AGREEMENT BETWEEN ATTRIBUTES ASSOCIATED WITH BILATERAL JUMP ASYMMETRY

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The purpose of this study was to examine the relationship between bilateral countermovement jump (bCMJ) asymmetry and asymmetries in lower extremity flexibility, anthropometry, strength and single leg jump performance. Three criteria were identified for each of these attributes. Thresholds were determined to diagnose asymmetry in all criteria based on exceeding the mean ± sd of the absolute difference between limbs. A total of 145 subjects across a variety of sports were tested. The overall agreement in diagnoses compared to bCMJ were 49.7% flexibility, 58.6% anthropometry, 66.9% strength and 70.3% single leg jumps. Individual attributes had associations of between 27.5-32.5% with actual bCMJ asymmetries and this rose to 72.5% when all attributes were combined. 82.9% of subjects possessed at least one lower extremity asymmetry.

KEY WORDS: asymmetry, countermovement jump, strength, anthropometry, flexibility

INTRODUCTION: The underlying premise of assessing lower extremity asymmetry is to evaluate the possible compensatory effects on movement and examine how asymmetrical differences may relate to performance and injury risk. Many sports skills require athletes to frequently repeat the execution of unilateral and asymmetrical movements and consequently this may lead to an enhancement in performance. However, over time this repetition may lead to asymmetrical differences in strength, power and joint ranges of motion due to the unique loading patterns and coordination of movement. It is also important to recognise that asymmetrical differences may also manifest themselves in bilateral exercises that athletes perform as part of their training, e.g. countermovement jumps, which may eventually lead to an injury but this association remains inconclusive.
There are several limitations to previous research examining bilateral jump asymmetry. Most research has focussed on investigating the association between individual factors, e.g. strength and jump asymmetry (Impellizzeri et al. 2007; Newton et al. 2006). There has been no holistic examination of the multiple factors that may be associated with jumping asymmetry, e.g. strength, anthropometrical differences, range of motion or single leg performance. Additionally the use of correlations may not be the most appropriate choice of analysis as they compare associations in the magnitude of the asymmetry. In clinical scenarios it is more meaningful to classify whether an athlete is asymmetrical or not in order to make interventions. Every measure would need a specific threshold, above which an asymmetry would be classified. Previous research has suggested arbitrary thresholds of 10% (Schiltz et al., 2009) to 15% (Bennell et al., 1998; Croisier et al., 2002), but these would be inappropriate for measures such as leg length discrepancy where differences of 10% are extremely unlikely. To understand the real association between factors it would be of more interest to examine the level of agreement between the diagnoses of asymmetry between factors.
The aims of this study were to establish thresholds for the diagnosis of lower extremity asymmetry and to determine the level of agreement in the diagnoses of asymmetries between bCMJ with strength, anthropometry, flexibility and single leg jump attributes.

METHODS: A total of 145 subjects from a diverse range of sports (124 male, 21 female) with an average age of 22 ±5 years participated in the study. 73 subjects were professional and 72 were recreational. All subjects underwent a screening battery which involved assessments of asymmetry in bilateral countermovement jump (bCMJ), strength, anthropometrical measures, lower extremity flexibility and single leg jump tests. Three criteria were used for each attribute.

Bilateral CMJ: Countermovement jump performance and bilateral asymmetry was assessed utilising two Kistler 9286AA portable force platforms, sampling at 1000Hz. The subjects' body weight was measured on both force platforms to ensure that they registered the same force, prior to performing 3 maximal effort jumps without arm swing. Overall jump performance was determined by summation of the two vertical forces to calculate jump height, peak power and the point of maximal downward displacement (which was used to separate the movement into eccentric and concentric phases). The onset of movement was taken from the point when the vertical force deviated 20N from body weight whilst take-off was when the vertical force dropped below 10N. Vertical displacement was determined from double differentiation of the acceleration data. Three force variables from the left and right limbs were selected for analysis: the peak force and the averages forces in the eccentric and concentric phases.
For the assessment of asymmetry in bilateral movements we feel it is better to express the difference between limbs as the difference in the percentage contribution to the total force (equation1).

