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Anthropometric evaluation of trunk parameters in chronic low back pain: a comparative study with age- and sex-matched controls

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Abstract

Background Low back pain (LBP) is a complex and multifaceted condition influenced by factors such as obesity, skeletal deformities, and abdominal muscle dysfunction, though the exact occurrence and interrelationships of these factors remain unclear. The aim of this study is to investigate the anthropometric differences in the trunk between LBP sufferers and healthy controls, exploring the association with obesity and respiratory function.

Methods This cross-sectional study evaluated 50 adult patients with chronic LBP and 50 age- and sex-matched healthy controls. Anthropometric parameters including waist circumference, waist-to-height ratio, respiratory amplitude, sternum length, and the distance between the xiphoid process and pubic symphysis were measured, and the occurrence of diastasis recti was investigated. Group differences were analyzed using independent *t*-tests and chi-square tests.

Results The LBP group exhibited significantly larger waist circumferences ($p = .016$), higher waist-to-height ratios ($p = .004$), and reduced respiratory amplitudes ($p < .001$) compared to controls. No significant differences were observed in sternum length and xiphoid process-pubic symphysis distance. The study found no significant link between LBP and diastasis recti, but post-hoc analysis indicated that larger waist sizes are associated with a 10.7% higher likelihood of diastasis.

Conclusions LBP is significantly associated with increased waist circumference and waist-to-height ratio, as well as decreased respiratory amplitude, highlighting the potential role of obesity and compromised respiratory function in LBP. No significant differences were observed in measures related to postural development, such as sternum length and the distance between the xiphoid process and the pubic symphysis.

Clinical implications Although our findings highlight associations between LBP and increased waist circumference, waist-to-height ratio, and reduced respiratory amplitude, the cross-sectional nature of this study does not allow for

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causal conclusions. These results suggest areas for further research into whether targeted interventions focusing on weight management and respiratory function training could benefit individuals with LBP.

Keywords Spinal pain, Waist-to-height ratio, Respiratory amplitude, Diastasis recti, Trunk anthropometry

Introduction

Low back pain (LBP) is a multifactorial symptom stemming from innumerable causes. It constitutes significant amounts of disability, imposing substantial financial burdens among sufferers [1]. Determining the exact causes of LBP, including identifying a specific structural correlate, is extremely challenging. Age, sex, social status, educational level, psychosocial influences, postural stabilization quality, and genetic factors, among others, are considered the most prevalent risk factors contributing to LBP [2, 3]. While numerous studies indicate an association between obesity and prevalence of LBP and disability [4–6], strong consensus regarding the specific anthropometric parameters related to obesity that contributing to LBP does not exist. In a large observational study including 5887 men and 7018 women, no interactions were identified between waist and height, waist-to-hip ratio, or body mass index (BMI) with LBP symptoms in either sex. However, an increased likelihood of LBP was noted in women, but not men with larger waist sizes [4]. A more recent meta-analysis evaluating such metrics noted an increase in LBP with increased waist circumference, waist-to-hip ratio, body fatness, and total body fat mass, regardless of BMI [6].

The relationship between morphological skeletal deformities and LBP also remains unclear. Some studies suggest that LBP is more prevalent in individuals with spinal deformities [7], disc degeneration [8–11], structural hip abnormalities [12, 13] or pelvic asymmetry [14]. Conversely, other authors have noted weak evidence of such positive associations between specific morphological parameters and LBP [15, 16]. The objective of this study is to investigate the associations between specific anthropometric parameters, including waist-to-height ratio, respiratory amplitude, and the occurrence of diastasis recti, with chronic LBP in a controlled cohort. We hypothesize that individuals with LBP will exhibit larger waist-to-height ratios, reduced respiratory amplitudes, and a higher prevalence of diastasis recti compared to age- and sex-matched healthy controls.

