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Research article

The relation between mild leg-length inequality and able-bodied gait asymmetry

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Abstract
The causes of able-bodied gait asymmetries are unclear. Mild (< 3 cm) leg-length inequality (LLI) may be one cause of these asymmetries; however, this idea has not been thoroughly investigated. The purpose of this study was to investigate the nature of the relationship between LLI and able-bodied gait asymmetries. We hypothesized that subjects (n = 26) with relatively large LLI, quantified radiographically, would display less symmetrical gait than subjects with relatively small LLI. Gait asymmetries for joint kinematics and joint kinetics were determined using standard gait analysis procedures. Symmetry coefficients were used to quantify bilateral gait symmetry for sagittal-plane hip, knee, and ankle joint angles, moments, and powers. A Pearson product-moment correlation coefficient (r) was used to evaluate the relationship between LLI and the aforementioned symmetry coefficients. Also, these symmetry coefficients were compared between subjects with relatively small LLI (LLI < 1 cm; n = 19) and relatively large LLI (LLI ≥ 1 cm; n = 7). Statistically significant relationships were observed between LLI and the symmetry coefficient for knee joint moment (r = -0.48) and power (r = -0.51), and ankle joint moment (r = -0.41) and power (r = -0.42). Similarly, subjects with relatively large LLI exhibited significantly lower symmetry coefficients for knee joint moment (p = 0.40) and power (p = 0.35), and ankle joint moment (p = 0.40) and power (p = 0.22) than subjects with relatively small LLI. Degree of bilateral symmetry for knee and ankle joint kinetics appears to be related to LLI in able-bodied gait. This finding supports the idea that LLI is one cause of able-bodied gait asymmetries. Other factors, however, are also likely to contribute to these gait asymmetries; these may include other morphological asymmetries as well as asymmetrical neuromuscular input to the lower limb muscles.

Key words: Leg length, gait, asymmetry, kinematics, kinetics.

Introduction

Human able-bodied gait has been described extensively, yet many fundamental aspects of walking are still not well understood. For example, bilateral asymmetries, defined as a lack of perfect agreement between lower limbs (Herzog et al., 1989; Sadeghi et al., 2000), have been documented during able-bodied gait for kinematic (Allard et al., 1996; Maupas et al., 2002), kinetic (Herzog et al., 1989; Sadeghi et al., 1997; Seeley et al., 2008), and electromyographic (Arsenault et al., 1986; Ounpuu and Winter, 1989) variables. The underlying causes of these asymmetries, however, remain unclear. An understanding of the causes of these asymmetries is important, as it could aid in the development of enhanced rehabilitation programs for various acute and chronic movement disorders that are characterized by asymmetrical gait. Several different explanations have been put forth as plausible causes of able-bodied gait asymmetries (Sadeghi et al., 2000). Most of the proposed explanations fall into one of two primary categories: (1) morphological asymmetry, and (2) asymmetrical neural input. Theoretically, if both legs are morphologically identical and receive the same neural input while in a controlled environment (e.g., a flat laboratory walkway), a symmetrical gait pattern should emerge. It is unlikely, however, that morphology or neuromuscular input are ever perfectly symmetrical, and both likely contribute to gait asymmetry. In this study, we focused on one possible morphological cause of gait asymmetry.

Mild leg-length inequality (LLI) has been defined as an anatomical LLI that does not exceed 3 cm (McCaw & Bates, 1991), and has frequently been cited as a possible morphological cause of asymmetry in able-bodied gait (Du Chatinier & Rozendal, 1970; Gurney et al., 2001; Kaufman et al., 1996; Perttunen et al., 2004; Subotnick, 1981; White et al., 2004). The relationship between LLI and gait asymmetry, however, is not well understood. While it makes sense that bilateral differences in leg length would contribute to gait asymmetry, some prior research has contradicted this idea (Goel et al., 1997). Among those who have suggested an association between LLI and gait asymmetry, some have concluded that any LLI greater than 1.0 cm will affect function (Cathie, 1950; McCaw & Bates, 1991). Others, however, have indicated that a LLI up to 2.5 cm will not affect gait mechanics (Gross, 1983; Siffert, 1987).