$$Asymmetry\ (\%) = Abs\ difference\ \{\left[\frac{(Force\ leg\ A)-(Force\ leg\ B)}{(Force\ leg\ A+Force\ leg\ B)}\right]x100]\quad [equation\ 1]$$

Anthropetrical measures: Leg Length (LL) and thigh circumference (TC) were measured with the subject laying supine on a plinth. LL were measured as the distance between the anterior superior iliac crest and the medial malleolus, TC was taken at the midpoint between the inguinal crease and the proximal border of the patella. Calf Circumference was measured in a standing position at the point of maximal circumference.

Flexibility: Quadriceps range of motion (ROM) was assessed using the modified Thomas test. Subjects were required to sit at the end of a plinth, roll backwards and pull one knee towards the chest while the leg being measured hung off the end of the plinth. The angle of the between the lateral malleolus, lateral side of the patellar and the greater trochanter was measured from a video taken in the sagittal plane using Qunitic Biomechanics software (9.03v17). The mean of three attempts was recorded.
Hamstrings ROM was assessed using the active knee extension (AKE) test. With the subject laying supine on the plinth with the hip stabilised at 90° flexion (relative to a vertical reference frame) the subject was instructed to slowly extend the knee. The knee angle in its most extended position was recorded on a video camera and analysed in Qunitic Biomechanics software (9.03v17). The mean of three attempts was recorded.
Gastrocnemius ROM was measured using a universal goniometer positioned on the lateral malleolus with the arms in line with the head of the fibula and the 5th metatarsal. The ahletes adopted a lunge position with the front leg being flexed and the back leg fully extended at the knee with the entire foot and heel in contact with the floor. The angle at the lowest position was recorded and a mean of three attempts taken.

Strength: Gravity corrected peak torque measurements of the concentric quadriceps and hamstring muscle groups were assessed using a Biodex Isokinetic Dynamometer (Biodex System3, Shirley, New York) set to an angular velocity of 60°/sec. Subjects were in a seated position with the hip joint at 90°and the dynamometer lever arm was aligned with the femoral condyle. Extraneous movement was prevented by body straps, positioned at the hip, shoulders and thigh. Following a low intensity warm up on a cycle ergometer for 5 minutes and performing familiarisation repetitions of increasing effort, the subjects were tested performing 5 maximal repetitions. The peak torques for quadriceps and hamstrings over the 5 repetitions were used to calculate the H/Q ratio and left-right strength asymmetry.

Single leg jumps: The single leg hop for distance (SLH), the single leg triple hop for distance (SLTH) and the single leg vertical jump (SLVJ) were performed to assess unilateral performance. For the SLH and the SLTH the distance was measured from the toe at the onset to the heel at the end. Subjects were required to hold the position for 2 seconds after the final landing. The maximum of three attempts were recorded. The SLVJ was performed on a Kistler force platform with hands on hips and followed a similar analysis procedure to that described earlier for the bCMJ.

Asymmetry for all single leg measures was measured using equation 2.

$$Asymmetry\ (\%) = Abs\left[\frac{(difference\ between\ limbs)}{(maximum\ of\ limbs)}\right] x100 \qquad [equation\ 2]$$

The asymmetry threshold was taken as the mean ± sd of the absolute difference between limbs. If one or more of the three criteria exceeded the threshold then that attribute was deemed asymmetrical. The overall level of agreement in diagnoses between bCMJ and the other attributes was examined by counting the frequency and percentage of like for like diagnoses of asymmetry, i.e. either both asymmetrical or both balanced using equation 3:

$$Overall\ Agreement\ (\%) = \left[\frac{frequency\ of\ like\ for\ like\ diagnoses\ (asymmetrical\ \&\ balanced)}{no.of\ subjects}\right] x100$$