Among various structural factors, some authors discuss the presence of diastasis recti, a separation of the rectus abdominis muscles, as a potential cause of LBP [17–19]. The precise cause and consequences of diastasis are not entirely clear; however, it is associated with pregnancy and obesity, as connective tissue weakening and abdominal wall dysfunction is described in the literature [17, 20, 21]. During postural-stabilization activities, the diaphragm moves downward to increase intra-abdominal pressure, while a weakened abdominal wall due to diastasis can compromise the ventral support and stability of the lumbar spine to prevent pathological overload [22, 23]. Disruption of abdominal muscle coordination further leads to dysfunctional breathing mechanics and poor breathing stereotypes [23, 24].

Motor development and levels of physical activity during childhood and adolescence may be additional factors related to LBP incidence [25]. The interaction between muscle activity and skeletal development is a fundamental aspect or early human ontogenesis [26]. The chest is mainly influenced by the movement of the upper limbs, the development of the lungs and breathing. The circumference of the chest gradually increases from birth and the so-called invagination occurs (the thoracic spine sinks into the chest cavity between the costal arches) [27]. Abnormal development of these structures can impact thoracic biomechanics of the thoracic spine and affect the loading and stability of the spine as a whole [28]. Even throughout adulthood, maintaining muscle health to ensure skeletal integrity remains crucial. An interdependency exists between muscle and bone; as viable muscle function is critical for bone health [29] and muscle strength is critical for healthy aging [30]. The fundamental principles of form-function relationships imply that any significant alteration in form, including skeletal alignment, can impact skeletal muscle performance, and similarly, changes in muscle performance can influence skeletal form [31]. This reciprocal relationship underscores the interconnectedness of skeletal structure and muscle functionality.

In summary, while prior studies have investigated associations between obesity, anthropometric parameters, and LBP, there is limited consensus on which specific parameters contribute to LBP. Furthermore, the interactions between parameters such as waist-to-height ratio, respiratory amplitude, and diastasis recti remain underexplored in controlled, comparative settings. To address this gap, our study examines these anthropometric measures in a well-matched cohort of LBP patients and healthy controls, offering new insights into their potential roles in LBP pathophysiology.

Methods

Participants

A total of 100 participants were included in this cross-sectional study, with each providing written informed consent prior to any data collection. The study conformed with The Code of Ethics of the World Medical

Association and was approved by an Institutional Ethics Committee. The sample included 50 patients with chronic lumbar spine pain and 50 healthy individuals matched by age and sex to the patient group. Patient data were collected from January 2022 to June 2023 at a hospital rehabilitation department. Matching healthy controls were recruited from among the hospital staff, and patients' and hospital staff relatives. The inclusion criteria for participants in the LBP group required the presence of lumbar pain for a minimum duration of six months, a diagnosis of degenerative spine diseases, and a score of at least 5 points on the Oswestry Disability Index (ODI) [32]. Exclusion criteria encompassed participants whose symptoms were caused by injuries (e.g., acute trauma, fractures), congenital defects, tumors, neurological disorders (e.g., radiculopathy, myelopathy), or systemic diseases (e.g., rheumatoid arthritis). The LBP group comprised 50 individuals; 28 women (age = 57.8 ± 15.8 years, ODI = 16.8 ± 7.7) and 22 men (age = 58.6 ± 10.3 years, ODI = 12.9 ± 6.4), with reported back pain durations ranging from 6 months to 40 years, with an average problem duration of 11.1 ± 10.8 months. The control group comprised 50 individuals who were matched by sex and age; 28 women (age = 59.5 ± 16.2 years, ODI = 0.18 ± 0.77) and 22 men (age = 60.6 ± 14.4 years, ODI = 0.59 ± 1.8) without long-term lumbar pain (less than 5 points on the ODI). The exclusion criteria for the control group mirrored those of the patient group.

Assessments

Firstly, all participants provided anamnestic data, which included their sex, age, body height, and weight, as well as information on whether they experienced pain in the lumbar spine and the duration of this pain. Additionally, all participants completed the Oswestry Low Back Pain Disability Questionnaire version 2.1a [33] to calculate the Oswestry Disability Index (ODI). The questionnaire assesses limitations of common daily activities due to LBP, thus quantifying the subjective difficulties of the patient and expressing the degree of disability. It is available in the local language and has undergone linguistic validation for that version [34].

