A NOVEL, MORE ROBUST METHOD TO QUANTIFY SYMMETRY

Becky Avrin Zifchock [1] and Irene Davis [1,2]

[1] University of Delaware, Newark, DE [2] Drayer Physical Therapy Institute, Hummelstown, PA
E-mail: beckyaz@udel.edu

INTRODUCTION

Measurement of gait symmetry is used for many clinical and research applications. Asymmetry is most often quantified using the symmetry index (SI) (Robinson, 1989), which is simply the percent difference between sides. This method is prone to inconsistencies based upon the choice of reference value. Further, the SI method introduces the potential for artificial inflation of the symmetry index, when the difference between sides is much larger than the side chosen as the normalization factor. Therefore, a more robust method of assessing symmetry is necessary. The purposes of this study were (1) to assess the difference in SI based upon whether the left or right side is used as the reference value and (2) to correlate the values generated using a novel measure, the symmetry angle (SA) to the more traditionally-used SI.

METHODS

Ten rearfoot strikers, running at least 20 miles/week, with no current injuries were included in this study. Subjects ran along a 25m runway, striking two forceplates with consecutive steps. A 6-camera Vicon motion capture system tracked the motion of reflective markers mounted on the pelvis and both thighs, shanks, and rearfeet. Two kinematic and kinetic variables were assessed in both sides of each runner: hip internal rotation velocity (HIRv), rearfoot eversion velocity (REVv), impact peak of the grf along the shank (SHFz), and peak tibial shock (PPA). All variables, aside from PPA, were assessed from heel strike to vertical impact peak. Additionally, two strength and structural measures were assessed: frontal projection knee valgus angle (KVA), hip internal rotation range of motion (HIRr), hip abduction strength (HABs), and hip external rotation strength (HERs). In order to compare between normalization methods, for each variable, the SI between consecutive footstrikes was calculated as: $\mathbf{SI_L = (X_R\text{-}X_L)/X_L*100}$ and $\mathbf{SI_R = (X_R\text{-}X_L)/X_R*100}$. The absolute difference between the two methods was calculated to determine the magnitude of the discrepancy. A 5 point difference between methods was considered clinically relevant.

The SI, normalized to the average of the left and right sides, was also calculated as: $\mathbf{SI_{AVG} = (X_R\text{-}X_L)/avg(X_R,X_L)*100}$ for comparison to the SA. In order to calculate the SA for a given variable, the right and left sides are plotted against each other as seen in Fig. 1. Any set of values will create a vector that creates some angle, α, with respect to the x axis and can be quantified as $\alpha = \arctan(X_L/X_R)$. In order to quantify the deviation, δ, of this vector from the 45º vector of perfect symmetry, α must be subtracted from 45: $\delta = 45 - \alpha$. This formula is sufficiently robust to quantify the asymmetry between values that fall within any of the graphed quandrants. Since the maximum

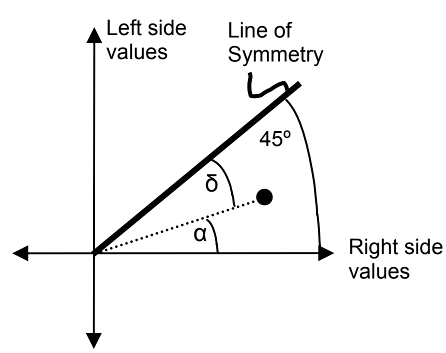

Fig. 1: Calculation of the SA

deviation from the vector of perfect symmetry is set at 90º, the following equation for SA, converted to percent of the maximum is:

$$SA = (45 - \arctan(X_L/X_R))/90 * 100$$

A linear regression was used to relate the SI_{AVG} and SA.

RESULTS AND DISCUSSION

Seven of the eight variables were at least 5 points different when calculated as SI_L versus SI_R (see Fig. 2). The absolute difference is particularly large in the kinematic variables and KVA. These variables may be particularly prone to artificial inflation, where the difference between the sides is much larger than the side chosen as the reference value. These findings suggest that a different choice in reference value can produce alternative interpretations of the magnitude of asymmetry between two identical left and right side values.

Another limitation of the SI is highlighted in the results of the second aim. Table 1 shows the R^2 values of the regressions between the SI_{AVG} and SA methods. Six of the eight variables exhibited perfect regressions. The two variables that exhibited somewhat lower R^2 values were a result of artificial inflation of the SI. The SI_{AVG} values were inflated in two runners for HIRv and in one runner for KVA. Fig. 3 shows that the regression for HIRv is strongly influenced by the inflated cases, shown in gray. When those cases were removed, the regression improves to R^2 = 0.97. When the aberrant case was removed from analysis of KVA, the regression improved to R^2 = 1.00.

Table 1: R^2 values of the regressions between the SI_{AVG} and SA methods

Variable	R^2
HIRv	0.45*
REVv	1.00
SHfz	1.00
PPA	1.00
KVA	0.89*
HIRr	1.00
HABs	1.00
HERs	1.00

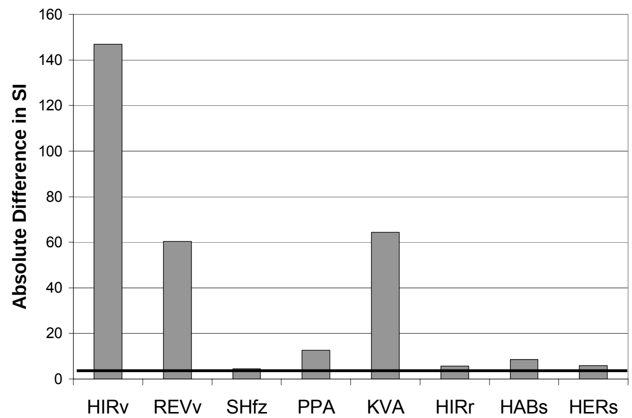

Fig. 2: Difference between assessing SI using the left versus right sides as reference values, where the bold line denotes at least 5 points difference

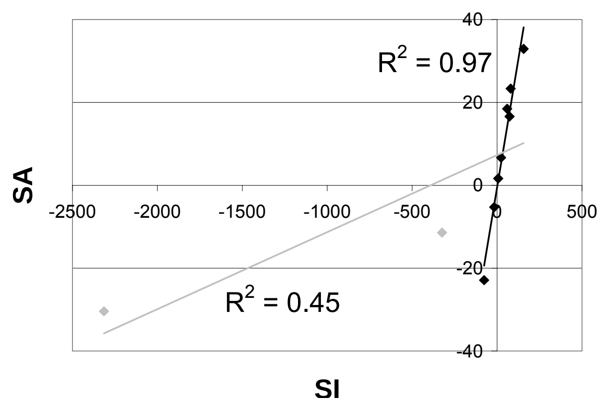

Fig. 3: Aberrant, artificially inflated SI values poorly influenced the regression between SI and SA for HIRv

SUMMARY/CONCLUSIONS

This study demonstrates that choosing two different normalization factors can result in alternative interpretations regarding the asymmetry between sides. This can make comparisons within the biomechanics literature difficult. The SA does not require the choice of a normalization factor and is not prone to artificial inflation. Yet it yields almost identical results as compared to the SI.

REFERENCES

Robinson, R.O. et al. (1987*). J Manipulative Physiol Ther*, **10(4)**, 172-176.