# LOWER EXTREMITY LEAN MASS ASYMMETRY CORRELATED WITH FORCE AND POWER ASYMMETRY DURING JUMPING IN ADULTS

**Boyi Dai, Mitchell Stephenson, Erika Heinbaugh, Rebecca Moynes, Shawn Rockey, Joi Thomas, and Derek Smith**

**Division of Kinesiology and Health, University of Wyoming, Laramie, USA**

The purpose of the current study was to quantify the relationships between lower extremity lean mass asymmetry and force and power asymmetry during jumping in adults aged 18-75 years old. Forty younger adults (18-35 years of age), 28 middle-aged adults (36-55 years of age), and 34 older adult (56-75 years of age) participated in the study. Subjects underwent Dual Energy X-ray Absorptiometry to assess lower extremity bilateral lean mass asymmetry. Subjects performed 3 trials of a counter movement jump on two force plates to measure lower extremity bilateral force and power asymmetry. Lower extremity lean mass asymmetry was significantly correlated with force and power asymmetry in younger and middle-aged adults, but not in older adults. Improving lean mass asymmetry might assist in correcting force asymmetry in younger and middle-aged adults.

**KEY WORDS:** strength, kinetics, biomechanics.

**INTRODUCTION:** Lower extremity bilateral strength asymmetry is defined as the difference in maximum strength between two lower limbs (Impellizzeri, Rampinini, Maffiuletti & Marcora, 2007). Maximum strength is commonly measured as the maximum force or torque a group of muscles can produce (Impellizzeri et al., 2007). Increased force asymmetry is associated with decreased sports performance (Hart, Nimphius, Spiteri & Newton, 2013) and increased injury risks (Croisier, Ganteaume, Binet, Genty & Ferret, 2008; Laroche, Cook & Mackala, 2012). Following unilateral injuries, individuals commonly demonstrate abnormal force asymmetry in force production (Kvist, 2004). Assessing lower extremity bilateral force asymmetry is used to monitor the rehabilitation processes and help make the return to play decisions (Kvist, 2004). Understanding the mechanism that causes force asymmetry may inform performance training, injury prevention, and post-injury rehabilitation.

From a neuromuscular control perspective, the force generated by an active muscle is mainly determined by muscle activation, muscle physiological cross-sectional area, muscle stress, and force-length-velocity relationship (Hoy, Zajac & Gordon, 1990). Additionally, muscle physiological cross-sectional area is positively correlated with muscle mass (Narici, Landoni & Minetti, 1992). Therefore, bilateral asymmetry in muscle mass could contribute to bilateral force asymmetry. One recent study showed that lean mass asymmetry was positively correlated with force and power asymmetry during jumping in collegiate athletes aged 18-23 years old (Bell, Sanfilippo, Binkley & Heiderscheit, 2014). However, these associations (similar or different) are unknown in a general adult population. Therefore, the purpose of the current study was to quantify the relationships between lower extremity lean mass asymmetry and force and power asymmetry during jumping in adults aged 18-75 years old. It was hypothesized that lean mass asymmetry would be positively correlated with force and power asymmetry.

**METHODS:** One hundred and two adults (58 males, 44 females; Age: 43.4 ± 16.7 years; Height: 1.70 ± 0.12 m; Mass: 74.2 ± 15.0 kg) participated in the current study. Forty subjects were in the younger adult group (18-35 years of age). Twenty-eight subjects were in the middle-aged adult group (36-55 years of age). Thirty-four subjects were in the older adult group (56-75 years of age). The current study was approved by University of Wyoming Institutional Review Board.

Subjects underwent Dual Energy X-ray Absorptiometry (DXA) to assess lower extremity lean mass (Bell et al., 2014). Subjects performed three trials of a double-leg counter movement jump with each foot on a separated Bertec 4060-10 force plate to measure lower extremity force and power production. The force data were sampled at 1600 Hz and filtered using a low-pass filter at 50 Hz. Asymmetry indices (Impellizzeri et al., 2007) were calculated for lower extremity bilateral lean mass, maximum force during jumping and maximum power during jumping.

Asymmetry index = (larger value – smaller value) / larger value

Asymmetry index was positive when the right side had a larger value and negative when the left side had a larger value.

Pearson correlation tests were performed between lean mass asymmetry and maximum force asymmetry as well as between lean mass asymmetry and maximum power asymmetry. Pearson correlation tests were performed for the combined group and each age-group cohort. A type I error rate was set at 0.05 for statistical significance.