The anthropometric parameters were consistently measured by the same clinician, and all data were recorded in a specially prepared protocol. Initially, a stadiometer was used to measure patient's body height which was recorded in cm. Then, the patient's waist circumference was measured in an upright position, adhering to the NHANES III guidelines for waist measurement [35] (Fig. 1A). Subsequently, we measured the respiratory amplitude of the chest at the xiphoid level. This involved using a cloth tape to record the difference in chest circumference between maximum inhalation and exhalation [36] (Fig. 1B). We conducted this measurement over three breathing cycles and calculated the average value from these three measurements for statistical purposes. Using a standardized anthropometric gauge (Fig. 1C), the distance between the fossa jugularis and the xiphoid process was measured while the patient lay in a supine position (Fig. 1D). As reported by Marcus et al. [37], this gauge is as reliable as CT scans for such measurements. Then, the distance from the xiphoid process to the pubic symphysis was measured (Fig. 1E). Both these distances were then expressed as a percentage of the patient's body height. Finally, the determination of abdominal muscle diastasis was conducted using the method published by Oplova et al. [38]. The subject lied on their back with flexed lower limbs and support on the soles, and performed a lifting of the head, shoulders, and torso with extended upper limbs until the angulus inferior of the scapulae was lifted off. During such activation, the medial edges of the rectus abdominis muscle bellies were palpated (Fig. 1F) and the distance between these edges was measured using the anthropometric gauge. Diastasis was identified as a separation between the two rectus muscles exceeding 15 mm above the umbilicus [39]. All measurements were conducted in the morning between 9:00 and 12:00, as this was the designated time allocated for assessments by the examiner. While participants were not given specific instructions regarding the timing of their last meal, it is likely that most participants had eaten breakfast at least one hour before the assessment and had not yet eaten lunch.

1A: Waist circumference measurement; 1B: Respiratory amplitude measurement; 1C: Anthropometric gauge; 1D: Measurement of the fossa jugularis –xiphoid process distance; 1E: Measurement of the xiphoid process –pubic symphysis distance; 1 F: Diastasis recti assessment.

Statistical analysis

Descriptive statistics were calculated for all variables. Data are mean ± standard deviation, unless otherwise noted. All variables were normally distributed, by assessing calculated z-score kurtosis and skewness values. An independent samples *t*-test (two-tailed) was used to compare the chosen variables in all patients with LBP to sex-matched controls. A two-way analysis of variance (ANOVA) was used to determine the effect of sex and condition on the chosen variables. Main effects were run for condition and sex, and post hoc tests when necessary. Chi-square analyses were used to assess relationships between LBP and those with diastasis recti. Power analysis, using G*Power 3.1 indicated the number of subjects necessary for an 80% chance of detecting a medium effect size was 90 subjects for independent samples *t*-tests (effect size = 0.6) 99 subjects for ANOVA ($\eta^2 = 0.075$) and 88 subjects for chi-square tests ($df = 1$). The alpha level for statistical significance was determined a-priori at

