Research Report

Factors Associated With Paraspinal Muscle Asymmetry in Size and Composition in a General Population Sample of Men

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Background. Paraspinal muscle asymmetry in cross-sectional area (CSA) and composition have been associated with low back pain and pathology. However, substantial multifidus muscle asymmetry also has been reported in men who were asymptomatic, and little is known about other factors influencing asymmetry.

Objective. The goal of this study was to identify behavioral, environmental, and constitutional factors associated with paraspinal muscle asymmetry.

Design. A cross-sectional study of 202 adult male twins was conducted.

Methods. Data were collected through a structured interview, physical examination, and magnetic resonance imaging. Measurements of multifidus and erector spinae muscle CSA and the ratio of fat-free CSA to total CSA were obtained from T2-weighted axial images at L3–L4 and L5–S1.

Results. In multivariable analyses, greater asymmetry in multifidus CSA at L3–L4 was associated with lower occupational physical demands and less disk height narrowing. Handedness was the only factor associated with multifidus muscle CSA asymmetry at L5–S1. For the erector spinae muscle, greater age, handedness, and disk height narrowing were associated with CSA asymmetry at L3–L4, and sports activity, handedness, disk height narrowing, and familial aggregation were associated with CSA asymmetry at L5–S1. In multivariable analyses of asymmetry in muscle composition, familial aggregation explained 7% to 20% of the variance in multifidus and erector spinae muscle side-to-side differences at both levels measured. In addition, handedness and pain severity entered the model for erector spinae muscle asymmetry at L5–S1, and disability, handedness, and disk height narrowing entered the model for multifidus muscle asymmetry at L5–S1.

Limitations. Reliance on participants' recall for low back pain history, occupation, and physical activity levels was a limitation of this study.

Conclusions. Few of the factors investigated were associated with paraspinal muscle asymmetry, and associations were inconsistent and modest, explaining little of the variance in paraspinal muscle asymmetry.

Paraspinal muscle asymmetry and fatty infiltration have received considerable attention with regard to the etiology and prognosis of low back pain (LBP).[1–5] More specifically, attention has been focused on the multifidus muscle, with reports suggesting level- or side-specific atrophy in relation to symptoms and localized spinal pathology.[2,6–12] The paraspinal muscle asymmetry observed in people with LBP and pathology has been suggested to be a consequence of disuse, denervation, or reflex inhibition,[12] although the mechanism is not fully understood. Despite the development of imaging procedures to quantify the size, degree of asymmetry, and fatty infiltration of the paraspinal muscles, investigators use a wide variety of methods, and there are inconsistencies in the association of LBP with paraspinal muscle morphology.

Ultrasound studies have shown that the paraspinal muscles are relatively symmetrical in people without a history of LBP, with multifidus mean side-to-side differences of 2.9% to 9.2%.[2,8,13] Accordingly, Hides et al[2] suggested that asymmetry of greater than 10% could be interpreted as an abnormality. However, a recent magnetic resonance (MR) imaging study showed that 40% of 126 men who were asymptomatic had multifidus muscle asymmetry exceeding 10%.[14] Furthermore, evidence from a recent systematic review suggested that the multifidus muscle and the paraspinal muscle group are significantly smaller in people with chronic LBP than in people who are healthy and that they are significantly smaller on the symptomatic side of patients with chronic, but not acute, unilateral LBP than on the asymptomatic side.[15] Accordingly, many physical therapists attribute clinical meaning to atrophy and asymmetry observed in patients with LBP, and this attribution influences rehabilitation protocols. However, other factors may influence or lead to such muscle variations; therefore, these factors should be considered before such variations are judged as signifying risk or the presence of back pain and pathology.

Several individual and environmental factors have been associated with paraspinal muscle cross-sectional area (CSA); these include age,[16–18] sex,[2,13,17,19] anthropometric factors (such as body mass[16] and height[16]), lean body mass,[16,17] maximum weight lifted at work,[16] and time spent in sports and physically demanding leisure activities[16,20] and familial aggregation.[16] However, with the exception of studies of athletes performing asymmetrical sports,[21–25] few studies have specifically investigated determinants of paraspinal muscle asymmetry[2,13] and composition (eg, fatty infiltration)[18,26,27] other than LBP and nerve root pathology.

To better interpret findings of paraspinal muscle asymmetry in clinical and research contexts, it is important to be aware of the range of factors that can influence such findings. The purpose of the present study was to examine the associations of a wide range of behavioral, environmental, and constitutional factors with asymmetry in paraspinal muscle size and fatty infiltration in a general population sample of men. We hypothesized that greater asymmetry in paraspinal muscle size and composition would be associated with a history of LBP, greater age, disk height narrowing (degeneration), and participation in asymmetrical sports or work activities. We also hypothesized that more of the suspected factors related to LBP and pathology would be associated with asymmetry of the multifidus muscle than with asymmetry of the erector spinae muscle and that asymmetry would be greater at the L5–S1 level than at the L3–L4 level because of a higher prevalence of spinal pathology at the former level.