[*equation 3*]

The agreement for bCMJ asymmetries only with the asymmetries in the other attributes was also quantified to evaluate the most likely cause of bCMJ asymmetry (equation 4).

$$Asymmetry\ Agreement\ (\%) = \left[\frac{frequency\ of\ like\ for\ like\ diagnoses\ of\ asymmetry\ only}{no.of\ bCMJ\ assymetries}\right] x100$$

[*equation 4*]

RESULTS: The asymmetry thresholds for each individual criteria, the number of asymmetries within each attribute and the levels of agreement are presented in table 1.

Table 1
Asymmetry thresholds and levels of agreement

Attribute	bCMJ			.	Flexibility			.	Anthropometry			.	Strength			.	Single Leg Jumps		
Criteria	Peak Force	Ave Ecc Force	Ave Con Force		Quad	Ham	Gastro		LL	TC	CC		Quad	Ham	H/Q		SLH	SLTH	SLVJ
Threshold (%)	10.1	14.4	11.6		10.6	27.5	13.7		1.0	3.8	3.2		17.6	21.4	20.4		13.9	11.3	18.8
Asymmetries		40				57				46				30				29	
Overall Agreement																			
- Frequency						72				85				97				102	
- (%)		-				49.7				58.6				66.9				70.3	
Asymmetry Agreement																			
- Frequency						12				13				11				13	
- (%)		-				30.0				32.5				27.5				32.5	

DISCUSSION: Past research has quantified asymmetrical differences based on left-right, or dominant-non dominant limb classifications. The problem here is that there is a tendency for the average difference to tend to zero, depending on the characteristics of the population being examined. The use of the mean absolute difference between limbs provides a more realistic estimation of 'typical' asymmetrical differences. Setting an asymmetry threshold based on the mean ± sd of the absolute difference between limbs has enabled us to diagnose an asymmetry in a more robust manner and is therefore practically more meaningful than using arbitrary values of 10-15% commonly adopted in the literature. The asymmetry thresholds can be seen to be as low as 1% for leg length discrepancy to 27.5% for hamstring range of motion. Using these thresholds a total of 40 asymmetries were detected in the bCMJ, 57 in flexibility, 46 anthropometry, 30 strength and 29 in single leg jumps. The overall level of agreement with bCMJ asymmetries which included all like for like diagnoses (asymmetrical and balanced) highlighted levels of agreement between 49.7% for flexibility up to 70.3% for single leg jump. For the sub group of the 40 bCMJ asymmetrical subjects each of the attributes were found to exhibit similar levels of agreement of between 27.5 to 32.5%. These relatively low levels of agreement highlight that bCMJ asymmetry is likely to be multi-factorial and not due to any one single attribute. Indeed following the summation of asymmetries across all attributes the level of agreement with bCMJ rose to 72.9%. However, the overall level of agreement with the summation of attributes with bCMJ was only 35.9%. Interestingly we observed that 121/145 (83.4%) subjects carried at least one asymmetry across all attributes (including bCMJ) which was a far greater incidence of lower extremity asymmetry than first anticipated.

CONCLUSION: Without definitive thresholds for specific criteria and attributes it is difficult to classify whether an athlete is asymmetrical and in need of some form of intervention. We have successfully set thresholds for 15 criteria across 5 different attributes, including bCMJ, flexibility, anthropometry, strength and single leg jump performance. Associations based on the agreement in diagnosis of asymmetry was a novel approach and this provided a different insight into the relationship between attributes that may have an effect on the execution of a bCMJ. Results suggest that in reality the majority of athletes would carry at least one lower extremity asymmetry and they will be able to operate mostly injury free (given the subjects were participating in sport injury free). If asymmetry does have a cause-effect relationship to injury then the severity and combinations of asymmetries should be examined alongside other factors relating to the loading characteristics and mechanisms of specific injuries.

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