A weakness of the existing literature regarding a potential relationship between LLI and gait asymmetries is that no studies have combined accurate measures of LLI (i.e., radiography) with quantitative measures of gait asymmetry. It is generally agreed that radiography is necessary to accurately and reliably measure LLI (Sabharwal & Kumar, 2008) and without an accurate measure of LLI, it is difficult to accurately assess the potential relationships between LLI and gait asymmetries. Therefore, the purpose of this study was to investigate the nature of the relationships between LLI, determined via X-ray, and able-bodied gait asymmetries, determined using computerized gait analysis procedures. We hypothesized that subjects with greater LLI would exhibit a less symmetrical gait than subjects with smaller LLI. Specifically, we predicted that there would be significant negative correlations between LLI and measures of gait symmetry. We also expected that, if the subjects were considered as two groups, with one group having relatively small LLI (< 1 cm) and the other group having relatively large LLI

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(≥ 1 cm), the subjects with relatively large LLI would exhibit significantly less symmetrical gait patterns. We chose 1 cm as a dividing point between relatively small and relatively large LLI because 1 cm has been suggested by some investigators (Cathie, 1950; McCaw & Bates, 1991) as the magnitude of LLI that will begin to affect biomechanical function during gait.

Methods

Twenty six subjects (13 females; 13 males; age = 30 ± 6 yrs; height = 1.74 ± 0.10 m; mass = 73.9 ± 5.7 kg) who reported no lower-limb impairment participated in this study. Nineteen of the twenty six subjects exhibited a LLI that was less than 1 cm (11 females; 8 males; age = 30 ± 5 yrs; height = 1.73 ± 0.11 m; mass = 71.5 ± 16.8 kg). Seven subjects had a LLI that was greater than or equal to 1 cm (2 females; 5 males; age = 28 ± 8 yrs; height = 1.76 ± 0.07 m; mass = 74.6 ± 16.2 kg). Prior to data collection, all subjects gave informed consent in accordance with local ethical committee regulations.

LLI was determined using total body dual energy absorptiometry (DXA; Lunar DPX-IQ, Lunar Inc., Madison, WI, USA) scans. Total limb length was computed as the summed lengths of the tibia and femur (Ganley and Powers, 2004) and was quantified using the 'ruler' function of the Lunar 4.3 software. Femoral length was the distance between the superior greater trochanter and most distal aspect of the lateral femoral epicondyles (Ganley and Powers, 2004). Tibial length was the distance between the distal lateral femoral epicondyle and most inferior aspect of the lateral malleolus (Ganley and Powers, 2004). LLI was the absolute difference between left and right total limb lengths.

During a separate lab visit, subjects underwent a standard gait analysis. Six high-speed video cameras (60 Hz; Motion Analysis Inc., Santa Rosa, CA, USA) and two force platforms (960 Hz; Kistler Instrument Corp., Amherst, NY, USA) were used to collect kinematic and kinetic data. Reflective markers were applied to anatomical landmarks in a previously described arrangement (Ferber et al., 2003). Five successful walking trials were then performed at a self-selected pace across a 10-m walkway. A trial was considered successful when the right foot and left foot each contacted a separate force platform during consecutive steps. Three-dimensional coordinates for each marker were determined using Motion Analysis EvaRT 4.0 software (Motion Analysis, Santa Rosa, CA, USA). Coordinate data were smoothed using a dual-pass Butterworth filter with a 6-Hz cutoff (D. Winter, 2005). Ground reaction force and coordinate data were then exported into OrthoTrac 5.0.2 software (Motion Analysis, Santa Rosa, CA, USA) for the calculation of joint kinematics and kinetics. Researchers who assisted with the gait analyses were blinded to LLI to minimize experimental bias.

Bilateral sagittal-plane joint angles, net joint moments, and joint powers were calculated for the hip, knee, and ankle over five successful trials. For each successful trial, data were time normalized to one complete gait cycle (heel strike to ipsilateral heel strike). Bilateral ensemble average curves for the aforementioned measures of angle, moment, and power at the hip, knee, and ankle were created by averaging the data across the five gait cycles for each subject. A Pearson product-moment correlation coefficient was then used to evaluate the degree of between-limb symmetry (Arsenault et al., 1986; Pierotti et al., 1991) for the ensemble curves related to joint angle, moment, and power, for each subject. This measure of between-limb symmetry will be referred to as the "*symmetry coefficient*" to avoid confusion with the correlation coefficients later used as part of the statistical analysis, as described in the next section. Larger symmetry coefficient values indicated greater between-limb symmetry. The symmetry coefficients computed in this study were used to evaluate bilateral symmetry for joint angles, moments, and powers over the whole gait cycle. No discrete variables were considered.

