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Fluctuating asymmetry and low back pain

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Abstract

Fluctuating asymmetry (FA), a pattern of bilateral variation that is normally distributed around a mean of zero, appears to correlate inversely with fitness and health. In this study, we compared the FA of asymptomatic control subjects ($n = 51$) and patients with low back pain ($n = 44$). We measured eight traits, from the upper and lower limbs, and used them to obtain asymmetry indices for each subject. We also measured pelvic asymmetry in standing subjects. The low back pain (LBP) group showed significantly higher asymmetry in the pelvis, and in ulnar length and bistyloid breadth. Our results demonstrate a link between LBP and asymmetry not only in a weight-bearing trait (i.e., pelvic configuration), but in two traits that are not functionally related to the back (i.e., ulnar length and bistyloid breadth). We can now consider LBP as another health and fitness measure correlated with FA.

Keywords: Fluctuating asymmetry; Low back pain; Pelvic structural asymmetry

1. Introduction

Some asymmetry in body dimensions, such as length of limbs, is the norm rather than the exception for humans. In individuals, random deviations from perfect symmetry in any

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morphological bilateral traits are referred to as fluctuating asymmetry (FA). Within a population, the values of signed FA are normally distributed around a mean of zero (Van Valen, 1962).

For most morphological features of the musculoskeletal system, development of the left and right sides of the body is usually controlled by the same genetic and environmental factors (Livshits & Smouse, 1993; Møller, 1993). Hence, a disturbance in symmetry of what are supposed to be symmetrical traits might indicate a disturbance in the genetic or environmental control of development. Consequently, FA has been considered an inverse measure of developmental stability and homeostasis; i.e., the higher the FA, the greater the instability (Møller, 1993; Van Valen, 1962).

Many studies on FA in humans emphasize the strong relationship between FA and sexual selection (Soler et al., 2003; for a review, see Thornhill & Møller, 1997). FA in humans has also been shown to be related to voice attractiveness (Hughes, Harrison, & Gallup, 2002), romantic jealousy (Brown & Moore, 2003), running speed (Manning & Pickup, 1998), and metabolic rate (Manning, Koukourakis, & Brodie, 1997). Also, FA in palmar epidermal ridges was observed in individuals with congenital vertebral anomaly and scoliosis (see Goldberg, Fogarty, Moore, & Dowling, 1997, and papers cited therein).

Asymmetry in the pelvis and lower extremities could cause asymmetry in biomechanical loading on joints, especially during weight-bearing activities. Accordingly, assessment of lower body asymmetry is part of the postural evaluation undertaken by health professionals when treating patients with musculoskeletal problems (Subotnick, 1981). A common musculoskeletal complaint, low back pain (LBP), is often ascribed to skeletal asymmetry, and efforts to correct asymmetry are used to treat LBP symptoms (Lee, 1989).

Researchers have inferred that asymmetry of the lower limb, such as leg length discrepancy (LLD), contributes to LBP, although no direct cause-and-effect relationship has been established (Egan, Cole, & Twomey, 1995). There is some evidence to support an association between asymmetry and soft tissue changes in the back (Bogduk & Twomey, 1997), but studies investigating the effect of lower limb asymmetry on LBP have yielded conflicting results (for a review, see Egan & Al-Eisa, 1999). For example, some authors have questioned the effect of pelvic asymmetry and LLD on the etiology of LBP (Levangie, 1999), although when the lower limb asymmetry was measured with higher precision using radiographs, an association between LBP and asymmetry has been suggested (Friberg, 1983).

To our knowledge, only one study has attempted to assess whether there is a relationship between FA and LBP. Shackelford and Larsen (1997) examined the correlation between facial FA and physical symptoms such as headache and sore throat, over a 2-month study period; backache was not precisely defined, but was one of the symptoms in a self-report checklist. Women with greater facial FA were more likely to complain of muscle soreness and backaches, but there was no such relationship in men.

In the present study, we examined differences between healthy subjects and patients with LBP with respect to FA in selected traits, and with separate consideration of upper and lower limb asymmetries.

2. Methods

2.1. Participants

Asymptomatic controls (males and females, age 20 – 45 years) were recruited through poster and media advertisement. We contacted local physiotherapy clinics to refer subjects diagnosed with mechanical LBP, recruiting only those who had obtained professional help for LBP at least once in the 6 months prior to the study. Pain was predominantly unilateral in the lumbosacral region, buttocks, and thigh. Nerve-root pain, recent trauma, history of fracture, pregnancy, back surgery, tumor, or spinal pathology excluded the subject from the study.

We initially screened 143 subjects, but after applying our exclusion criteria, 95 were included in the study: a LBP group ($n=44$; 17 males and 27 females, mean age ± S.D. = 34.9 ± 7.1 years), and a normal control group with no history of LBP ($n=51$; 17 males and 34 females, mean age ± S.D. = 29.3 ± 5.6 years).

