Bilateral Characteristics of Running Mechanics

D. A. Schieb

Kistler Instrument Corporation, 75 John Glenn Drive; Amherst, NY 14120, USA

Lateral dominance of one side of the body as a result of hemispheric dominance, is a generally accepted notion. The extent to which one's movements approach absolute symmetry varies greatly among individuals. Many factors act to define or limit motion symmetry such as: laterality (Czabanski, 1975), skill and learning (Cavanagh et al., 1977), training technique (Deuel & Lawrence, 1985), anatomical asymmetries (Klein, 1983; Subotnick, 1980), CNS functioning and limb function (Schieb, 1975; de Schonen, 1977).

It is difficult to equate motion symmetry with performance effectiveness (Table 1). Cavanagh and associates (1977) found elite distance runners to exhibit greater symmetry than good distance runners, and Bates and colleagues (1979) found no significant kinetic or kinematic differences between runner's footstrikes.

TABLE 1

Summary of Asymmetrical Running Characteristics from Literature

Reference	Selected Findings
Cavanagh et al, 1977 N = 22	Found elite distance runners to exhibit greater bilateral symmetry than good distance runners
Bates et al, 1979 N = 11	Found some variability between footstrikes but no significant differenees
Williams, 1985 N = 31	Found significant kinematic and kinetic differences for many runners

The study of bilateral symmetry is important in repetitive activities like walking, running, cycling and swimming where the events require a certain degree of symmetry. The nature of walking and running motion symmetry raises several concerns including:

1) the prescription of orthotics to correct for asymmetrical limb movements
2) the use of heel lifts
3) the use of corrective surgery
4) the re-training of the individual to become more symmetrical

The purpose of this study was to investigate bilateral temporal and center of gravity characteristics during running

METHOD

Six collegiate distance runners (Table 2) were given 75 minutes of treadmill training over five days prior to the study. To minimize stride variability (Bates, 1979; Schieb, 1986) subjects ran for eight minutes on a treadmill (Quinton) prior to being filmed at minutes 8 and 14 of a fifteen minute run. Approximately 17 strides were filmed for each subject at both daily filming times. Subjects ran at 4.0 m/s and were filmed on each of five consecutive days.

TABLE 2

Descriptive Information of Subjects

	Age (years)	Height (cm)	Mass (kg)	Best 5K Time	Best 10K Time
$\overline{X}$	21.7	182.8	66.8	15:42	33:12
SD	1.1	8.0	4.7	:41	1:34

Center of mass (CM) and several stride variables were determined from the film, and those reported herein are described as follows. A stride is defined as the period from touchdown of one foot to touchdown of the opposite foot. A right stride for example begins with the right foot touchdown and continues until left foot touchdown. Each stride consists of a time of support (TS) and time of non-support (TNS). Stride time

(ST) is the total time in seconds of the support and non-support phases of the stride. Stride rate (SR) is determined as the reciprocal of ST. SL is ST times treadmill belt speed (4.0 m/s).

Subjects were filmed with frontal and sagittal cameras (Photosonic) at 64 f/s. Temporal variables and SL were determined by film frame count, camera speed and running speed. Forty strides for each subject over five days were analyzed to determine mean temporal variables and stride length (SL). Mean values from these forty strides were used in the statistical analysis.

Twenty segment landmarks were marked on the subjects for analysis. A 17-segment rigid-linked model was used for determining CM x-y-z position throughout the stride. CM displacements were determined by using a sonic digitizer - computer system. System components included a 16 mm film projector (Vanguard), spark-pen digitizer (Science Accessories Graf/Pen), and an L-shaped microphone component framing a frosted glass tablet onto which the film was projected. Resolution of the microphone component elements was 3,000 by 3,000.

The digitizing system was interfaced to a micro-computer (Hewlett Packard) for data acquisition and recuction. Twenty strides for each subject over the five day period were analyzed for segmental CM. Vertical (z) displacement of the center of mass (VDCM) was determined by subtracting the lowest COMz position from the highest CMz during the stride. The mean VDCM of twenty strides was used in the statistical analysis.

Lateral horizontal displacement of the CM (LHDCM) was determined by subtracting the two extreme COMx positions. LHDCM represents the subjects medial - lateral CM displacement during a stride. For each variable, bilateral data, comparing the subject's largest absolute measure with the smallest, was statistically tested using a direct difference student's t-test ($p<0.05$).