Material and Method

Study Design

A cross-sectional, observational study was conducted to investigate factors associated with asymmetry in paraspinal muscle size and composition, as measured from T2-weighted axial MR images, in a general population sample of men. Information concerning behavioral, environmental, and constitutional factors was obtained from comprehensive structured interviews and clinical examinations of study participants.

Study Sample

All 116 male monozygotic (MZ) twin pairs (232 men) initially recruited into the Twin Spine Study were candidates for the present study.[28] The Twin Spine Study participants came from the population-based Finnish Twin Cohort, which included all same-sex twins born in Finland before 1958 and still alive in 1975.[29] The initial selection of MZ twins for the Twin Spine Study was based on co-twin discordance for one of several common exposures, including occupational or leisure physical activities. The MZ participants in the Twin Spine Study were shown to be highly representative of the Finnish Twin Cohort, which is representative of the Finnish population, on a variety of factors examined, including LBP histories.[30] Other examined factors for which the MZ participants in the Twin Spine Study were

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- Discussion Podcast with Steven George, Mark Bishop, and authors Michelle Battié and Maryse Fortin. Moderated by Leonardo Costa.

shown to be similar to the Finnish Twin Cohort included occupational category, outdoor versus indoor work, shift work, work monotony, level of leisure-time physical activity, smoking status, life satisfaction, level of education, and social class.[30] However, the MZ participants in the Twin Spine Study were found to have slightly more physically demanding jobs than the Finnish Twin Cohort and were more likely to be employed.[30] Of the 116 MZ twin pairs considered, only those with a history of spinal surgery or traumatic spinal fractures were excluded.

Before their participation in the Twin Spine Study, all participants were informed of study procedures and gave informed consent.

Data Acquisition

Occupational physical demands. A detailed lifetime job history was obtained from each participant. In this history, every job, with its associated tasks, was described and classified into 1 of 18 categories according to job type and degree of physical loading.[28] After cluster analysis, each job held by a participant was placed in 1 of 4 categories: 1=sedentary work, 2 and 3=progressive degrees of materials handling and positional loading, and 4=very heavy loading.[28] In the present study, 2 variables were used to examine occupational physical loading: the mean lifetime job code (4-point scale) and the mean job code during the previous year, weighted by the number of months on the job. In a previous study of the same population, the response reliability for work history was evaluated; the intraclass correlation coefficients were .75 for sitting, .77 for driving, and .60 for total lifting per day.[28] In addition, for each identified job, participants described the types of tasks performed and the time spent in different postures (eg, sitting twisted or bent). A variable based on the time spent working in various combinations of bent and twisted positions (mean minutes per day) during the previous year was then created. The associations of occupational physical loading variables with paraspinal muscle asymmetry were assessed because the amount of physical loading has been shown to be associated with paraspinal muscle size[16] and composition[26] and many manual handling jobs comprise asymmetrical tasks.[31]

Sports and leisure physical activities. Each participant was questioned about his history of sports and exercise participation. All regularly performed exercises and competitive sports were reviewed from the age of 12 years up to the time of the interview. Participants were asked to describe the type of activity as well as the frequency, intensity, session duration, and number of months or years of participation. Through the use of a 5-year test-retest reliability interval, an intraclass correlation coefficient of .81 was obtained for the repeatability of lifetime history of “mean exercise hours per week” for the most commonly performed exercise mode.[32]

In the present study, a variable was created to summarize the mean number of hours per week spent in any regularly performed sports or exercise during the previous year. A second variable (mean number of hours per week) was created to specifically examine current participation in asymmetrical sports (eg, volleyball, soccer, tennis, squash, other ball games, ice hockey, golf, bowling, and field sports involving throwing). Because participants were also asked about participation in other leisure activities involving heavy physical loading in the current year, a third summary variable (mean number of hours per week spent in such activities) was created. The associations of these variables with paraspinal muscle asymmetry were investigated because the amount of time spent in sports and exercise has been shown to influence muscle size.[20,32] Moreover, athletes participating in asymmetrical sports have been found to have asymmetrical trunk and back muscles.[21–25]

LBP history. A detailed history of LBP was obtained from each participant. The frequency of LBP during the previous 12 months was classified with a 7-point scale ranging from none to daily (1=daily; 7=none).[28] Participants also were asked to rate their worst episode of LBP in the previous 12 months on a scale of 0 to 100. To quantify disability associated with LBP, participants were asked about the number of days they experienced difficulty doing daily work because of their LBP during the previous 12 months. The back pain history questions were repeated in interviews conducted approximately 1 month later in 48 participants. Test-retest reliability was examined by use of weighted kappa coefficients with 95% confidence intervals (95% CIs) obtained from 1,000 bootstrap samples. Weighted kappa coefficients were .83 (95% CI=.67–.93) for the LBP frequency measurements, .79 (95% CI=.61–.92) for the pain numeric scale measurements, and .68 (95% CI=.40–.92) for the number of days of disability, indicating good to moderate reliability.

