Inter-limb Asymmetries: Are Thresholds a Usable Concept?

Abstract

The concept of thresholds have commonly appeared in the literature for the topic of inter-limb asymmetry. However, with an abundance of literature showing asymmetry to be task and metric-specific, the use of thresholds seems flawed. When computed, practitioners are often left with a percentage figure and it is not always entirely obvious how to interpret this value. This article aims to provide practitioners with some guidelines on meaningful ways to use and interpret inter-limb asymmetry data.

Key Words: Between-limb differences; coefficient of variation; individual interpretation.

Introduction

Inter-limb asymmetries refers to the difference in function or performance of one limb relative to the other (17), and has been a very popular topic of investigation in recent years. Given the rising interest in this area, an abundance of studies have reported the prevalence of between-limb differences across a range of physical qualities such as strength (10,28), power (5,22), speed (13,15) and change of direction speed (7,11). However, reporting the prevalence of asymmetry alone does little to aid our understanding of whether we should be concerned about larger between-limb imbalances. Consequently, this has led to some studies trying to suggest thresholds which may indicate associations with reduced physical performance or a heightened risk of potential injury (1,21,26,27).

The purpose of this article is to highlight some of the thresholds that have been previously outlined in the literature, identify the flaws in the use of thresholds for the concept of asymmetry, and offer several alternative solutions to the way in which practitioners may consider using asymmetry data (should they collect it). Whilst not specific to one injury type, this article will refer to anterior cruciate ligament (ACL) injuries (where appropriate), owing to the available body of evidence in this area. In addition, because of the way some of the literature has presented this information, the notion of symmetry and asymmetry will be discussed inter-changeably.

Is there a magic threshold for asymmetry?

If we go back to studies from the early 1990's, there was a suggestion that 15% was deemed the threshold which if surpassed, meant that your risk of injury would increase (1,26). For example, Barber et al. (1) showed that over 90% of healthy subjects (recruited from both a local community and non-professional soccer team) reported limb symmetry of 85% (15%

asymmetry) or better in the single leg hop for distance and single leg timed hop tasks. Similarly, Noyes et al. (26) investigated the lower limb symmetry from hop test protocols (single, triple, crossover and timed hop tests) after ACL rupture in a college sample and again, classified ‘normal’ and ‘abnormal’ symmetry to be above or below 85% symmetry, respectively. Grindem et al. (14) then aimed to determine which unilateral hop test (from those already mentioned) had the highest sensitivity and specificity for predicting self-reported knee function in returning patients with previous ACL trauma (but no reconstructive surgery). It was reported that a cut-off of 88% symmetry for the single leg hop showed a sensitivity and specificity of 71.4 and 71.7%, respectively.

More recently, Rohman et al. (27) undertook an extensive test battery in 122 patients who had undergone ACL reconstruction. Test measures included balance exercises (single leg reach and stork tests), compound movements (step ups and single leg squats) and hop tests (single leg, triple, crossover and timed hops). The results showed the compound movements and hop tests to be better at detecting larger asymmetries compared to the balance exercises, and results appeared to be interpreted within the context of 90% symmetry (or 10% asymmetry). This 10% figure is partially supported by Kryitsis et al. (21), who performed a return-to-play test battery for 158 professional athletes with prior ACL reconstruction. Before returning to sport, athletes completed isokinetic strength testing at 60, 180 and 300°/s, single leg, triple, crossover hop tests, an agility t-test, and an on-field specific rehabilitation protocol. Discharge criteria required athletes to demonstrate < 10% asymmetry for the strength and hop tasks, run the t-test in < 11s, and fully complete the on-field rehabilitation. Athletes were monitored for ACL ruptures (not purely re-ruptures on the same side) for an average of 646 days post return to play, and of the total sample, 26 sustained a second ACL rupture on average 105 days after returning to sport. Further to this, statistical analysis revealed that not meeting all of the discharge criteria led to a four times greater risk of an ACL rupture, compared to those athletes that met all discharge criteria. Finally, decreased hamstring to quadriceps ratio of the injured limb at 60°/s was also deemed a risk factor for injury. Whilst this provides some element of support for the '10% rule', it is worth noting that no single test had any predictive capacity for the risk of a second ACL rupture.

