figure 3. *Heat Map correlation of all variables (n=1000). Reported lumbar back pain showed the strongest correlations with trunk asymmetry (r = 0.29), muscle imbalance score (r = 0.14), and previous lumbar injury (r = 0.44), while other variables demonstrated minimal associations.*

Wrestlers reporting lumbar back pain demonstrated significantly greater trunk asymmetry and muscle imbalance compared to those without LBP. Among all evaluated variables, previous lumbar injury exhibited the strongest association with reported LBP (r = 0.44). Other biomechanical measures, including spinal load and range of motion variables, showed minimal association with LBP.

DISCUSSION

The purpose of this study was to determine modifiable muscular risk factors that are associated with LBP. The initial hypothesis was supported only in the sense that statistically significant associations were observed; however, the strength of these relationships was weak. The scope of the research pivoted from purely muscular markers to a variety of biomechanical markers, such as trunk asymmetry, spine load, or trunk flexion and extension angles, and how these markers are related to LBP.

Trunk asymmetry demonstrated a statistically significant but weak association with reported lumbar back pain, as shown in Figure 1. Trunk asymmetry was calculated through differences in trunk muscle strength and rotational range of motion. Muscle imbalance is a factor in the calculation of trunk asymmetry index. As shown in Figure 2, this result is reinforced by the difference of reported LBP in groups with and without muscle imbalance, which resulted in a statistically significant difference.

It was found that direct muscular asymmetry or imbalance was not the most identifiable marker of LBP. According to statistical analysis conducted, the strongest indicator of LBP in this study was shown to be any instance of previous lumbar injury. Whilst determining whether previous lumbar injury is a main marker of future LBP, it is still a notable result, as prior injuries may lead to other muscular imbalances, asymmetries, or biomechanical limitations. These correlation magnitudes all represent weak/moderate associations that do not indicate substantial biomechanical or clinical predictive value.

It has been shown that varsity athletes with a history of lumbar back injury have greater muscular imbalance in their lumbar and thoracic erectors (9–11). Because muscular imbalance was calculated based on the different between left and right erector strength and activation, these findings suggest a possible cyclical relationship, which in turn lead to higher incidence of lumbar erector muscle imbalance in athletes (9–11). Though it is important to note that the associations in this study were weak and cannot establish causality.

Previous reviews and studies have shown correlation between athletes in sports where asymmetric movements are common (wrestling, tennis, etc.) are more likely to have an incidence of muscle imbalance in the lumbar region. In a recent study, Zemkova *et al*. (2024) identified five contributing factors of lower back injury in wrestlers: repetitive trunk rotation, asymmetric movements, repetitive motion, trunk compression, and prolonged flexion (8). Whilst this study did not directly identify five factors of lower back injury, there are many aligned findings and overlapping of biomarkers that are associated with injury, such as trunk asymmetry and muscle imbalance, which were the two main findings of this study.

On the other hand, results from this research seem to differ from Boden *et al*. (2008), as they found that direct axial compression forces are the leading cause of spinal fracture in wrestlers. In this study, there was no correlation found between Spinal Load and Reported Lumbar Back Pain (6). However, it is also important to identify the differences between these two studies, as this study aimed to identify specific biomarkers that may lead to lumbar back injury and pain, whilst Boden *et al*. (2008) analyzed biomarkers of cervical spine injury. The differences in results can therefore be attributed to the specific anatomical differences of the lumbar and cervical spine. The results of this study, although holding weak correlations, are aligned with prior studies: muscle imbalance and trunk asymmetry are possible markers of LBP and injury (1, 2, 5, 8).

One major limitation of this study is the utilization of synthetic data. Although specific data and biomechanical markers may line up with previously established trends in the medical field, synthetically generated data follow predefined patterns, whether intentional or not. Therefore, it is difficult to attribute the findings to actual clinical practices. Data was also only collected during one moment in time. Therefore, it is uncertain which markers are caused by LBP or injury, and which are good indicators of future or current LBP or injury.

The evolution of the analytic scope beyond the original hypothesis also impacts the validity of findings. The initial hypothesis specifically predicted that muscular imbalance and instability would be the most identifiable risk factors associated with lumbar back pain. However, during analysis, the scope expanded to include additional biomechanical markers such as trunk asymmetry. While these variables remain biomechanically relevant, this broader inclusion may dilute the clarity of hypothesis-based testing, introducing elements of unexpected analysis. As a result, findings related to non-muscular markers should be interpreted cautiously.

An additional limitation of this study was the wide range of simulated height and weight values, which may not accurately reflect the distribution typically observed in competitive wrestling populations. This variability is likely a byproduct of synthetic data generation and may limit the external validity of the findings. The initial hypothesis has been partially supported based on direct correlation testing between muscle imbalance and reported LBP yielding weak correlation and insignificance to practical or clinical use. Future studies evaluating muscular markers linked to lumbar back pain or injury should consider longitudinal designs, tracking athletes' biomechanical markers and symptoms over an extended period.

CONCLUSION

It was found that there is a weak but statistically significant difference between trunk asymmetry and groups of reported LBP and no reported LBP ($p < 0.0001$; $r = 0.29$). A weak but statistically significant difference was also observed between muscle imbalance and groups of reported LBP and no reported LBP ($p < 0.0001$; $r = 0.14$). Muscle imbalance in spinal erectors has been shown to be caused by sports where asymmetric movements are common (i.e. wrestling), which indicates LBP and injury caused by muscular imbalance is more likely to occur in wrestlers. Outside of biomechanical risk factors, previous lumbar injury had the strongest –although still moderate– correlation to reported LBP ($r = 0.44$). Though this study cannot establish that modifying imbalance would reduce LBP due to the weak associations observed, interventions that address muscular imbalance are commonly recommended in athletic training literature. Muscular imbalance in the spinal erectors can be mitigated through targeted training and rehabilitation programs. Simple training recommendations to improve spinal erector strength and stability include bird dog exercises (rows, stable holds, extensions, etc.), and back extensions. Larger compound movements, such as deadlifts, standing barbell rows, or barbell good mornings require spinal erectors as both stabilizing and working muscles for the movements (11). Future studies are encouraged to employ a controlled cohort of competitive wrestlers and track biomechanical markers longitudinally to better understand their correlation with lumbar back pain and injury.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this work

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