The relationship between LLI (quantified via DXA) and gait symmetry (quantified via the symmetry coefficient) was evaluated using the Pearson product-moment correlation coefficient (r). Negative r values would indicate that subjects with greater LLI tended to exhibit less symmetrical gait. Also, the mean symmetry coefficients for hip, knee, and ankle joint angles, moments, and powers were compared between the groups of subjects with relatively small (< 1 cm) and relatively large LLI (≥ 1 cm), using a nonparametric statistic (Mann-Whitney; $\alpha = 0.05$).

Results

Mean LLI for the entire sample was 0.8 ± 0.7 cm and ranged from 0.0 to 2.3 cm. The mean LLI for the subjects who exhibited a relatively small LLI (< 1 cm; n = 19) was 0.4 ± 0.3 cm, while the mean LLI for subjects who exhibited a relatively large LLI (≥ 1 cm; n = 7) was 1.7 ± 0.4 cm. One subject did not exhibit any detectable LLI. The sample mean for walking speed was 1.36 ± 0.10 $m \cdot s^{-1}$, and the average within-subject coefficient of variation for walking speed was 0.02. Ensemble means and standard deviations for all of the trials for hip, knee, and ankle joint angle, moment, and power are shown in Figure 1. Figure 2 presents knee joint angle, moment, and power curves for an individual subject displaying low LLI (0.0 cm) and high symmetry (left panels), and another subject with relatively high LLI (1.6 cm) and low symmetry (right panels). The means and standard deviations for the symmetry coefficients are presented in Table 1, recalling that a larger symmetry coefficient indicates greater between-limb gait symmetry.

The correlational analyses indicated that LLI was related to gait symmetry for several mechanical variables (Table 2 and Figure 3). Significant, moderate, negative correlations existed between LLI and gait symmetry for knee moment (p = 0.013), knee power (p = 0.008), ankle moment (p = 0.035), and ankle power (p = 0.013). Significant correlations, however, did not exist between LLI and gait symmetry for any other dependent variables. The weakest and strongest relationships between LLI and gait symmetry were for knee angle (r = -0.29; p = 0.155) and knee power (r = -0.51; p = 0.008), respectively. All of the correlation coefficients were negative, indicating that subjects with greater LLI tended to exhibit less symmetrical gait. The statistical significance tests revealed that gait