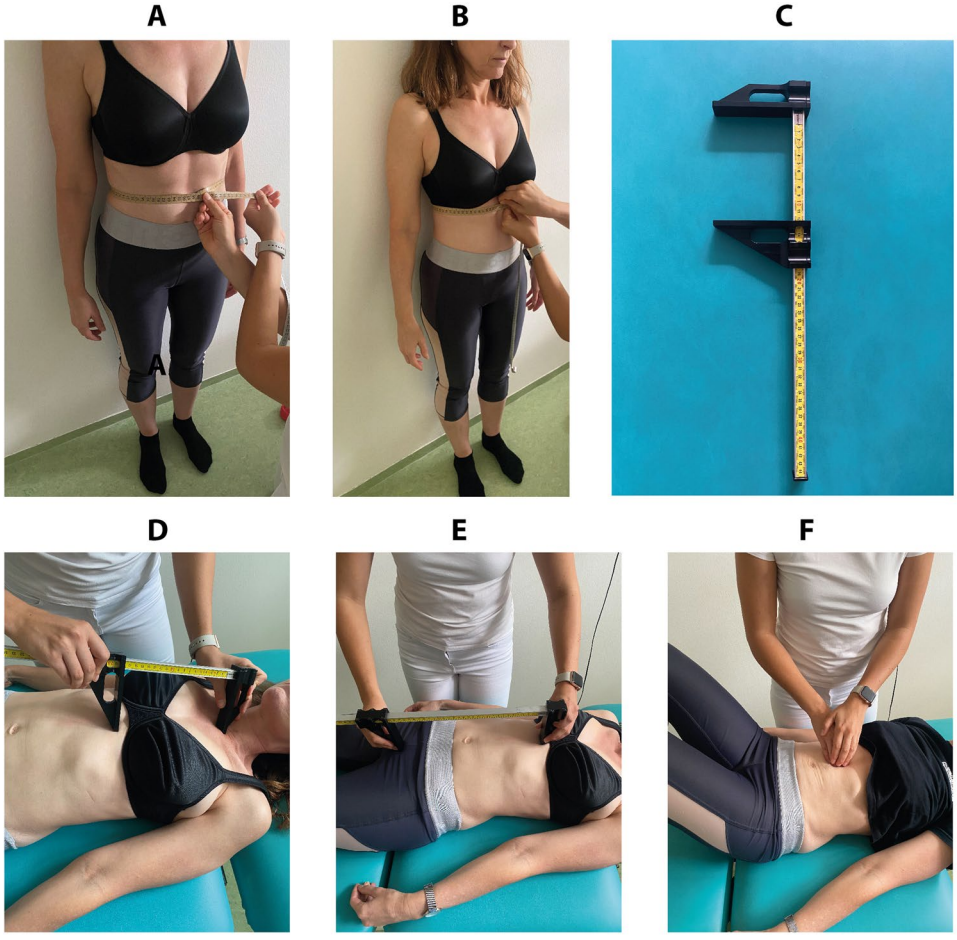

Fig. 1 Assessment procedures

Table 1 Comparison of anthropometric values (cm) in all patients with LBP and controls (Mean [Standard Deviation])

Measure	LBP ($n=50$)	Control ($n=50$)	Mean Difference	95% CI	Effect Size	*P* Value
Height	171.43 (10.91)	172.64 (9.35)	−1.21	(−5.24, 2.82)	−0.12	0.553
Waist Size	90.58 (13.92)	84.71 (9.52)	5.87	(1.14, 10.60)	0.49	0.016*
W: H Ratio	0.53 (0.07)	0.49 (0.05)	0.04	(0.01, 0.06)	0.60	0.004*
Chest Amplitude	3.42 (1.69)	4.83 (1.90)	−1.41	(−2.13, −0.69)	−0.78	< 0.001*
JUG-XIF	21.93 (2.33)	22.17 (2.31)	−0.24	(−1.16, 0.68)	−0.1	0.609
XIF-SYM	34.06 (3.02)	33.15 (2.72)	0.9	(−0.24, 2.04)	0.32	0.119

Note: LBP: Low back pain, W:H: Waist to height ratio

JUG-XIF: fossa jugularis - processus xiphoideus distance

XIF-SYM: processus *xiphoideus* - symphysis pubica distance

Effect size = calculated Cohen's d

*Statistically significant difference observed ($P<.05$)

$p<.05$. Effect sizes, using Cohen's *d* for independent samples *t*-tests, and Cramer's V for Chi-square tests, were interpreted as very small (< 0.2), small (0.2–0.5), medium (0.5–0.8), or large (> 0.8). All data was analyzed using the Statistical Package for the Social Sciences (SPSS v28 for Mac; IBM Corp, Armonk, NY).

Results

Main analyses

Distribution of the 100 participants who completed the study were: males ($n=44$) and females ($n=56$), and half of the participants ($n=50$) reported experiencing LBP, with sex-matched controls ($n=50$). The independent samples *t*-test with 95% confidence intervals is presented in Table 1. When comparing all participants with LBP to