Lumbar MR imaging and disk height narrowing (degeneration). T2-weighted sagittal and axial MR images of each participant’s lumbar spine were obtained with a 1.5-T scanner and a 256 × 256 matrix in accordance with a standardized protocol. All participants were lying prone for 30 to 45 minutes immediately before imaging.

Each lumbar disk was assessed for disk height narrowing (degeneration) on the midsagittal MR image with a 4-point scale (0=normal, disk thicker than the upper disk; 1=slight, disk as thick as the upper disk, if normal; 2=moderate, disk thinner than the upper disk, if normal; and 3=severe, end plates almost in contact). The intrarater reliability of the measurements was previously examined in the same sample, yielding an intraclass correlation coefficient of .84.[33] We used disk height narrowing as an indicator of possible disk pathology, with or without nerve root involvement, because disk and associated nerve root lesions have been associated with paraspinal muscle asymmetry at the involved level as well as the levels below.[12] Two variables were created from qualitative ratings of disk height narrowing. First, a rating of disk height narrowing was obtained from a measurement taken at the same level as the paraspinal muscle measurement. Second, a rating of the greatest disk height narrowing at any of the 3 levels above the measurement level was obtained. Disk height narrowing has been reported to be a predictor of LBP,[34] and paraspinal muscle asymmetry has been observed in people with disk degeneration.[10]

Age, handedness, lean body mass, and body mass index. The associations of age, handedness, lean body mass, and body mass index with paraspinal muscle asymmetry were also of interest. Several studies have reported associations of paraspinal muscle asymmetry with LBP and spinal pathology, which vary by age,[35–37] as does fatty infiltration.[3,18]

Handedness was coded as a dichotomous variable evaluating whether the larger side (in muscle CSA or the ratio of functional CSA [FCSA] to CSA) corresponded to the participant's dominant hand.

Lean body mass was computed on the basis of the percent body fat obtained via bioelectrical impedance [(1 − % of body fat) × weight], and body mass index was calculated from weight and height measurements. Lean people (individuals with a greater lean body mass) have larger paraspinal muscles (high muscle density). Lean body mass has been reported to account for 45% to 65% of the variance in paraspinal muscle CSA,[16] and a higher body mass index has been associated with a larger paraspinal muscle CSA[16] but a lower muscle density (more fatty infiltration).[38]

Paraspinal Muscle Measurements

Paraspinal muscle measurements for the multifidus and erector spinae muscles (dependent variables) were obtained from T2-weighted, axial MR images oriented through the center of each L3–L4 and L5–S1 intervertebral disk, perpendicular to the paraspinal muscle mass. Because most underlying spinal pathologies are believed to occur at the 2 lowest lumbar levels and fatty infiltration has been reported to be most notable at the L5–S1 level,[26] this level was selected as a level likely to be affected if lumbar pathology were present. The L3–L4 level was selected as a level less likely to be affected by pathology. The rater (M.F.) was experienced in using quantitative MR imaging muscle measurements and was unaware of participants' clinical histories.

The following 2 muscle measurements were obtained separately for the multifidus and erector spinae muscles: side-to-side difference in total CSA (percent asymmetry) and side-to-side difference in the ratio of FCSA to total CSA.

The rater directly obtained total CSA by segmenting or tracing the multifidus and erector spinae muscles separately, bilaterally, at each of the lumbar spinal levels investigated. Asymmetry in total CSA was calculated as a percentage with the following formula: [(larger side − smaller side) / larger side] × 100. Because a change in muscle composition can occur without a change in muscle size, FCSA is a better indicator of muscle atrophy and contractility.[39] Functional CSA was calculated with a highly reliable threshold technique.[40] This technique is based on the difference in signal intensity between muscle tissue (low signal) and fat tissue (high signal), allowing for the separation of both tissues. Thus, the ratio of FCSA to CSA was used as an indicator of muscle degeneration (fatty infiltration), and the side-to-side difference in the ratio of FCSA to CSA was used to assess asymmetry in muscle composition.

Quantitative measurements of the multifidus and erector spinae muscles were obtained from T2-weighted axial images by use of ImageJ software (version 1.43, National Institutes of Health, Bethesda, Maryland; available at: http://rsbweb.nih.gov/ij/download.html). Details regarding the measurement protocol have been published elsewhere.[40]

Data Analysis

To account for correlated observations in co-twins, we used random-effects models to determine the contributions of suspected independent predictors of asymmetry in paraspinal muscle and fatty infiltration. A twinship variable indicating the twin pairs was used as a random effect in the analyses. The normality assumption was assessed, and a log transformation was performed, wherever appropriate. Spinal levels were analyzed separately.