**RESULTS:** Lean mass asymmetry was significantly correlated with maximum force asymmetry and maximum power asymmetry (Table 1) in the combined group (Figure 1, 2), younger adult group (Figure 3, 4), and middle-aged adult group (Figure 5, 6). These significant correlations were low to moderate. However, lean mass asymmetry was not significantly correlated with maximum force asymmetry and maximum power asymmetry in the older adult group (Table 1, Figure 7, 8).

**Table 1. Pearson correlation coefficients and p values between lean mass asymmetry and maximum force and power asymmetry in different groups**

| | Lean mass asymmetry and force asymmetry | Lean mass asymmetry and power asymmetry |
|---|---|---|
| Combined Group (n = 102) | r = 0.29 (***p < 0.01***) | r = 0.36 (***p < 0.01***) |
| Younger group (n = 40) | r = 0.31 (***p = 0.048***) | r = 0.45 (***p < 0.01***) |
| Middle-aged group (n = 28) | r = 0.40 (***p = 0.03***) | r = 0.51 (***p < 0.01***) |
| Older group (n = 34) | r = 0.12 (p = 0.50) | r = 0.03 (p = 0.86) |

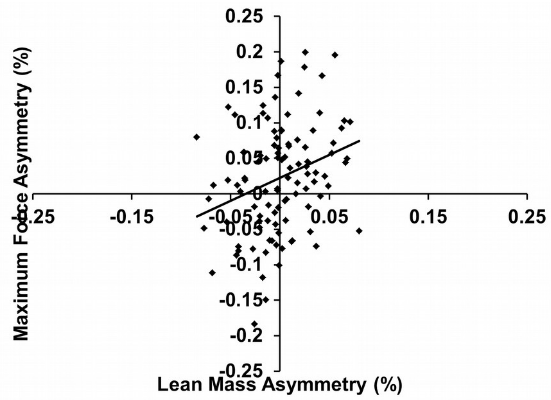


**Figure 1. Lean mass asymmetry and force asymmetry in the combined group**

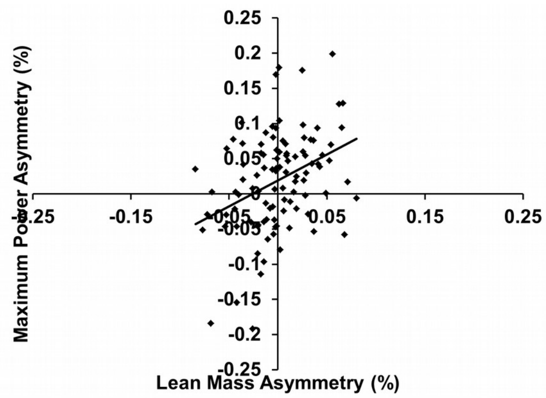


**Figure 2. Lean mass asymmetry and power asymmetry in the combined group**

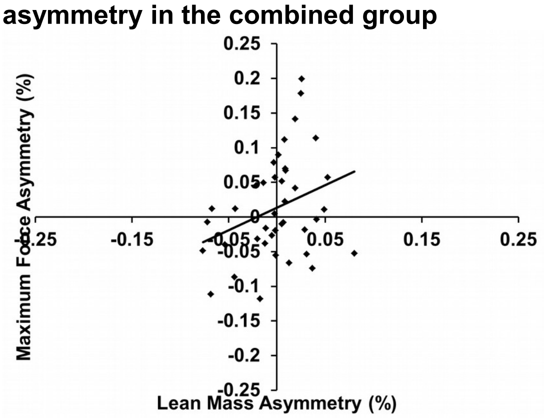


**Figure 3. Lean mass asymmetry and force asymmetry in the younger adult group**

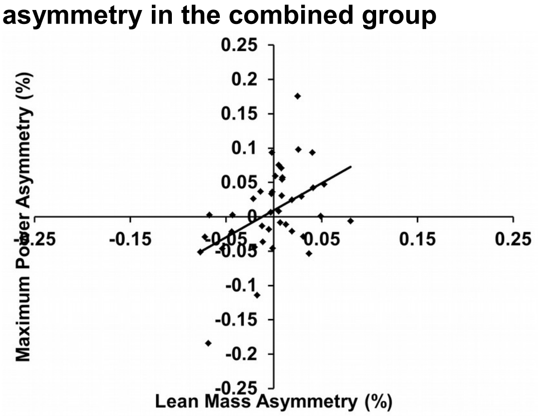


**Figure 4. Lean mass asymmetry and power asymmetry in the younger adult group**

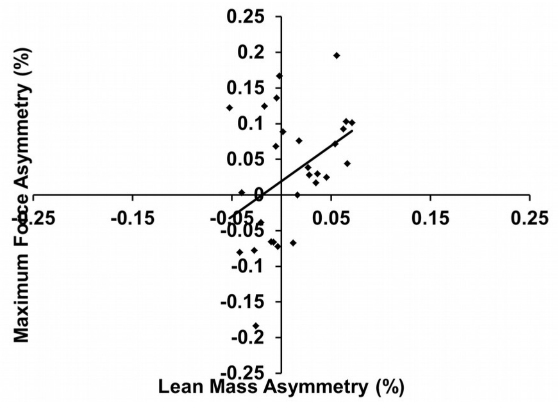


**Figure 5. Lean mass asymmetry and force asymmetry in the middle-aged adult group**

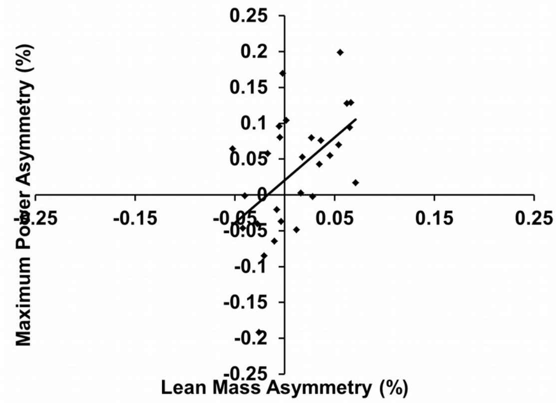


**Figure 6. Lean mass asymmetry and power asymmetry in the middle-aged adult group**

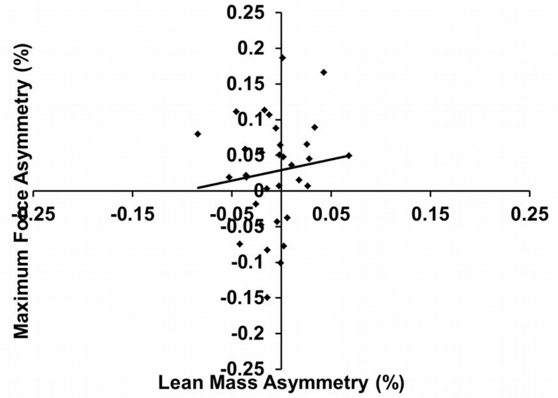


**Figure 7. Lean mass asymmetry and force asymmetry in the older adult group**

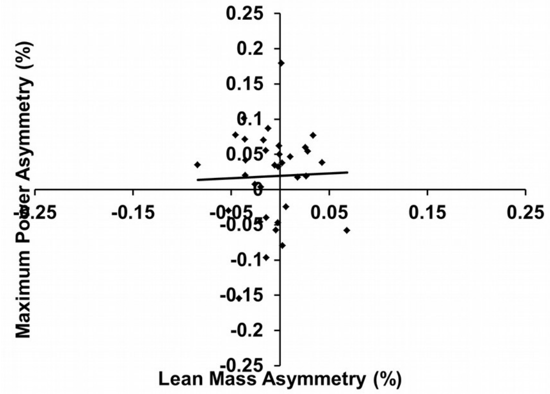