Table 2 *ANOVA results for Sex, LBP, Sex x LBP for anthropometric measures*

	df	F	*p*	η^2
Height				
Sex	(1, 96)	145.503	< 0.001*	0.602
LBP	(1, 96)	0.757	0.387	0.008
Sex x LBP	(1, 96)	0.236	0.628	0.002
Waist Size				
Sex	(1, 96)	57.138	< 0.001*	0.373
LBP	(1, 96)	10.193	0.002*	0.096
Sex x LBP	(1, 96)	1.117	0.293	0.012
W: H Ratio				
Sex	(1, 96)	9.456	0.003*	0.090
LBP	(1, 96)	9.951	0.002*	0.094
Sex x LBP	(1, 96)	0.466	0.497	0.005
Chest Amplitude				
Sex	(1, 96)	0.111	0.740	0.001
LBP	(1, 96)	14.127	< 0.001*	0.128
Sex x LBP	(1, 96)	0.698	0.406	0.007
JUG-XIF				
Sex	(1, 96)	51.130	< 0.001*	0.348
LBP	(1, 96)	0.466	0.496	0.005
Sex x LBP	(1, 96)	0.236	0.628	0.002
XIF-SYM				
Sex	(1, 96)	9.094	0.003*	0.087
LBP	(1, 96)	2.691	0.104	0.027
Sex x LBP	(1, 96)	0.036	0.850	0.000

Note: Total $N = 100$, Males $n = 44$, Females $n = 56$, LBP $n = 50$, Control $n = 50$

LBP Low back pain, *W:H* Waist – Height ratio, *JUG-XIF* Jugularis – xiphoid process, XIF-SYM: xiphoid process – pubic symphysis

their sex-matched controls, the LBP group demonstrated greater waist sizes ($p = .016$), greater waist-height ratios ($p = .004$), and smaller chest amplitude ($p < .001$). Table 2 shows the interaction effects of the ANOVA analyses comparing participants by sex and condition, and Table 3 displays the estimated marginal means of the main effects. Men with LBP demonstrated greater waist sizes ($p = .006$) and greater waist-height ratios ($p = .012$), with the only difference observed between females with LBP was smaller chest amplitudes ($p < .001$). No other significant differences were observed when comparing anthropometric measures. Thirty-two participants reported having diastasis, yet chi-square analyses revealed no significant association between LBP and diastasis recti, $\chi^2(1) = 2.94$, $p = .086$. Of the 50 participants who did experience LBP, there were no significant differences noted when comparing males to females in age, length of time experiencing LBP, or questionnaire values.

Exploratory analyses

There were significant correlations between age and waist size, along with significant correlations between waist size and height. As an exploratory analysis, we performed binomial logistic regressions to ascertain the effects of age, waist, and height on the likelihood that participants reported LBP or diastasis. The logistic regression models were statistically significant, LBP: $\chi^2(3) = 20.14$, $p < .001$, Diastasis: $\chi^2(3) = 21.74$, $p < .001$. The models explained 24.0% (Nagelkerke R^2) of the variance

Table 3 ANOVA estimated marginal means, standard errors for each measure, condition, and sex

	LBP M(SD)	Control M(SD)	Mean Difference	95% CI	*P*	η^2
Height						
Males	180.59 (1.38)	181.09 (1.38)	−0.500	(−4.37, 3.37)	0.798	0.001
Females	164.23 (1.22)	166.00 (1.22)	−1.77	(−5.20, 1.67)	0.309	0.011
Waist Size						
Males	99.82 (2.03)	91.68 (2.03)	8.14	(2.45, 13.83)	0.006*	0.077
Females	83.32 (1.80)	79.23 (1.80)	4.09	(−0.913, 0.953)	0.111	0.026
W: H Ratio						
Males	0.553 (0.013)	0.507 (0.013)	0.045	(0.10, 0.08)	0.012*	0.064
Females	0.508 (0.011)	0.479 (0.011)	0.029	(−0.002, 0.060)	0.065	0.035
Chest Amplitude						
Males	3.66 (0.387)	4.73 (0.387)	−1.07	(−2.15, 0.017)	0.054	0.038
Females	3.23 (0.343)	4.91 (0.343)	−1.68	(−2.64, −0.716)	< 0.001*	0.111
JUG-XIF						
Males	23.36 (0.403)	23.80 (0.403)	−0.445	(−1.58, 0.687)	0.437	0.006
Females	20.81 (0.358)	20.89 (0.358)	−0.075	(−1.08, 0.929)	0.882	0.000
XIF-SYM						
Males	35.06 (0.591)	34.04 (0.591)	1.02	(−0.637, 2.68)	0.224	0.015
Females	33.27 (0.524)	32.46 (0.524)	0.811	(−0.661, 2.28)	0.277	0.012