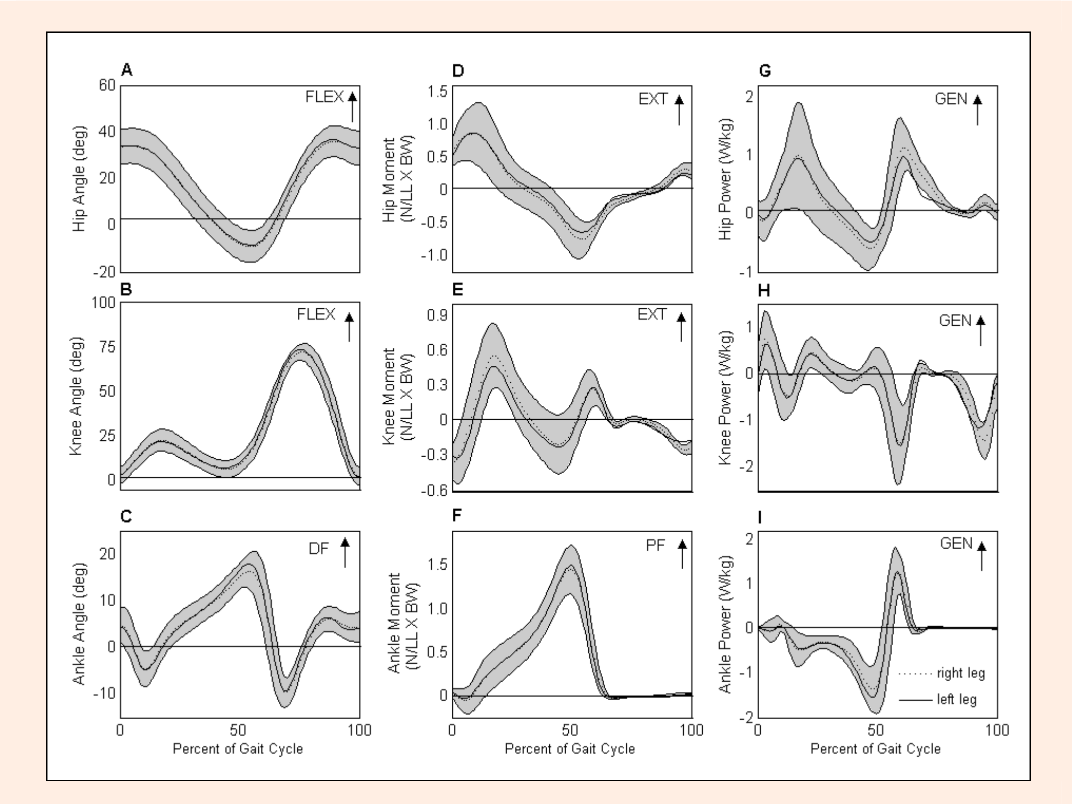

Figure 1. Means and standard deviations (shaded area) for right (dotted line) and left (solid line) legs for all recorded trials, for sagittal plane joint angles (A-C), moments (D-F), and powers (G-I). Because the standard deviations were bilaterally similar, only the standard deviations for one side (right) are shown, to increase figure clarity.

symmetry for joint moments and powers tended to be more strongly related to LLI than for joint angles.

Table 1. Means (±standard deviations) for the symmetry coefficients that were used to quantify the degree of between-leg gait symmetry for sagittal-plane joint angle, moment, and power at the hip, knee, and ankle (n = 26). Lower coefficient values indicate less symmetrical gait. Joint moments and powers were generally less symmetrical than joint angles.

Joint	Measure	Mean symmetry coefficient
Hip	Angle	.99 (.02)
	Moment	.87 (.23)
	Power	.71 (34)
Knee	Angle	.99 (.04)
	Moment	.77 (.26)
	Power	.75 (.26)
Ankle	Angle	.94 (.12)
	Moment	.95 (.09)
	Power	.87 (.19)

The results of comparisons between the groups of subjects with relatively large (≥ 1 cm) and relatively small (< 1 cm) LLI also indicated that LLI was related to gait asymmetry for several of the dependent variables. Subjects with relatively large LLI exhibited greater gait asymmetry for knee moment ($p = 0.040$), knee power ($p = 0.035$), ankle moment ($p = 0.040$), and ankle power ($p = 0.022$) than subjects with relatively small LLI (Table 3). These differences at the knee and ankle joints indicated that joint moments and powers were less symmetrical for subjects with a relatively large LLI. While not quite reaching statistical significance, hip joint power ($p = 0.069$) and ankle joint angle ($p = 0.064$) also exhibited a tendency towards being less symmetrical for subjects with relatively large LLI. In summary, angle tended to be highly symmetrical, while power was least symmetrical (Table 1). The degree of symmetry for moment differed across joints, with the ankle moment being most symmetrical and the knee moment the least symmetrical (Table 1).

Table 2. Pearson product-moment correlation coefficients (*r*) that were used to quantify the relationship between leg-length inequality and degree of gait symmetry for a sample of able-bodied subjects (n = 26). Degree of symmetry for sagittal-plane knee joint moment and power, and ankle joint moment and power were moderately and negatively related to leg-length inequality. This indicates that as leg-length inequality increased, gait symmetry for knee and ankle joint moment and power decreased.

Joint	Measure	r value	p value
Hip	Angle	-.30	.135
	Moment	-.38	.053
	Power	-.36	.072
Knee	Angle	-.29	.155
	Moment	-.48	.013
	Power	-.51	.008
Ankle	Angle	-.34	.094
	Moment	-.41	.035
	Power	-.42	.032

Discussion

Bilateral able-bodied gait asymmetries are well documented (Allard et al., 1996; Arsenault et al., 1986; Herzog