**Figure 8. Lean mass asymmetry and power asymmetry in the older adults group**

**DISCUSSION:** The purpose of the current study was to quantify the relationships between lower extremity lean mass asymmetry and force and power asymmetry during jumping in adults aged 18-75 years old. The findings support the hypothesis that lower extremity lean mass asymmetry is correlated with force and power asymmetry in the combined group and in younger and middle-aged adults. However, the correlation was not significant in older adults.

The force produced during jumping is mainly generated by lower extremity muscle forces. The factors that contribute to muscle forces include muscle activation, muscle physiological cross-sectional area, muscle stress, and force-length-velocity relationship (Hoy et al., 1990). Muscle physiological cross-sectional area can be calculated from muscle mass, muscle density, muscle pennation angle, and muscle fiber length (Narici et al., 1992). Based on the direct relationship between muscle mass and muscle force, it was expected that lean mass asymmetry would be correlated with force and power asymmetry in jumping.

In the study by Bell et al. (2014), lean mass asymmetry was assessed using DXA scan and lower extremity maximum force and power asymmetry were calculated during jumping. The authors showed significant but weak correlations between lean mass asymmetry and force and power asymmetry in collegiate athletes aged 18-23 years old. The findings of younger adults in the current study were consistent with the study by Bell et al. (2014). Hart et al. (2013) assessed leg strength and lean mass symmetry in Australian football players. Significant asymmetry in strength and lean mass was observed in inaccurate kickers but not in accurate kickers. However, the correlation between lean mass asymmetry and strength asymmetry was not quantified. In the current study, the significant correlations in younger adults and middle-aged adults suggest that improving limb mass symmetry might assist in correcting force asymmetry in these populations.