Total $N = 100$, Males $n = 44$, Females $n = 56$, LBP $n = 50$, Control $n = 50$

LBP Low back pain, *W:H* Waist – Height ratio, *JUG-XIF* Jugularis – xiphoid process, *XIF-SYM* xiphoid process – pubic symphysis

*Statistically significant difference observed w/Bonferroni adjustment

Table 4 Logistic regression predicting likelihood of LBP based on age, waist and height ($n = 100$)

	B	SE B	Wald	df	*p*-value	Odds Ratio	95% CI Lower	Upper
Age	−0.06	0.021	8.73	1	0.003	0.939	0.901	0.979
Waist	0.114	0.03	14.69	1	< 0.001	1.12	1.06	1.19
Height	−0.09	0.03	8.87	1	0.003	0.914	0.861	0.970
Constant	9.28	4.46	4.32	1	0.038	10686.66		
Logistic Regression Predicting Likelihood of Diastasis based on Age, Waist and Height ($n = 100$)								
	B	SE B	Wald	df	*p*-value	Odds Ratio	95% CI Lower	Upper
Age	0.001	.021	.003	1	.959	1.001	.960	1.04
Waist	0.102	.03	12.55	1	<.001	1.107	1.05	1.17
Height	-0.03	.03	1.29	1	.257	.968	.915	1.03
Constant	-4.33	4.60	.887	1	346	.013		

Note = Exploratory analysis (under-powered odds ratios)

noted for LBP, and 27.0% (Nagelkerke R^2) of the variance for diastasis, while correctly classifying 71.0% of cases for LBP and 80% of the cases for diastasis. For LBP, all three predictor variables were significant when controlling for the other variables; whereas for diastasis, only waist was statistically significant when controlling for age and height (Table 4). Waist size was the strongest predictor in both models, whereas participants had a 12.% increased odds of reporting LBP and a 10.7% increased odds of diastasis with greater waist sizes. These findings demonstrate interesting trends in the relationships of LBP and Diastasis between age, height, and waist size, however these findings should be interpreted with caution as we acknowledge the sample size was under-powered for the regression results based on the observed odds ratios. Therefore, future investigation into these relationships is warranted.

Discussion

This study investigated the relationships between anthropometric measures and occurrence of diastasis in a cohort of participants who were experiencing LBP compared with controls. The key findings indicate that individuals with LBP exhibit larger waist circumferences, higher waist-to-height ratios, and reduced respiratory chest amplitude compared to healthy, age-matched controls. These outcomes were consistent in male subjects, whereas only the diminished respiratory chest respiratory amplitude was observed in females with LBP when compared to their healthy counterparts. These findings highlight important anthropometric and functional disparities that may contribute to the pathophysiology of LBP. It is important to emphasize that these findings are exploratory and serve as a foundation for further research to validate these associations and assess their clinical relevance.

The regression analysis provided additional insights, revealing that greater waist size was a significant predictor for both LBP and diastasis. Age and height were also identified as individual predictors for LBP, with older and taller participants showing an increased likelihood of reporting LBP. These results align with theoretical understandings of the multifactorial nature of LBP but require caution due to the limited sample size and the exploratory nature of the regression analysis. Larger, adequately powered studies are needed to validate these findings.

Interestingly, our regression results demonstrated similarities to those of Heuch et al. [40], who analyzed anthropometric measures in over 25,000 participants from the Nord-Trøndelag Health Study (HUNT). Heuch et al., reported that body size measures (body weight, BMI, waist circumference, and waist-hip ratios) were significant predictors of future LBP, with an increased risk ranging from 7.3 to 9.7% in women and 8.5–11.5% in men. This aligns closely with our finding of a 12% increased risk of LBP associated with greater waist size in our sample. Even in the adequately powered study by Heuch et al., the relationship between body size and LBP was identified as weak, reinforcing the multifactorial etiology of LBP and the need for further exploration into its contributing factors.