RESULTS

Mean SL and temporal variables were determined from 40 strides while mean CM variables were from 20 strides. Kinematic differences among subjects right and left footstrikes are reported in Table 3. These values represent maximum average values for each of the six subjects. Subject 1 had the largest ST difference between the right and left footstrikes with the right ST being 17.0 ms greater than the left. Subject 1 also exhibited the greatest difference between right and left SL; right SL was 7.0 cm greater than the left.

Only one subject (S2) exhibited greater results for all six kinematic variables on the *same* side. Five of the six subjects had mixed laterality in terms of right or left measures dominating.

Significant differences ($p<0.01$) were found between the subject's largest and smallest bilateral kinematic measures (Table 4) and CM measures (Table 5). Mean bilateral difference for ST was 10.0 ms, for SL was 3.0 cm, for VDCM was 1.15, and for LHDCM was 0.33 cm.

TABLE 3

Bilateral Comparative Kinematic Differences* Among Subjects

S	Stride Time (ms)	Time of Support (ms)	Time of Non-Support (ms)	Stride Length (cm)	Vert. Displ. of CM (cm)	Lat. Displ. of CM (cm)
1	17.0 R	3.0 R	11.0 R	7.0 R	.46 L	.30 L
2	11.0 R	7.0 R	9.0 R	3.0 R	.34 R	.31 R
3	6.0 L	12.0 R	18.0 L	2.0 L	1.52 L	.34 L
4	4.0 L	2.0 L	2.0 L	2.0 L	1.36 L	.57 R
5	5.0 L	5.0 R	6.0 L	2.0 L	1.85 L	.14 L
6	12.0 R	10.0 R	3.0 R	5.0 R	1.34 L	.33 L

* Values indicate subject limb differences with the dominate (larger) value marked R-right or L-left.

TABLE 4

Temporal, Stride Length, and Center of Mass Comparisons Between Footstrikes

	Stride Time (ms)		Time of Support (ms)		Time of Non-Support (ms)		Stride Length (m)	
	L	S	L	S	L	S	L	S
$\overline{X}$	366	356	238	232	130	122	1.46	1.43
SD	(24)	(27)	(13)	(14)	(27)	(27)	(.01)	(.11)
t	4.45*		4.51*		12.56*		4.14*	

* $p<0.01$

L — Largest right/left variable

S — Smallest right/left variable

TABLE 5

Vertical and Lateral Horizontal Displacements of Center of Mass Comparisons Between Footstrikes

	Vertical Displacement of CM (cm)		Lateral Horizontal Displacement of CM (cm)	
	L	S	L	S
$\overline{X}$	11.00	9.85	1.50	1.17
SD	(2.31)	(1.80)	(.17)	(.12)
t	4.60*		5.92*	

* $p < 0.01$
L — Largest right/left variable
S — Smallest right/left variable

DISCUSSION AND CONCLUSIONS

The findings of this study indicate that bilateral asymmetries during running are unique and yet consistent among subjects. In addition, better runners based on performance were no more symmetrical than those with slower race times. The best runner exhibited near symmetry in VDCM. However, bilateral differences in his temporal and SL measures were not as symmetrical as other dusbjects.

Wearing prescribed orthotics does not necessarily afford complete running symmetry. The best runner in this study, who wore orthotics, exhibited the greatest asymmetry in ST and SL. Perhaps these large asymmetries would have been greater without the orthotics, thus increasing his injury potential.

Since orthotics are of ten prescribed based solely on static measurements and foot form, certain kinematic and kinetic information might also be utilized to assist in the orthotic prescription.

Several reasons could be postulated as to why one's bilateral stride characteristics would be different. For an asymmetric VDCM, one longitudinal arch may be weaker allowing for a lower CM during support. Functional leg length discrepancy has frequently been associated with bilateral asymmetries (Klein, 1983; Subotnick, 1980). Another reason for asymmetries might be muscular imbalances; for example greater strength in the right lower leg extensors may contribute to a greater SL on that side.

Other arguments have been used to explain asymmetry. Some researchers have reported that the right lower limb performs functions that require speed and precision while the left lower limb is used more often in movements requiring greater strength (see Czabanski and Koszczyc, 1979, p. 148). If this is true for runners, then some bilateral differences could be explained relative to the runner's dominate leg function.

Czabanski and Koszczyc in a study of breaststroke swimming found women to be more symmetrical than men at slower speeds. This is an interesting finding given that some researchers indicate women to be more right-handed, left-legged, and men to be more right-handed, right-legged dominant.