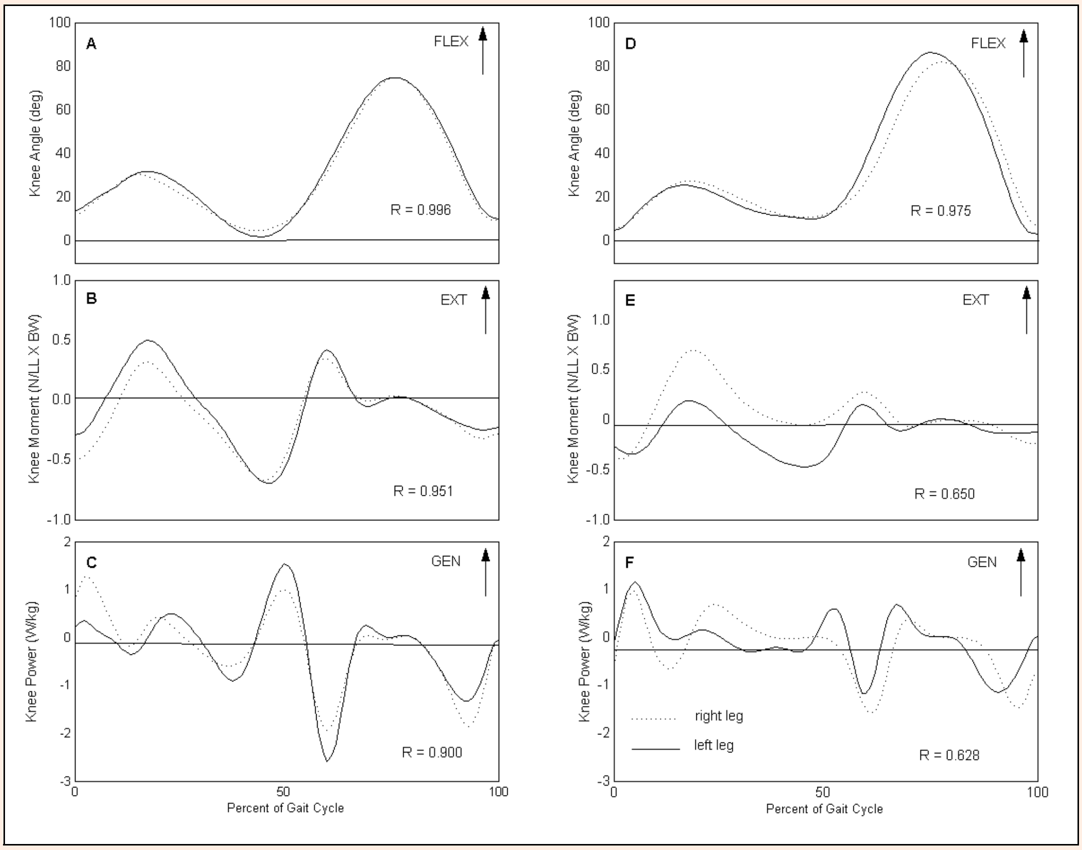

Figure 2. Mean ensembles for bilateral knee angle, moment, and power for an individual with a small leg-length inequality (0.0 cm) and high degree of gait symmetry (A-C), and an individual with a relatively large leg-length inequality (2.3 cm) and low degree of gait symmetry (D-F). These two subjects were representative of general trends in the data: bilateral asymmetry for the observed measures was generally greater for subjects with greater limb-length inequalities.

et al., 1989; Maupas et al., 1999; Ounpuu and Winter, 1989; Sadeghi et al., 1997; 2000; Seeley et al., 2008), yet their causes have not been fully explained. LLI may be one cause of gait asymmetries (Du Chatinier and Rozendal, 1970; Gurney et al., 2001; Kaufman et al., 1996; Perttunen et al., 2004; Subotnick, 1981; White et al., 2004), and the purpose of this study was to investigate the nature of the relationship between LLI and able-bodied gait asymmetries. This was accomplished by accurately quantifying LLI and gait asymmetries within a relatively large sample of subjects. Our results showed that LLI was not significantly related to the degree of bilateral symmetry for joint angles during gait (Table 2). Our results do, however, support the idea that LLI influences gait symmetry for joint moment and power at the hip, knee, and ankle joints (Table 2). Each of the correlations for moments and powers were negative (r values ranged from -0.36 to -0.51), and nearly all of them met statistical significance (Table 2). The two p values that exceeded 0.05 (hip moment: 0.053, and hip power: 0.072) did so only by small margins. Overall, these moderate negative correlations indicate that in able-bodied walking, subjects with larger LLI tend to exhibit a greater degree of asymmetry in joint kinetics. It should be emphasized, however, that the highest r value was -0.51, meaning that no more than 26% of the observed gait asymmetries can be explained by LLI. Other morphological asymmetries (e.g., segment mass or moment of inertia) or neuromuscular factors probably also contributed to the observed gait asymmetries. Some of the other possible causes of gait asymmetries could actually be long-term adaptations to the structural differences in leg length.