Associations were initially examined with univariate linear regression. Because of the multiple comparisons and the possibility for chance findings, particular attention was paid to the consistency of the findings. A

Table 1.
Participant Characteristics and Possible Determinants of Paraspinal Muscle Asymmetry[a]

Possible Determinant	Value[a]
General	
Age, y	49.35 (8.40)
Body mass index, weight in kg/height in m^2	25.96 (3.44)
Lean body mass [(1 − % of body fat) × weight]	59.69 (7.31)
Right-handedness	94.0%
Occupational physical demands	
Mean lifetime job code, on a weighted 4-point scale	2.50 (0.92)
Mean job code in the previous year, on a weighted 4-point scale	1.83 (1.30)
Mean time working in twisted or bent postures, min/d	97.19 (100.46)
Sports and leisure physical activities	
Sports and exercise, mean h/wk	3.87 (5.63)
Leisure activities with heavy physical loading, mean h/wk	1.29 (6.86)
Asymmetrical sports, mean h/wk	0.33 (1.07)
Low back pain	
Low back pain frequency in the previous 12 mo, on a 7-point scale	5.03 (2.02)
Pain severity in the previous 12 mo, on a scale of 0–100	28.54 (31.62)
No. of days experiencing difficulty doing daily work in the previous 12 mo	11.16 (52.47)

[a] Values are reported as mean (standard deviation), unless otherwise indicated.

Table 2.
Participant Disk Height Narrowing Investigated as Possible Determinants of Paraspinal Muscle Asymmetry

Possible Determinant	Rating (Points) on a Scale of 0–3	No. (%) of Participants
Disk height narrowing at L3–L4[a]	0	120 (59.70)
	1	58 (28.86)
	2	18 (8.96)
	3	5 (2.49)
Disk height narrowing at L5–S1	0	92 (45.54)
	1	60 (29.70)
	2	27 (13.37)
	3	23 (11.39)
Greatest disk height narrowing at any of the 3 levels above L3–L4	0	100 (49.50)
	1	63 (31.19)
	2	31 (15.35)
	3	8 (3.96)
Greatest disk height narrowing at any of the 3 levels above L5–S1	0	31 (15.35)
	1	91 (45.05)
	2	44 (21.78)
	3	36 (17.87)

[a] Ratings for disk height narrowing were available for only 201 participants at L3–L4.

multivariable random-effects model was fitted with the purposeful selection model strategy.[41] Variables with a P value of less than .20 in univariate analyses were candidates for the multivariable model. Variables with a P value of greater than .05 were removed from the multivariable model after being assessed as potential confounders (variables leading to a ±15% change in the beta coefficients of the significant variables included in the multivariable model). Potential 2-way interactions were assessed for variables remaining in the multivariable model. Diagnostic plots were used to evaluate model assumptions and possible influential observations. The assumptions were tenable for each model, and no influential observations were detected. Model collinearity also was investigated and was not an issue. We estimated the relative contribution of or variance explained by familial aggregation (genetic influence and early shared environment) by using intraclass correlation coefficients. All analyses were performed with STATA (version 9.2, StataCorp LP, College Station, Texas).

Role of the Funding Source

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Results

Of the 116 pairs of MZ twins, 15 pairs were excluded. Five pairs were excluded because of poor MR image quality, 9 pairs were excluded because of earlier back surgery, and the last pair was excluded because of spinal fracture. Therefore, our final sample population was composed of 101 MZ twin pairs (202 men). The participants' mean age was 49.35 years (SD=8.40, range=35–69), and LBP frequency during the previous

12 months was 5.03 (SD=2.02) on a 7-point scale (5=2 or 3 times per year). Participant characteristics are shown in Tables 1 and 2. The percentages of participants with multifidus muscle asymmetry of greater than 10% were 34.2% at L3–L4 and 30.7% at L5–S1; 13.4% of participants had erector spinae asymmetry of greater than 10% at L3–L4, and 57.9% had this characteristic at L5–S1 (Tab. 3).

Table 3.
Muscle Measurements by Spinal Level and Percentage of Participants With Asymmetry Exceeding 10%[a]

Muscle Measurement	L3–L4 Multifidus	L3–L4 Erector Spinae	L5–S1 Multifidus	L5–S1 Erector Spinae
% asymmetry in total CSA, $\bar{X}$ (SD)	8.44 (5.92)	5.24 (4.03)	7.46 (5.72)	13.61 (9.39)
Side-to side difference in ratio of FCSA to CSA, $\bar{X}$ (SD)	0.07 (0.05)	0.12 (0.07)	0.07 (0.05)	0.16 (0.10)
% of participants with CSA asymmetry of >10%	34.2	30.7	13.4	57.9

[a] CSA=cross-sectional area, FCSA=functional cross-sectional area.