Thus, it seems as though a trend has somewhat occurred suggesting a greater level of symmetry (from 15 to 10%) as time has progressed in the last ~30 years. Further to this, it appears there is no uniform consensus on the threshold that athletes should be aiming for when returning from injury, which begs the question: can we use thresholds when reporting and monitoring inter-limb asymmetry?

What's the problem with using these thresholds?

Firstly, as alluded to previously, it appears that there is no agreement between studies on one specific threshold. Furthermore, when reading some studies, 10 or 15% is often suggested as a proposed threshold for consideration based off previous works, not their own empirical findings (1,26).

Secondly, as the previous section highlights, much of the reported data revolves around outcome measures (e.g., jump distance for hop tests), which recent literature has shown to be somewhat limited (19,20). For example, King et al. (18) showed total time (outcome measure) to be a poor metric to detect between-limb differences during planned and unplanned change of direction speed testing, with no meaningful differences evident. In contrast, when analyzing more strategy orientated variables (e.g., knee abduction moment, knee internal rotation and flexion angle, knee extension and external rotation moments), considerable limb differences were evident (effect size = 0.50-0.72). Thus, highlighting the way a task is executed may be better at detecting existing side-to-side differences. In a separate study by King et al. (19), 156 patients were tested using the single leg hop and single leg drop jump (amongst other tests), 9-months after surgery. At the time of testing, distance asymmetry was 6% during the single leg hop, but 22% for reactive strength index, measured during the drop jump test. Collectively, these studies show there are limitations to outcome measures based data, with the second of these studies suggesting that the single leg hop test may actually over-estimate a patients readiness to return to sport or activity (19).

This was partly reinforced in a recent systematic review by Kotsifaki et al. (20), who showed that measuring jump distance alone during the single leg hop test was insufficient at detecting deficits in knee function. Whilst not specific to asymmetry, it is worth noting that if raw jump scores (such as distance) are not sensitive enough to detect meaningful limb differences (20), it stands to reason that asymmetry values would be minimal as well. This is also supported in recent empirical studies using healthy athlete populations, which have shown distance asymmetry to rarely be reported > 6% (5,11,22). Whilst this information presents a reasonable case for monitoring more than outcome measures data, it is worth noting that if practitioners have minimal budgets and no other test options are available, hop tests may still be worth considering as a means to collect some information.

Thirdly, and related to the need to monitor more than simply outcome-measures data, there is an abundance of literature showing asymmetry to be task-specific (3,4,5,6,11,22,23,25). This highlights that an asymmetry value is unlikely to be comparable for different metrics within the same test or repeated across test sessions. For example, when considering the unilateral isometric squat test, Bishop et al. (4) showed that inter-limb asymmetry in peak force ranged from 8.4-9.0% between test sessions, using recreational sport athletes. However, when considering impulse as a metric from the same test, between-limb differences ranged from 9.6-15.5% (4). This pattern has also been shown using jump tests in professional cricket athletes. During pre-season testing, Bishop et al. (3) reported mean asymmetries of 11.49% and 6.85%

for jump height and contact time during the unilateral drop jump test. Further support can also be offered when comparing between jump tests as well. When using jump height as the metric of interest, the unilateral countermovement jump portrayed inter-limb asymmetries of 7.1-7.8%, whereas the unilateral drop jump showed asymmetries of 10.1-11.1% (4).

Thus, when considering our original problem, if we know it might be advantageous to monitor more than a single metric for our given test measures (9), how could any single threshold be applied if different asymmetry values are evident for each metric within the same test? Furthermore, this leads to a second question: if the use of thresholds are not realistic (or advised), how do we interpret inter-limb asymmetry scores?

Practical Applications: How can we use asymmetry during the monitoring process?