The results from the comparisons between subjects with relatively small and relatively large LLI reinforced the idea that LLI influences joint moment and power symmetry during gait. Subjects with relatively large LLI showed significantly less symmetrical gait for knee and ankle moment and power than subjects with relatively small LLI (Table 3). In combination, the moderate negative correlations described in the previous paragraph, and the between-group (large vs. small LLI) differences described here, indicate that bilateral symmetry for joint moments and powers is related to LLI. In contrast, our results provided little evidence that joint angle asymmetries are strongly influenced by LLI. Particularly at the hip and knee, the joint angles were so bilaterally symmetrical that there was little variance to be explained by LLI, or any other potential variable. This may reflect a tendency for humans to maintain stable and consistent kinematics, by varying joint kinetics. This phenomenon, which has been referred to as kinematic invariance, has been reported for normal (Borghese et al., 1996; Winter, 1983) and amputee gait (Selles et al., 2004). This idea of kinematic invariance fits well with our findings and

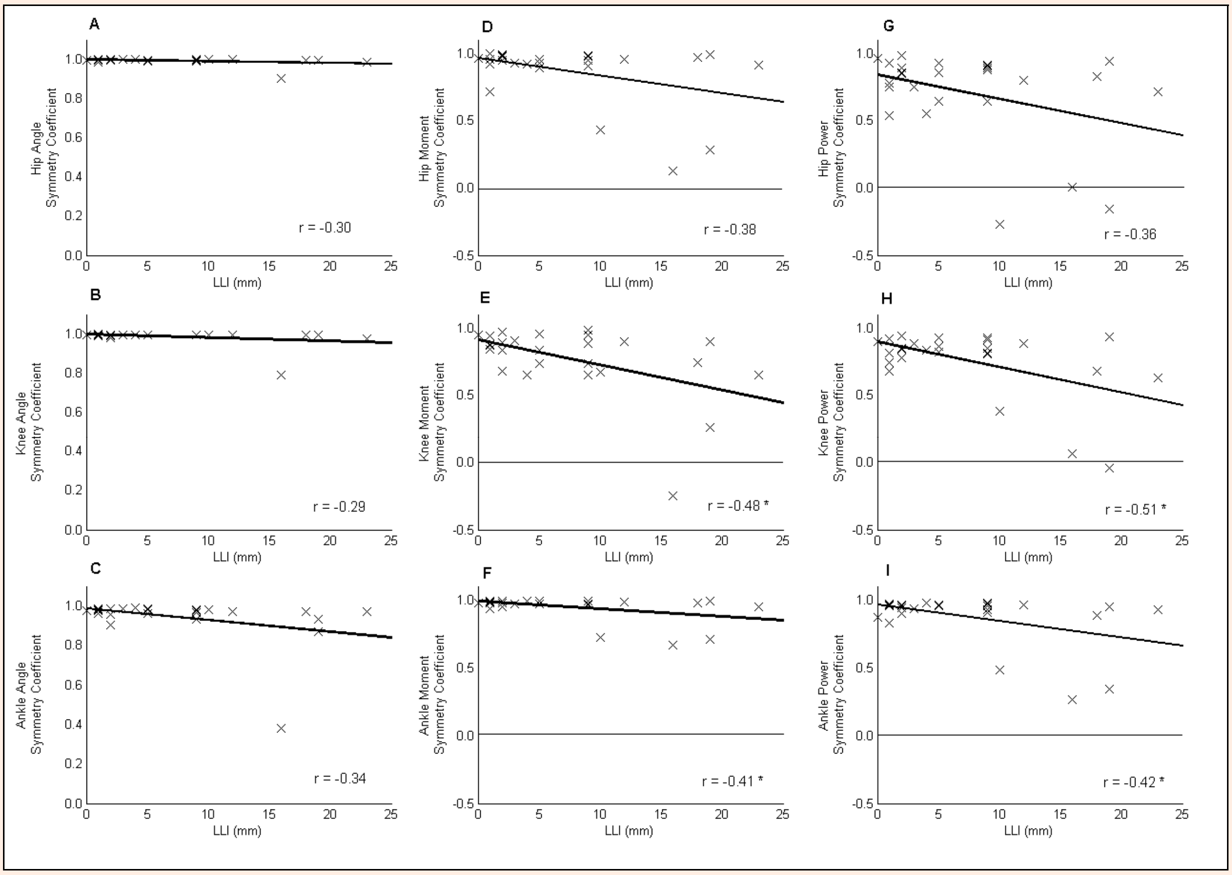

Figure 3. Scatter plots showing the relationships between leg-length inequality and between-leg gait symmetry for sagittal-plane joint angles (A-C), moments (D-F), and powers (G-I). Greater symmetry coefficients (vertical axis) indicate more symmetrical gait. The relationships between leg-length inequality and gait symmetry were all negative, indicating that gait was less symmetrical for subjects with relatively larger leg-length inequality. The asterisks indicate relationships that were statistically significant (α = 0.05).

suggests that humans can maintain a high degree of kinematic symmetry during walking, despite varying degrees of LLI.