Crude analyses, followed by multivariable analyses, were conducted for asymmetry in total CSA and ratio of FCSA to CSA for each muscle and spinal level.

Factors Associated With Paraspinal Muscle CSA Asymmetry

Statistically significant associations with asymmetry in CSA were more often detected at the L3–L4 spinal level than at the L5–S1 spinal level (Tab. 4). Of the factors investigated, handedness (*P*=.03) was associated with less CSA asymmetry, and greater age (*P*=.02) and more disk height narrowing at the same level (*P*=.001) were associated with more erector spinae muscle CSA asymmetry at L3–L4. Less time spent in sports and exercise (*P*=.04) and handedness (*P*=.015) were associated with erector spinae muscle CSA asymmetry at L5–S1. Age, disk height narrowing, and handedness remained in the multivariable model, explaining 9% of the variance in erector spinae muscle total CSA asymmetry at L3–L4. Sports and exercise participation, disk height narrowing at any of the 3 levels above, and handedness entered the multivariable model of total erector spinae muscle CSA asymmetry at L5–S1, explaining 6% of the variance; familial aggregation explained an additional 18% of the variance.

For the multifidus muscle, more CSA asymmetry at L3–L4 was associated with lower (less physically demanding) job codes, both over the previous year (*P*=.01) and over the lifetime (*P*=.04), and less disk height narrowing at any of the 3 levels above (*P*=.01). Both mean job code over the previous year and disk height narrowing remained in the multivariable model and, together, explained 6% of the variance in multifidus muscle CSA asymmetry at L3–L4. Handedness (*P*=.001) was the only significant factor associated with greater multifidus muscle CSA asymmetry at L5–S1 in the crude and multivariable analyses, explaining 5% of the variance.

Factors Associated With Side-to-Side Differences in the Ratio of FCSA to CSA

Unlike CSA asymmetry, associations with side-to-side differences in the ratio of FCSA to CSA, representing asymmetry in fatty infiltration, were more often observed at L5–S1 (Tab. 5). Handedness was the only significant factor associated with fewer side-to-side differences in the ratio of FCSA to CSA at L3–L4 for the erector spinae (*P*=.026) and multifidus (*P*<.001) muscles in the crude and multivariable analyses. Handedness explained 3% of the variance in the erector spinae muscle side-to-side differences in the ratio of FCSA to CSA and 7% of the variance in the multifidus side-to-side differences in this parameter; familial aggregation explained an additional 16% and an additional 7% of the variance, respectively.

At L5–S1, handedness (*P*=.001), less sports and exercise participation (*P*=.04), and more back pain severity over the previous year (*P*=.009) were associated with erector spinae muscle side-to-side differences in the ratio of FCSA to CSA. Handedness and pain severity remained in the multivariable model, together explaining 7% of the variance at L5–S1; familial aggregation explained an additional 20%.

With respect to multifidus muscle side-to-side differences in the ratio of FCSA to CSA at L5–S1, handedness (*P*<.001) and more disk height narrowing (*P*=.03) at any of the 3 levels above were crudely associated, and the number of days experiencing difficulty doing daily work during the previous 12 months because of LBP approached significance (*P*=.06). All 3 variables entered the multivariable model, together explaining 13% of the variance; familial aggregation explained an additional 10%.

Discussion

Few of the investigated factors were associated with paraspinal muscle asymmetry, and those identified explained little of the variance in muscle asymmetry. Furthermore, the associations identified, including

Table 4.
Associations of Percentages of Asymmetry in Muscle Cross-Sectional Area With Factors of Interest