2.2. Bilateral traits

Noninvasive calipers were used to measure eight upper and lower limb traits (see Table 1), chosen because they exhibit FA (Livshits & Smouse, 1993; Manning & Pickup, 1998; Trivers, Manning, Thornhill, Singh, & McGuire, 1999), and can be measured reliably using bony landmarks. The landmarks were palpated and marked using adhesive skin markers (8 mm in

Table 1
Morphological traits in the study and the methods used to measure them

Trait	Land-marks	Position
3rd digit length	Metacarpophalangeal joint to end of 3rd digit	Hand flat on a table, palm down
Hand length	Distal end of radius to end of 3rd digit	Hand flat on a table, palm down
Ulnar length	Elbow to ulnar styloid process	Elbow on a table, forearm aligned against a vertical ruler
Bistyloid breadth	Ulnar styloid to radial styloid process	Forearm flat on a table, palm down
Tibial length	Medial knee joint line to medial malleolus	Participant lying supine on a plinth, knee slightly bent
Femur length	Lateral knee joint line to greater trochanter	Participant lying supine on a plinth, knee slightly bent
Foot length	Most distal point on the heel to end of longest toe	Participant standing on a foot frame that measures foot length, with the heel placed against one end of the device
Bimalleolar breadth	Medial to lateral malleolus	Participant lying supine on a plinth
Pelvic asymmetry	Anterior and posterior iliac spines width apart and height from the floor	Participant standing with arms supported on a standard walker

diameter and marked in the center); procedures used to measure each trait (to the nearest 0.1 mm) are outlined in Table 1. An anthropometric measuring frame was used to measure the width and height of the anterior and posterior iliac spines, while participants were in a standing position (Egan, Cole, & Twomey, 1999). Each trait was measured three times and averaged to minimize measurement error. Test−retest reliability of asymmetry indices was examined. The measurements of all traits were taken on two occasions for 10 subjects who participated in the experiment twice. Intraclass correlation coefficients (ICCs) ranged between .83 and .95.

2.3. Asymmetry calculations

A relative fluctuating asymmetry (RFA) index was defined as the absolute difference between the sides $|R-L|$ divided by the mean total size of the trait, or $RFA=100\ [|R-L|/0.5\ (R+L)]$ (Palmer & Strobeck, 1986).

Summing the values of FA indices over a number of traits sums the information in those traits (Trivers et al., 1999), so we computed a composite FA index by summing relative FA values over the eight upper and lower limb traits. We also summed the relative FA indices of the four upper limb traits (bistyloid breadth, 3rd digit, hand, and ulnar lengths) as an upper limb asymmetry index, and of the four lower body traits (bimalleolar breadth, tibial, femoral, and foot lengths) as a lower limb asymmetry index.

Pelvic asymmetry was computed as the [mean anterior superior iliac spines (ASIS's) height difference/mean ASIS width apart]+[mean posterior superior iliac spines (PSIS's) height difference/mean PSIS width apart]. This ratio defines the slope between the ASIS's and PSIS's in the frontal plane (Egan et al., 1999). An important advantage of this method of measurement is that it is normalized to each individual's pelvic width.

2.4. Statistical analyses

Analyses were conducted with SPSS 10.0. Asymmetry differences between the LBP and control groups were initially assessed by two-factor ANOVA with sex as the second factor, but since there were no statistically significant sex effects in any analysis, this variable is not considered further, and results are based on univariate ANOVA with age, weight, height, and body mass index treated as covariates. Before conducting ANOVA, we tested the underlying assumptions by testing for deviations from normality (skewness or kurtosis), and homogeneity of variances (Levene's test). Two-tailed t tests were used to test for differences between upper and lower limb asymmetry indices.

Since this paper is the first to present pelvic asymmetry as a possible FA trait, we assessed bivariate correlations between the pelvic asymmetry ratio and other traits.

3. Results

Mean relative FA indices for LBP and control groups are shown in Table 2. Significant differences between the two groups were found in only two limb traits: ulnar length and

Table 2
Asymmetry scores in controls and low back pain groups

Trait	Group		P
	Controls ($n=51$) Mean±S.D.	LBP ($n=44$) Mean±S.D.	
3rd digit length	0.016±0.01	0.014±0.01	0.303
Hand length	0.011±0.01	0.010±0.01	0.975
Ulnar length	0.006±0.00	0.008±0.01	0.044*
Bistyloid breadth	0.024±0.01	0.032±0.01	0.036*
Tibial length	0.007±0.01	0.009±0.01	0.423
Femur length	0.009±0.01	0.010±0.01	0.920
Foot length	0.009±0.01	0.010±0.01	0.352
Bimalleolar breadth	0.026±0.02	0.019±0.01	0.212
Pelvic asymmetry	0.046±0.03	0.068±0.04	0.005*
Composite fluctuating asymmetry	1.669±0.68	1.815±0.72	0.259
Upper limb asymmetry	0.058±0.02	0.064±0.02	0.147
Lower limb asymmetry	0.052±0.03	0.048±0.02	0.764