Table 3. Means (±standard deviations) for degree of gait symmetry, quantified via the symmetry coefficient, for two groups of able-bodied subjects: (1) leg-length inequality less than 1 cm (n = 19), and (2) leg-length inequality equal to or greater than 1 cm (n = 7). Lower symmetry coefficients indicate less gait symmetry. The degree of gait symmetry was significantly less for sagittal-plane knee and ankle joint moment and power for subjects with a leg-length inequality that was greater than or equal to 1 cm.

Joint	Measure	LLI < 1 cm	LLI ≥ 1 cm	p value
Hip	Angle	.99 (.01)	.98 (.04)	.285
	Moment	.94 (.06)	.66 (.37)	.174
	Power	.81 (.14)	.41 (.52)	.069
Knee	Angle	.99 (.01)	.96 (.08)	.418
	Moment	.85 (.11)	.55 (.41)	.040
	Power	.85 (.07)	.50 (.38)	.035
Ankle	Angle	.97 (.02)	.87 (.22)	.064
	Moment	.98 (.02)	.86 (.15)	.040
	Power	.94 (.04)	.69 (.31)	.022

While the statistical analyses indicated moderate, negative relationships between LLI and most of the moment and power variables, some aspects of these findings warrant further comment. First, it should be noted that these negative relationships were due in part to results from a relatively small number of subjects who exhibited the most substantial asymmetries for joint angle, moment, and power (Table 2 and Figure 3). It would be tempting to consider some of these subjects as outliers. However, we did not exclude these subjects from the statistical analyses, as their presentation was in fact consistent with our hypotheses (i.e., larger LLI is associate with greater asymmetry). In contrast, none of the subjects with relatively low (< 1.0 cm) LLI exhibited large asymmetries for any variable. However, there tended to be more variability in the symmetry coefficient values for the moment and power variables than for the angle variables (Figure 3), even in the low LLI group. For subjects with relatively large LLI (≥ 1.0 cm), there was considerable variability in the symmetry coefficient values for most of the kinetic variables (Figure 3), with some subjects maintaining nearly perfect symmetry, while other exhibit substantial gait asymmetries for some variables. Thus, another way to interpret the statistical results is that subjects with no meaningful LLI (i.e., LLI < 1.0 cm) walk with highly symmetrical gait kinematics and kinetics, whereas it is difficult to predict the amount of asymmetry that a subject with a larger LLI will exhibit. The subjects with larger LLI and high gait symmetry must have made neuromuscular adaptations to compensate for the structural asymmetry. It is not clear why and how these subjects made the necessary adaptations, or why some of the other subjects with larger LLI did not.

It is also worth commenting on the technique that was used to quantify the degree of gait symmetry for each subject. Our symmetry coefficient was based on the Pearson product-moment correlation coefficient (Arsenault et al., 1986; Pierotti et al., 1991). The Pearson coefficient has the advantage of being simple and familiar, and takes into account the whole gait cycle, not just discrete estimates. The Pearson coefficient is sensitive to differences in both timing and amplitude in the curves being compared (Derrick et al., 1994), which can be a limitation in certain applications. The present data did exhibit asymmetries in both timing and amplitude (Figure 2). Our intent was to quantify the degree of symmetry in general, rather than any specific aspects of it. Therefore, the Pearson coefficient was deemed to be an appropriate index of gait symmetry for the present study. Any attempt to more finely characterize the nature of the asymmetries would require the use of another approach.

A primary finding of this study was greater asymmetry for kinetic variables, compared to joint angles. While we believe the greater asymmetry for kinetic variables to be genuine, it is possible that cumulative errors in the data processing procedures may have contributed to these findings. Joint angles are subject to error related to reflective marker position data and skin movement relative to the underlying bony tissue (Cappozzo et al., 1996). Joint moments are subject to these same errors, but also to uncertainty in body segment inertial parameters (e.g., Pearsall and Costigan, 1999) and alignment of the kinematic and force plate reference frames (e.g., McCaw and DeVita, 1995). The computation of joint powers will carry forward all of these sources of error, and further involves time differentiation of the joint angle data. Thus, it is possible that accumulated error may have contributed to the trends in asymmetries from joint angle, to moments, to powers.