The sex differences observed in our study with only LBP males exhibiting larger waist circumferences, and higher waist-to-height ratios compared to healthy control can be attributed to several reasons. Men are more prone to accumulate visceral fat, particularly in the abdominal area, due to a combination of factors. These include higher dietary fat uptake by abdominal visceral fat [41], a less favorable metabolic profile [42], and a greater increase in visceral adipose tissue with total body fatness [42]. The relationship between abdominal obesity and back pain is complex and not fully understood. While some studies have found a positive association between the two [43–45], others have found the evidence to be inconclusive [46, 47]. The biomechanical effects of obesity, such as increased load on the lower back and altered center of gravity, are thought to contribute to back pain [43, 44]. However, the role of systemic inflammation associated with obesity in causing back pain is also being explored [43]. Our study corroborates the theory

between obesity and LBP exclusively in the male population. However, it is important to note that the sample size within the male and female subgroups in this study may have been too small to draw definitive conclusions. As the overall sample size was determined for analyses combining all participants, the sex-specific analyses should be considered exploratory. Larger studies with sufficient power for subgroup analyses are needed to confirm these findings.

The occurrence of reduced respiratory chest amplitude in individuals with LBP can be attributed to several interconnected factors, including pain, muscle dysfunction, and altered biomechanics. It is possible, that pain from LBP can make deep or full breaths uncomfortable, leading individuals to take shallower breaths to avoid exacerbating their pain. This can reduce the chest's respiratory amplitude as the person unconsciously limits the movement of the torso and diaphragm to minimize discomfort. However, a systematic review by Jafari et al. concludes, that acute pain augments respiratory frequency, flow, and volume; yet the clinical impact of chronic pain on respiration remains unclear and needs consideration in future studies [48]. Chronic LBP can lead to changes in posture and body mechanics, including altered spinal alignment and decreased mobility in the thoracic spine, which can restrict natural movement of the rib cage during breathing, a phenomenon similarly observed in patients with cervical spine pain [49]. Additionally, according to Janssens et al. [50] individuals with LBP often experience diaphragm fatigue and Roussel et al. [51] noted altered breathing patterns exist during lumbopelvic motor control tests in a sample of LBP subjects when compared with controls. The reduced respiratory amplitude observed in participants with LBP may also be influenced by increased obesity, as larger waist circumferences and higher waist-to-height ratios can impair respiratory mechanics. Further research is needed to clarify the contributions of obesity, pain, and other factors, with longitudinal and interventional studies offering valuable insights."

The initial analysis did not establish a significant link between LBP an diastasis recti. However, the post-hoc analysis uncovered an intriguing relationship between waist size and diastasis, indicating that larger waist sizes are associated with a 10.7% higher likelihood of diastasis. This finding aligns with the research conducted by Doubkova et al. [17], which identified a higher frequency of diastasis in men with LBP who also had an elevated BMI.

Considering the role of developmental factors in LBP, we explored the hypothesis that individuals with LBP would exhibit distinct trunk anthropometric characteristics compared to healthy controls. Our measurements focused on the sternum length and the distance between the xiphoid process and the pubic symphysis. We anticipated that LBP patients would present with a shorter sternum and a longer distance between the xiphoid process and the symphysis, mirroring neonatal characteristics where the chest is shorter, and the abdominal wall is weak and protruding [52, 53]. This assumption was based on the idea that disrupted early development could influence posture and anatomical features, causing adults to retain characteristics typical of a posturally immature child. However, our findings did not support this hypothesis, as significant differences in sternal length and the distance between the xiphoid process and the pubic symphysis relative to body height were not observed. Despite this, we argue that developmental morphological factors warrant further investigation, given that several studies have noted disparities in trunk anthropometric parameters between individuals with LBP and healthy controls, potentially linked to abnormal structural development during growth. For instance, Ebrall [54] and Nissinen [55] identified specific anthropometric dimensions associated with LBP in adolescents. Given the thorax's integration with the body, abnormal development of trunk skeletal structures could lead to biomechanical alignment impairments across various body regions [28], potentially resulting in pain.