Although not exclusively, asymmetry is often reported as a percentage and when calculated, practitioners are left with a value which may not have any obvious means for interpretation. Exell et al. (12) suggested that inter-limb differences might only be considered real if greater than intra-limb variability. Put simply, an asymmetry might only be meaningful if the percentage value is greater than the test variability score (often measured by the coefficient of variation [CV]). Both practitioners and researchers often state the importance of differentiating between 'the signal and the noise', and in this instance, asymmetry represents the signal and the CV represents the noise. Figure 1 shows a hypothetical scenario with jump height asymmetry data for 15 athletes during a unilateral countermovement jump (blue bars), with the CV value tracked as a red line for each athlete. It is worth noting that athletes 3, 4, 7, 9, 11, 12 and 15 have a CV value greater than the asymmetry score; thus, these athletes do not have a real between-limb imbalance. In addition, although the remaining 8 athletes are exhibiting real between-limb differences, this does not mean that training interventions should be conducted in an attempt to minimise the imbalance.

***** Insert Figure 1 about here *****

However, reporting asymmetry in line with test variability data does have some potential advantages:

1. Both values are reported as percentages and although anecdotal, it seems like an appropriate comparison. This seems especially relevant for practitioners given the importance of being able to differentiate between the signal and the noise.
2. If a test or metric has a high CV, it may well be unreliable. Although picking an acceptable value for CV is like 'drawing a line in the sand', multiple studies have suggested values < 10% represent acceptable test variability (3,4,9). Furthermore, if a given metric was to show large asymmetry values (e.g., 25%), but the CV value of that metric was 20%, the asymmetry score would likely be irrelevant because the test metric is probably not reliable. Thus, use of the CV not only enables us to determine what is real asymmetry, it also enables us to consider when data can potentially be ignored due to the inherent noise being too high.
3. This allows practitioners to interpret data on a more individualized level. Recent research has suggested that owing to the inherent variability that seems to frequently accompany asymmetry, individual data analysis is advised (2,3,4). Noting that each athlete is likely to have different asymmetry and CV values, an individualized approach using both the signal and the noise, may assist practitioners from a programming perspective. The reader should note that minimal information exists showing that

training interventions can truly reduce existing imbalances or whether it is even necessary. Thus, further research in this area is warranted.

There is also a second method of interpreting asymmetry that practitioners may wish to consider. Impellizzeri et al. (16) and Maloney (24) emphasised the importance of the 'direction of asymmetry'. This refers to the limb which performed better than the other, noting that anything other than equal scores on both limbs will always result in some level of asymmetry or imbalance. The relevance here being that if practitioners always report asymmetry as an absolute value, it will always be positive and this fails to identify which limb performed better or worse. Figure 2 shows the same hypothetical asymmetry data as Figure 1; however, the direction of asymmetry has now been represented. Individual bars above the 0 line indicate the asymmetry score favours the right leg and below the 0 line favours the left leg.

***** Insert Figure 2 about here *****

Recent research has used the Kappa coefficient statistic (which can be calculated in Microsoft Excel) to determine how consistently asymmetry favours the same limb between test protocols (2) and test sessions (4). The Kappa coefficient provides an understanding of levels of agreement once any agreement by chance has been removed (8). The findings from these studies using the Kappa coefficient shows that the direction of asymmetry may be just as variable as the magnitude (2,4). Thus, monitoring the direction of asymmetry can provide practitioners with an understanding of the consistency of asymmetry (from a limb dominance perspective) which may help determine whether asymmetry is usable as part of the continued monitoring process. The relevance here is that recent research has highlighted a distinct lack of longitudinal data for inter-limb asymmetry (6). Thus, it is not clear whether asymmetry can be used consistently to aid the decision-making process for coaches. For further information on how to calculate the Kappa coefficient within the context of asymmetry, interested readers can view the following video:

https://www.youtube.com/watch?v=PVOoBb4rNMk&t=2s.

Conclusion

In summary, whilst numerous studies have tried to suggest possible thresholds for heightened risk of injury, it is likely that this is a somewhat flawed approach. Practitioners may wish to consider interpreting the percentage difference value in conjunction with the CV, enabling an understanding of what may be real asymmetry or what is within the error of the test. Further to this, calculating the consistency in the direction of asymmetry may also serve as a useful tool for practitioners as it helps to contextualise whether an imbalance is consistent to the same limb over repeated time points or test sessions. Understanding this may provide useful information on training load exposures for each limb, which could be exacerbated by positional differences in team sports, and may represent a useful line of monitoring for practitioners.