Factor	Univariate Regression Coefficient (95% Confidence Interval)			
	L3–L4		L5–S1	
	Multifidus[a]	Erector Spinae	Multifidus[a]	Erector Spinae[a,b]
Anthropometrics				
Age, y	0.0081 (−0.0065 to 0.0228)	0.0773[c] (0.0120 to 0.1425)	0.0155 (−0.0014 to 0.0325)	0.0008 (−0.0181 to 0.0164)
Body mass index, weight in kg/height in m^2	−0.0195 (−0.0553 to 0.0162)	−0.0042 (−0.1657 to 0.1572)	−0.0018 (−0.0437 to 0.0400)	−0.0072 (−0.0485 to 0.0340)
Lean body mass [(1 − % of body fat) × weight]	−0.0013 (−0.0176 to 0.0174)	−0.2453 (−0.1041 to 0.0550)	−0.0048 (−0.0250 to 0.0153)	0.0026 (−0.0176 to 0.0228)
Handedness	0.0538 (−0.2105 to 0.3182)	−1.2615[c] (−2.4190 to −0.1040)	0.4760[c] (0.1853 to 0.7668)	−0.3310[c] (−0.5981 to −0.6384)
Occupational physical loading				
Mean lifetime job code, on a weighted 4-point scale	−0.1382[c] (−0.2706 to −0.0059)	0.2562 (−0.3435 to 0.8561)	−0.0010 (−0.1568 to 0.1547)	−0.0364 (−0.1818 to 0.1088)
Mean job code in the previous year, on a weighted 4-point scale	−0.1177[c] (−0.2112 to −0.0246)	−0.0225 (−0.4506 to 0.4055)	−0.0840 (−0.1944 to 0.0262)	0.0455 (−0.0602 to 0.1512)
Mean time working in twisted or bent postures, min/d	$5.26e^{-06}$ (−0.0012 to 0.0012)	0.0035 (−0.0019 to 0.0090)	−0.0012 (−0.0026 to 0.0001)	0.0002 (−0.0011 to 0.0016)
Other physical activities				
Sports and exercises, mean h/wk	0.0004 (−0.0213 to 0.0223)	0.0246 (−0.0740 to 0.1233)	−0.0019 (−0.0275 to 0.0236)	−0.0251[c] (−0.0492 to −0.0010)
Leisure activities with heavy physical loading, mean h/wk	0.0023 (−0.0155 to 0.0202)	−0.0467 (−0.1274 to 0.0340)	−0.0036 (−0.0243 to 0.0173)	−0.0009 (−0.0208 to 0.0190)
Asymmetrical sports, mean h/wk	0.0100 (0.1053 to 0.1255)	−0.1125 (−0.6337 to 0.4086)	−0.1196 (−0.2538 to 0.0144)	−0.0204 (−0.1482 to 0.1074)
Low back health				
Low back pain frequency in the previous 12 mo, on a 7-point scale	−0.0154 (−0.0767 to 0.0457)	0.0704 (−0.2042 to 0.3452)	0.0041 (−0.0671 to 0.0753)	−0.0332 (−0.1021 to 0.0356)
Pain severity in the previous 12 mo, on a scale of 0–100	−0.0007 (−0.0046 to 0.0031)	0.0012 (−0.0162 to 0.0188)	−0.0011 (−0.0056 to 0.0034)	$2.96e^{-06}$ (−0.0043 to 0.0043)
No. of days experiencing difficulty doing daily work in the previous 12 mo	−0.0001 (−0.0024 to 0.0022)	−0.0020 (−0.0125 to 0.0085)	0.0016 (−0.0010 to 0.0044)	−0.0002 (−0.0028 to 0.0023)
Disk height narrowing at the same level, on a scale of 0–3 points	−0.1095 (−0.2711 to 0.0519)	1.1912[c] (0.4790 to 1.9035)	−0.0117 (−0.1528 to 0.1294)	0.0394 (−0.0980 to 0.1770)
Disk height narrowing at any of the 3 levels above, on a scale of 0–3 points	−0.1805[c] (−0.3214 to −0.0397)	0.1929 (−0.4515 to 0.8373)	−0.0011 (−0.1519 to 0.1496)	0.1309 (−0.0145 to 0.2763)

[a] The outcome measure was log-transformed.
[b] The morphology of the erector spinae muscle at L5–S1 was different from that at L3–L4; this difference might explain the different distributions of the data at the 2 levels.
[c] $P<.05$.

Table 5.

Associations of Side-to-Side Differences in Ratios of Muscle Functional Cross-Sectional Area to Cross-Sectional Area With Factors of Interest