The findings of this study have important clinical and societal implications. Chronic LBP is a leading cause of disability worldwide, with significant direct and indirect costs related to healthcare utilization, lost productivity, and reduced quality of life [1]. Our study highlights associations between LBP and specific anthropometric parameters, such as increased waist-to-height ratio and reduced respiratory amplitude, identifying modifiable risk factors that could inform targeted interventions. Notably, the post-hoc analysis revealed a 10.7% higher likelihood of diastasis associated with larger waist sizes, emphasizing the importance of addressing abdominal obesity in LBP management. These findings underscore the need for integrated strategies targeting weight management, respiratory function, and muscle coordination, ideally delivered through personalized rehabilitation programs. On a broader scale, public health initiatives promoting healthy lifestyle behaviors, such as regular exercise and weight control, could help mitigate the societal burden of LBP. Future research exploring the effectiveness of these interventions would provide valuable insights into their potential to reduce LBP prevalence and severity, ultimately improving population health and reducing healthcare costs.

The study presents several limitations that warrant consideration for a comprehensive understanding of the findings. While the sample size was sufficient for primary analyses, it may have been underpowered to detect smaller, clinically significant differences, particularly

in the logistic regression models for LBP and diastasis. Larger studies are needed to confirm these findings. The cross-sectional design limits causality, and longitudinal studies are required to determine whether anthropometric changes precede LBP or result from chronic pain and lifestyle adaptations. Participants were recruited from a hospital rehabilitation department, which may limit generalizability to the broader LBP population, including individuals who do not seek clinical care. The inclusion of degenerative spine disease (DSD) as a criterion for the LBP group may have influenced the observed differences in weight and anthropometric parameters between groups, given the established association between DSD and obesity. This potential confounding factor should be considered when interpreting the results. Although the control group was matched by age and sex, factors such as physical activity, socio-economic status, and psychological influences were not controlled for, potentially affecting the observed associations. The study relied on self-reported measures and clinical assessments, which may introduce reporting bias or inter-rater variability, despite efforts to standardize measurements. Also, clinical assessments were not included in this study as their broad scope (e.g., neurological, postural, orthopedic) would have significantly expanded its complexity and focus beyond the intended investigation of anthropometric and respiratory parameters. Lastly, while the tools used for respiratory amplitude and diastasis recti were practical and reliable, advanced imaging modalities like ultrasound or MRI might have provided more precise data, particularly for subtle structural differences. Future research should prioritize longitudinal studies to better understand the temporal relationships between anthropometric parameters, respiratory function, and the development of LBP. Larger studies with more diverse and representative populations are needed to confirm our findings and improve their generalizability across different demographic and clinical settings. In addition, incorporating advanced imaging modalities such as ultrasound or MRI could provide more detailed insights into structural and functional changes associated with LBP, particularly regarding muscle integrity and respiratory mechanics. Finally, interventional studies simultaneously targeting weight management, respiratory function training, and core stabilization could provide valuable insights into the clinical impact of these modifiable factors on LBP prevention and management.

Conclusion

This study provides valuable insights into the complex relationship between LBP and anthropometric parameters. We identified significant associations between LBP and larger waist circumferences, higher waist-to-height ratios, and reduced respiratory amplitude. We did not find significant differences in sternal length or the distance between the xiphoid process and the pubic symphysis between participants with LBP and those without LBP. Therefore, we did not confirm that there is a significant difference in these anthropometric characteristics, which could potentially be indicative of suboptimal postural development from early life. The results underscore the intricate links between body composition, respiratory health, and LBP. They suggest avenues for future research and potential therapeutic targets, such as weight management and respiratory function improvement.

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Authors' contributions
A.K., M.SV., and J.N. designed the study and made substantial contributions to its conception and development. M.SV. and A.K. were responsible for data curation. A.B. handled the methodology and data analysis. A.K., M.S.T., M.SV., J.N., and A.B. drafted the paper. A.K. was responsible for project administration, resources, and supervision. All authors have read and approved the final manuscript.

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Data availability
The datasets are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by an Institutional Ethics Committee of University Hospital Motol, Prague, Czech Republic. Informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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