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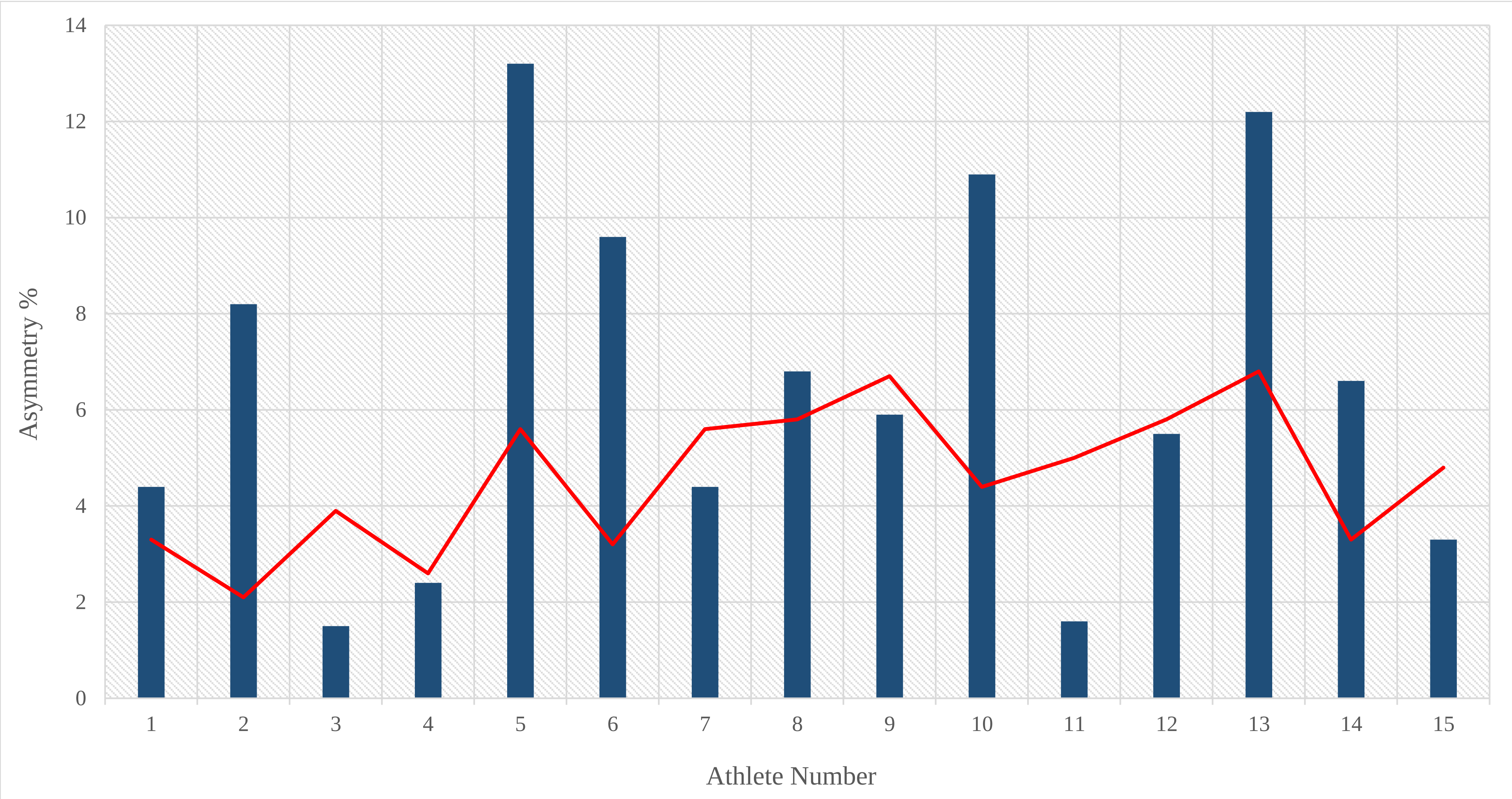

Figure 1. Hypothetical jump height asymmetry data (blue bars) during the unilateral countermovement jump and CV values (red line) for 15 athletes.