Factor	Univariate Regression Coefficient (95% Confidence Interval)			
	L3–L4		L5–S1	
	Multifidus[a]	Erector Spinae	Multifidus[a]	Erector Spinae
Anthropometrics				
Age, y	0.0028 (−0.0106 to 0.0164)	0.0008 (−0.0003 to 0.0020)	0.0020 (−0.0115 to 0.0162)	−0.0006 (−0.0022 to 0.0010)
Body mass index, weight in kg/height in m^2	−0.0039 (−0.0361 to 0.0282)	0.0007 (−0.0021 to 0.0036)	−0.0073 (−0.0397 to 0.0250)	0.0033 (−0.0006 to 0.0072)
Lean body mass [(1 − % of body fat) × weight]	0.0054 (−0.0104 to 0.0213)	0.0001 (−0.0013 to 0.0015)	0.0057 (−0.0215 to 0.0099)	0.0011 (−0.0007 to 0.0030)
Handedness	−0.4459[b] (−0.6812 to −0.2107)	−0.0347[b] (−0.0653 to −0.0040)	−0.4457[b] (−0.6766 to −0.2147)	−0.0618[b] (−0.0993 to −0.0243)
Occupational physical loading				
Mean lifetime job code, on a weighted 4-point scale	0.0502 (−0.0642 to 0.1648)	0.0063 (−0.0037 to 0.0164)	0.0149 (−0.1306 to 0.1008)	0.0084 (−0.0056 to 0.0225)
Mean job code in the previous year, on a weighted 4-point scale	−0.0167 (−0.1011 to 0.0676)	0.00003 (−0.0073 to 0.0074)	−0.0215 (−0.1073 to 0.0643)	0.0017 (−0.0085 to 0.0120)
Mean time working in twisted or bent postures, min/d	0.0001 (−0.0009 to 0.0011)	0.00003 (−0.00005 to 0.0001)	−0.0004 (−0.0015 to 0.0006)	0.0001 (−0.0001 to 0.0001)
Other physical activities				
Sports and exercises, mean h/wk	0.0125 (−0.0065 to 0.0316)	−0.0013 (−0.0029 to 0.0003)	−0.0013 (−0.0214 to 0.0186)	−0.0023[b] (−0.0047 to −0.00004)
Leisure activities with heavy physical loading, mean h/wk	0.0128 (−0.0281 to 0.0025)	0.0002 (−0.0011 to 0.0016)	0.0011 (−0.0141 to 0.0164)	−0.0005 (−0.0024 to 0.0014)
Asymmetrical sports, mean h/wk	0.0028 (−0.0970 to 0.1026)	−0.0005 (−0.0094 to 0.0083)	−0.0430 (−0.1422 to 0.0560)	−0.0013 (−0.0137 to 0.0110)
Low back health				
Low back pain frequency in the previous 12 mo, on a 7-point scale	0.0294 (−0.0236 to 0.0826)	0.0045 (−0.0093 to 0.0001)	−0.0148 (−0.0714 to 0.0417)	−0.0045 (−0.0111 to 0.0020)
Pain severity in the previous 12 mo, on a scale of 0–100	−0.0022 (−0.0056 to 0.0011)	0.0002 (−0.00007 to 0.0005)	0.0020 (−0.0014 to 0.0056)	0.0005[b] (0.0001 to 0.0009)
No. of days experiencing difficulty doing daily work in the previous 12 mo	−0.0017 (−0.0037 to 0.0002)	0.00006 (−0.0001 to 0.0002)	−0.0019 (−0.0039 to 0.0005)	−0.00004 (−0.0002 to 0.0002)
Disk height narrowing at the same level, on a 4-point scale	0.0021 (−0.1382 to 0.1424)	0.0117 (−0.0008 to 0.0243)	0.0878 (−0.0205 to 0.1961)	−0.0008 (−0.0141 to 0.0124)
Disk height narrowing at any of the 3 levels above, on a 4-point scale	−0.0366 (−0.1638 to 0.0905)	0.0073 (−0.0039 to 0.0187)	0.1285[b] (0.0147 to 0.2424)	0.0042 (−0.0099 to 0.0183)

[a] The outcome measure was log-transformed.

[b] $P<.05$.

age, handedness, physical activity levels at work or leisure, disk height narrowing, and back pain severity during the previous year, not only were modest but also were inconsistent (with the exception of handedness). Familial aggregation explained the greatest percentage of the variance in paraspinal muscle asymmetry; this result may not be entirely surprising because familial aggregation and genetic influences were previously shown to be substantial determinants of paraspinal muscle size.[16,42] Body mass index and lean body weight were not associated with any of the measures of paraspinal muscle asymmetry.

In our general population sample of men, the mean percentage of multifidus muscle CSA asymmetry was similar to those in other, related studies.[2,13] We found that 57.92% of participants had erector spinae muscle asymmetry of greater than 10% at L5–S1; this asymmetry was similar to what was previously reported. Ranson et al[23] reported that 56% of young professional fast bowlers (mean age=26 years) had erector spinae muscle FCSA asymmetry of greater than 10% at L5; a group of athletes involved in nonasymmetrical sports had 53% asymmetry.

Our results suggested that people with more physically demanding jobs or greater exercise and sports participation may have less asymmetry in paraspinal muscle size and fatty infiltration. In a previous report, people with greater participation in sports or physical work with heavy loading had significantly less severe multifidus fatty infiltration, but asymmetry was not examined.[26] Contrary to our original hypothesis, our results showed no significant association of paraspinal muscle asymmetry with mean hours per week spent in asymmetrical sports at noncompetitive levels. However, only a small group of men in our sample participated in such sports, and the time spent was far less than the time spent by elite athletes. Although some other imaging studies have reported significant paraspinal or trunk muscle asymmetry in elite athletes performing "asymmetrical sports,"[22–24,43] not all asymmetrical sports have been found to lead to significant paraspinal muscle asymmetry.[44] When hypertrophy was reported on the dominant side, the mean percent difference between the sides varied from 0.6% to 9.1%,[23,43] similar to what has been reported for people who are not athletes.[2,8,13]