The present results have important clinical implications. Several of our subjects exhibited LLI that we operationally defined as relatively large (> 1 cm), and the lowest symmetry coefficients were found among these subjects. However, many clinicians, especially those still relying on inaccurate tape measures, may ignore LLIs of this magnitude and consider them to be normal. Also, LLIs described as relatively large (> 1 cm) in the present study have been deemed pathologic (Friberg, 1982; Subotnick, 1981); however, all of the present subjects were asymptomatic. This suggests that for walking, it may not be feasible to identify a simple threshold magnitude for LLI that, if surpassed, will result in pathology and/or necessitate clinical intervention (Gurney, 2002; Reid and Smith, 1984). Such a threshold would likely vary among individuals, and would depend on many factors, such as anthropometrics, age, and activity level (Gurney, 2002; Reid and Smith, 1984). On the other hand, it should be noted that our subjects were relatively young, and symptoms related to LLI (e.g., osteoarthritis or back pain) may require more time to manifest. Related to this point, a longitudinal study of the cumulative effects of LLI on gait asymmetry is warranted. Finally, our results imply that clinicians should expect a certain degree of bilateral asymmetry in kinetic variables, and should consider this asymmetry when evaluating unilateral pathology. Asymmetrical joint kinematics, however, appear to be less typical and are more likely to indicate a need for clinical intervention because they will likely be associated with extremely asymmetric patterns of kinetics and energetics.

Our results for able-bodied walkers were generally consistent with previous research regarding gait symmetry and LLI for impaired subjects (Kaufman et al., 1996; Perttunen et al., 2004). Conclusions from this prior research also indicated that gait symmetry decreases with increases in LLI. The present data also agree with White et al. (2004) who showed various components of the ground reaction force become less symmetrical with increases in LLI. However, the present data differed from the results of Gurney et al. (2001) concerning the relationship between LLI and symmetry for quadriceps and plantarflexor muscle electromyographic activity, as measured with surface electromyography (Gurney et al., 2001). They reported that quadriceps and plantarflexor electromyographic activity are symmetrical in subjects with a LLI up to 3 cm (Gurney et al., 2001). This difference in results may be partially explained by the different variables considered. Electromyography data tend to be more variable than joint kinetics and kinematics, which would make asymmetry more difficult to detect.

This study was the first to quantify the relationship between LLI and gait asymmetry, using radiography and inverse dynamics analysis, to better understand the relationship between LLI and able-bodied gait symmetry. The use of radiography to determine LLI is an important component of this study, because previous evaluations of the relationship used less accurate methods for quantifying LLI such as the tape measure (White et al., 2004) and wooden block (Woerman and Binder-MacLeod, 1984). When considering the implications of LLI, it is critical to use radiography (Gurney, 2002), as other methods are unreliable (McCaw and Bates, 1991) and lack the precision necessary to accurately measure LLI.

Conclusion

Our primary conclusion is that the degree of bilateral asymmetry for knee and ankle joint kinetics is related to LLI in able-bodied gait. Although our subjects had LLI that was relatively mild (< 3 cm), knee and ankle joint moments and powers were, on average, less symmetrical for the subjects with larger LLI. Our conclusion was substantiated through two findings: First, moderate negative relationships were observed between LLI and the symmetry coefficient for knee and ankle moment and power. Second, subjects with relatively large LLI (between 1.0 and 2.3 cm) exhibited significantly less symmetrical gait for knee and ankle joint moment and power than subjects with relatively small LLI (< 1 cm). These results regarding the relationships between LLI and symmetry in able-bodied gait further our understanding of normal human walking and provide important background information for future studies on gait pathology associated with LLI.

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Key points

- Moderate negative relationships were observed between mild limb-length inequality and gait symmetry for knee and ankle moment and power.
- Subjects with relatively large mild limb-length inequality (between 1.0 and 2.3 cm) exhibited significantly less symmetrical gait for knee and ankle joint moment and power than subjects with relatively small mild limb-length inequality (< 1 cm).
- These results indicate that the degree of symmetry for knee and ankle joint kinetics appears to be related to mild limb-length inequality in able-bodied gait.
- These results further our understanding of normal human walking and provide important background information for future studies on gait pathology associated with mild limb-length inequality.

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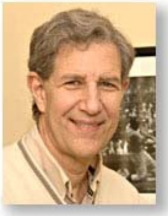

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