Significance of between-group differences was assessed by ANOVA.
* $P<.05$.

bistyloid breadth, in which the asymmetry scores of the LBP subjects were higher than those of the controls. The LBP group also had a significantly higher mean pelvic asymmetry ratio. There were no significant differences between the two groups in composite, upper limb, or lower limb FA indices, but the mean upper limb asymmetry index (mean±S.D. 0.061 ± 0.022) was significantly higher than the lower limb asymmetry index (mean ± S.D. = 0.050 ± 0.025) for the whole sample ($t=3.2$, $P=.001$).

We also tested the correlation between pelvic asymmetry and other traits. The strongest correlations were with tibial and femoral length asymmetry, and composite and lower limb FA (Table 3), correlations that were significant within the LBP group but not the control subjects.

4. Discussion

Two major results emerge from this study. First, patients with LBP had significantly greater pelvic asymmetry than the normal controls. Second, patients with LBP were

Table 3
Correlation coefficients (r) between pelvic asymmetry ratio and five other asymmetry indices

Trait	Group		
	Controls ($n=51$)	LBP ($n=44$)	Total ($n=95$)
Tibial length asymmetry	.164	.436*	.328*
Femoral length asymmetry	.259	.535*	.386*
Composite fluctuating asymmetry	.119	.512*	.341*
Lower limb asymmetry	.038	.478*	.155
Upper limb asymmetry	−.123	−.002	−.015

* Significant correlation at .01.

significantly more asymmetrical in upper limb traits, namely ulnar length and bistyloid breadth, which are unlikely to be causal factors affecting back function. Our results do not support the general belief that a composite FA index would be more effective in detecting relationships with fitness variables than single trait asymmetries.

LBP is considered a major socioeconomic and clinical problem due to its high incidence and growing costs of treatment (Waddell, 1996). Identifying predisposing human physical factors, such as altered posture, is of great value. The effect of pelvic asymmetry on LBP has been a source of debate among clinicians and researchers. While some authors attributed LBP to pelvic asymmetry and leg length discrepancy (e.g., Friberg, 1983), the results of more recent studies have not supported the assumption of positive association between pelvic asymmetry and LBP (e.g., Levangie, 1999). In our sample, pelvic asymmetry values were small, but they were still significantly higher in the LBP group. The pelvic asymmetry ratio that we used included anterior and posterior measurement of the pelvis, hence, evaluating the pelvic posture in the frontal as well as sagittal plane. Levangie (1999) described pelvic asymmetry as asymmetry of left–right innominate inclination; i.e., sagittal plane innominate torsion. Therefore, we infer that LBP may be more associated with frontal rather than sagittal plane pelvic asymmetry.

Leg length discrepancy has been recognized as a factor contributing to some musculoskeletal syndromes (Friberg, 1983), but tibial and femoral length asymmetry were not associated with LBP in our study, as indicated by the lack of significant group differences in those traits. The LBP group, however, did have higher mean relative asymmetry scores, so a larger data set might confirm a difference. Furthermore, tibial and femoral length asymmetry scores were correlated with pelvic asymmetry in the LBP group, but not in the control group. It is hard to explain the former finding. Statistically, though, this may be due to the higher pelvic asymmetry in the LBP group.

We found the upper asymmetry index to be significantly higher than that of the lower limb. This is consistent with the results of Trivers et al. (1999), who proposed that legs exhibit high developmental stability and hence lower FA due to selection for mechanical efficiency. Although symmetry in bilateral traits is thought to be the optimal condition, it is unlikely that an organism will attain perfect symmetry in all traits. One might suspect that the amount of asymmetry that can be tolerated in a bilateral trait would relate to the functionality of the trait. In birds, FA has been found to be higher in ornamental than in mechanical traits (Evans, Martins, & Haley, 1995). Our results demonstrate a possible link between FA and LBP mainly in upper limb traits, which are not so functionally linked to locomotion or axial movements.

Our study contributes to the growing literature on human asymmetry and health and is the first to address the relationship between FA and mechanical LBP, the most common form of LBP. Our results indicate a link between FA and LBP for two traits, ulnar length and bistyloid breadth, that are not themselves linked to the function of the back. In addition, the LBP group had significantly higher pelvic asymmetry than the normal group. In conclusion, LBP may be another parameter, like running speed, sexual activity, and metabolic rate, that can be added to the growing list of health and fitness variables linked to FA.

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