Handedness was associated with greater multifidus muscle CSA asymmetry at L5–S1, but the opposite was true for the erector spinae muscle at both spinal levels. Although the majority of participants had a larger multifidus muscle on the right side, 66.8% and 56.4% had a larger erector spinae muscle on the left side at L3–L4 and L5–S1, respectively. Although both muscles are extensors, the multifidus muscle is mainly a stabilizer, providing support to local spinal segments, because the fibers span only a few vertebrae. However, the activity of the erector spinae muscle varies with different positions. For example, when a person holds a weight in 1 hand, the center of gravity is displaced sideways and the contralateral erector spinae muscle must contract to avoid collapse and lateral flexion.[45] Our results also suggested that handedness was associated with fewer side-to-side differences in the ratio of FCSA to CSA. Because most participants had a larger erector spinae muscle on the left side, it is not surprising that the majority also had less fatty infiltration (higher ratio of FCSA to CSA) on the left side. Interestingly, participants with a leaner multifidus or erector spinae muscle on the side of their dominant hand were also more active and had less asymmetry in muscle composition; these results support our findings suggesting that more active people have less paraspinal muscle asymmetry.

We found no significant association of paraspinal muscle morphology with LBP severity or disability in our univariate analysis, with the exception of the difference in the erector spinae muscle composition at L5–S1. Other studies also failed to find a clear association of paraspinal muscle morphology with LBP intensity or disability.[3,4,6,10] Like Kalichman et al,[38] who reported no significant association of paraspinal muscle density (an indicator of muscle degeneration) with the occurrence of LBP, we found no significant association of paraspinal muscle asymmetry with LBP frequency. Thus, our results do not support our initial hypothesis because LBP history was not consistently associated with paraspinal muscle asymmetry. Moreover, contrary to our original hypothesis, LBP history and disk height narrowing were not found to be more highly associated with asymmetry in the multifidus muscle than with that in the erector spinae muscle. However, we did not distinguish unilateral LBP and radicular symptoms from other back pain problems. Most studies have reported on the association of paraspinal muscle asymmetry with LBP in patients with a clinical presentation of unilateral LBP.[2,6,8–10,46–48]

Because all of the Twin Spine Study MZ twin pairs meeting the inclusion criteria were included in the present study and because our analysis was a secondary data analysis, there was no possibility of adding more participants. However, the 95% CIs of the significant regression coefficients were quite narrow, suggesting that the precision of the estimates was good. The strengths of the present study include the use and representativeness of a general population sample with extensive interview data, allowing for the evaluation of several environmental and behavioral factors. Also, the selection of twins allowed us to investigate the portion of the variance in paraspinal muscle asymmetry explained by familial aggregation, representing shared early environmental and genetic influences. In a previous measurement study, we showed that our quantitative paraspinal muscle measurement technique was highly reliable when it was applied by the same assessor who obtained measurements in the present study.[40] Furthermore, we estimated that the standard errors of measurement for both outcomes and most asymmetry measurements in the present study were greater than 2 and were likely to represent true asymmetries rather than measurement errors. Thus, it is unclear what accounted for the large portion of unexplained variance in muscle asymmetry, but it is possible that some degree of asymmetry is a naturally occurring phenomenon in human anatomy, including the paraspinal muscles.

Limitations related to the study measurements include the facts that the MR images were obtained in the 1990s, when image quality was lower than what is typically seen at present, and the small amount of fatty infiltration present at L3–L4 increased the difficulty of determining muscle borders. Another limitation was the reliance on participants' recall for LBP history and occupational and leisure physical loading factors. Although the reliability coefficients were generally good for these measurements, they certainly contained some degree of error, diluting associations. Finally, because of the large number of investigated factors, many comparisons were made in our analysis, increasing the probability of chance findings or making a type I error.

Conclusion

Our findings suggested that the behavioral, environmental, and constitutional factors investigated, including age, body mass index, handedness, physical activities, intervertebral disk height narrowing, and back pain history, had little or no association with paraspinal muscle asymmetry, as observed in a population-based sample of men. The few associations identified were generally inconsistent across muscles and spinal levels, with the exception of handedness, and explained little of the variance in paraspinal muscle asymmetry in size and composition. Familial aggregation was found to be the strongest predictor of asymmetry in paraspinal muscle composition, although it, too, explained little of the asymmetry observed. Some degree of paraspinal muscle asymmetry may be a naturally occurring phenomenon, and the particular factors studied (such as those found in a general population sample) may not be of major concern for paraspinal muscle asymmetry observed in clinical or research contexts. Finally, the modest and inconsistent association of paraspinal muscle asymmetry with LBP history questions its consideration as an important aspect of clinical assessment or as a target for rehabilitation.

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Study protocols were approved by the Ethical Committee of the Department of Public Health at the University of Helsinki and the Human Subjects Committee at the University of Washington. This study also was approved by the Health Ethics Research Board of the University of Alberta.

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