It should be noted that the significant correlations were low to moderate, and a majority of variance in force and power asymmetry was not explained by lean mass asymmetry. Because a countermovement jump was a symmetric movement and the force asymmetry

was calculated for the same individual, the muscle stress, force-length-velocity relationship, muscle density, and muscle pennation angle were likely similar between the left and right limbs. Therefore, it is postulated that neural control of muscle activation might play a more important role in determining force and power asymmetry. Simon and Ferris (2008) found that 12 neurologically intact subjects were able to generate similar lower extremity maximum forces between left and right limbs during unilateral leg press. However, bilateral asymmetry was consistently observed during bilateral leg press. The authors concluded that bilateral force asymmetry was more likely caused by neural factors rather than mechanical capabilities between two limbs. Future studies are needed to better understand how other factors attribute to force asymmetry in jumping. Future studies can also calculate the asymmetry indices between the dominant and non-dominant sides to identify the effects on leg dominance on the relationships between lean mass asymmetry and force asymmetry.
The current study also found that the relationship between lean mass asymmetry and force asymmetry was age-dependent, as no asymmetry relationship was found in the older adults. Older adults generally demonstrate lower strength (Perry, Carville, Smith, Rutherford & Newham, 2007). In addition, because of an older age, older adults are more likely to have an injury history which could affect their movement patterns (Perry et al., 2007). While strength asymmetry has been identified as a risk factor for injury in older adults (Laroche et al., 2012), injury prevention and rehabilitation programs should consider a lack of correlation between lean mass asymmetry and force asymmetry in older adults.

**CONCLUSION:** Lower extremity lean mass asymmetry was significantly correlated with force and power asymmetry during jumping in younger adults and middle-aged adults, but not in older-adults. Improving lean mass asymmetry might assist in correcting force asymmetry in younger and middle-aged adults. However, other factors such as neural control may play a more important role in determining force and power asymmetry. The findings of the current study have implications in performance training, injury prevention, and rehabilitation.

**REFERENCES**
Bell, D. R., Sanfilippo, J., Binkley, N. & Heiderscheit, B. C. (In Press). Lean mass asymmetry influences force and power asymmetry during jumping in collegiate athletes. *Journal of Strength and Conditioning Research.*
Croisier, J. L., Ganteaume, S., Binet, J., Genty, M. & Ferret, J. M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study. *The American Journal of Sports Medicine,* 36(8), 1469-1475.
Hart, N. H., Nimphius, S., Spiteri, T. & Newton, R. U. (2013). Leg strength and lean mass symmetry influences kicking performance in australian football. *Journal of Sports Science and Medicine,* 12, 157-165.
Hoy, M. G., Zajac, F. E. & Gordon, M. E. (1990). A musculoskeletal model of the human lower extremity: The effect of muscle, tendon, and moment arm on the moment-angle relationship of musculotendon actuators at the hip, knee, and ankle. *Journal of Biomechanics,* 23(2), 157-169.
Impellizzeri, F. M., Rampinini, E., Maffiuletti, N. & Marcora, S. M. (2007). A vertical jump force test for assessing bilateral strength asymmetry in athletes. *Medicine and Science in Sports and Exercise,* 39(11), 2044-2050.
Kvist, J. (2004). Rehabilitation following anterior cruciate ligament injury: Current recommendations for sports participation. *Sports Medicine,* 34(4), 269-280.
Laroche, D. P., Cook, S. B. & Mackala, K. (2012). Strength asymmetry increases gait asymmetry and variability in older women. *Medicine and Science in Sports and Exercise,* 44(11), 2172-2181.
Narici, M. V., Landoni, L. & Minetti, A. E. (1992). Assessment of human knee extensor muscles stress from in vivo physiological cross-sectional area and strength measurements. *European Journal of Applied Physiology and Occupational Physiology,* 65(5), 438-444.
Perry, M. C., Carville, S. F., Smith, I. C., Rutherford, O. M. & Newham, D. J. (2007). Strength, power output and symmetry of leg muscles: Effect of age and history of falling. *European Journal of Applied Physiology,* 100(5), 553-561.
Simon, A. M. & Ferris, D. P. (2008). Lower limb force production and bilateral force asymmetries are based on sense of effort. *Experimental Brain Research,* 187(1), 129-138.