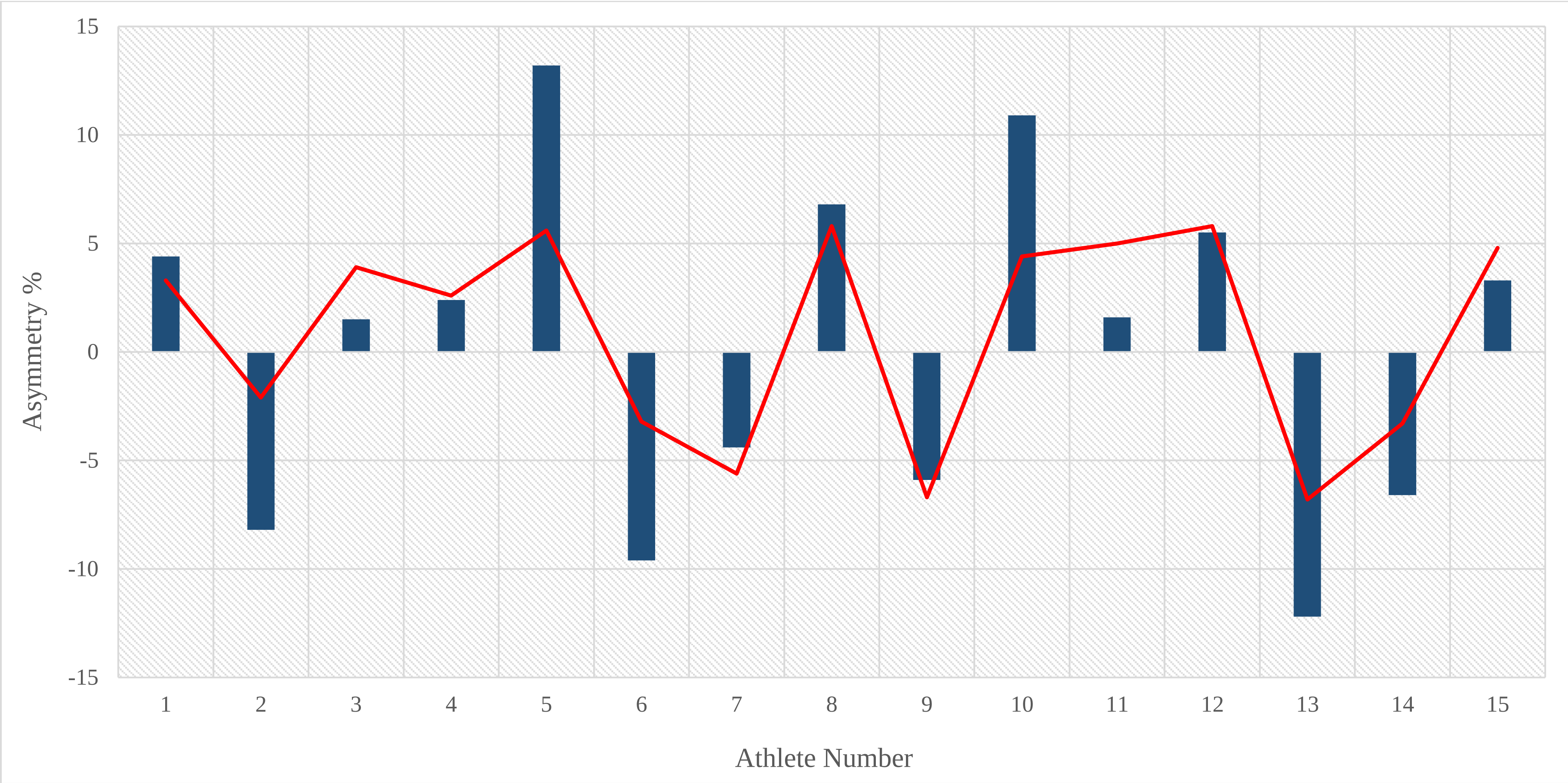

Figure 2. This shows the same data as Figure 1, but with the direction of asymmetry now represented. Above 0 indicates asymmetry favours the right leg and below 0 indicates asymmetry favours the left leg.