The degree to which attaining motion symmetry improves performance is not fully known. Furthermore, the process by which symmetry is attained, be it corrective surgery, orthotic devices, or training, may in certain individuals actually increase injury potential and/or decrease performance. While Klein (1983) suggests that upwards of 75% of the population may have a leg length diferential, and proposes corrective measures for many, other researchers caution against changing a running style that has been developed and refined over many years. Herein lies a significant problem: whether to correct an asymmetry, and if so, to what extent. Further research is needed to improve asymmetry assessment, identification and prescription capabilities.

Additional studies might include a comparison between asymmetry and speed of movement; or dominance and asymmetry; i.e. is a right-handed, right-legged person less symmetrical than a mixed dominant person? Are there beneficial reasons why most people have asymmetries? What is the mechanical effectiveness of bilateral muscle functioning? Does the elastic component contribution differ in asymmetrical versus symmetrical locomotion? Developing normative data from several hundred runners based on critical kinematic, kinetic and anthropometric variables, would provide a framework or asymmetry index for profiling bilaterality in runners.

From the findings of this study, the following conclusions are drawn:

1. Significant bilateral differences were found for several kinematic running variables.
2. Five of the six subjects exhibited mixed laterality in terms of having a greater right or left kinematic measure.

3. Maximum subject bilateral absolute differences for 4.0 m/s running were:
   a) 17.0 ms — Stride time
   b) 12.0 ms — Time of support
   c) 18.0 ms — Time of non-support
   d) 7.0 cm — Stride length
   e) 1.9 cm — Vertical displacement of CM
   f) 0.6 cm — Lateral horizontal displacement of CM

Supported by a grant from Sigma Xi, The Scientific Research Society.

REFERENCES

Bates, B. T., Osternig, L. R., Mason, B. R. and James, S. L., Functional variability of the lower extremity during the support phase of running. *Med. Sci. Sports Exerc.*, 11(4):328-331, 1979.

Cavanagh, P. R., Pollock, M. L. and Landa, J., A biomechanical comparison of elite and good distance runners. *Ann. NY Acad. Sci.* 301:328-345, 1977.

Czabanski, B., Asymmetry of the lower limbs in breaststroke swimming. *Swimming II* (eds. L. Lewillie and J. P. Clarys), pp. 207-213. University Park Press, Baltimore, 1975.

Czabanski, B. and Koszczyc, T., Relationship between stroke asymmetry and speed of breastroke swimming. *Swimming III* (eds. J. Terauds and E. W. Bedingfield), pp. 148-152. University Park Press, Baltimore, 1979.

Delacerda, F. G. and Wikoff, O. D., Effect of lower extremity asymmetry on the kinematics of gait. *J. Orthop. Sports Phys. Ther.* 3:105-107, 1982.

Deuel, N. R. and Lawrence, L. M., Bilateral asymmetry in gallop motion: Handedness in horses. *Am. Soc. Biom. Proc.*, pp. 57-58, 1985.

Dewer, M. E. and Judge, G., Temporal asymmetry as a gait quality indicator. *Med. Biol. Eng. Comput.*, 18:689-693, 1980.

Hamill, J., Bates, B. T. and Knutzen, K. M., Ground reaction force symmetry during walking and running. *Med. Sci. Sports Exerc.* 15(2):170, 1983.

Klein, K. K., Developmental asymmetries and knee injury. *Phys. Sportsmed.* 11(8):67-72, 1983.

Miller, D. I., Enoka, R. M., McCulloch, R. G., Burgess, E. M. and Frankel, V. H., Vertical ground reaction force-time histories of lower extremity amputee runners. *Biomechanics VII-A* (eds. E. Morecki, et al.), pp. 453-460. University Park Press, Baltimore, 1981.

Schieb, D. A., Dominant and non-dominant grip strength of children with learning disabilities. Masters Thesis, Southern Methodist University, 1975.

Schieb, D. A., Kinematic accomodation of novice treadmill runners. *Res. Quart.* 57(1):1-7, 1986.

de Schonen, S., Functional asymmetries in the development of bimanual coordinations in human infants. *J. Hum. Mov. Stud.* 3(3):144-156, 1977.
Simkin, A. and Mahler, Y., Systematic approach to foot-ground contact sequence during cyclic bipedal gait. *Isr. J. Med. Sci.* 17(12):1204, 1981.
Subotnick, S., Case history of unilateral short leg with athletic overuse injury. *J. Amer. Pod. Assoc.* 70(5):255-256, 1980.
Williams, K. R., Kinetic and kinematic asymmetry during distance running. *Med. Sci. Sports. Exerc.* 17(2):223, 1985.