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On uneven ground: embracing the challenges of inter-limb asymmetries and their assessment

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Highlights:

- Many asymmetries represent positive adaptations to sports demands or individual characteristics.
- Inter-limb asymmetries of 5–15% are ubiquitous and typically do not increase injury risk.
- Task specificity and context, temporal stability, and measurement quality are paramount.
- Raw limb data must be considered: similar asymmetry percentages may arise from different limb strength profiles.
- Intervention decisions should never rely solely on arbitrary thresholds or normative data.

Abstract: Inter-limb asymmetry is often misunderstood in sports and healthcare, with natural differences seen as problems usually needing correction. Evidence linking inter-limb asymmetries to increased injury risk or reduced performance is weak, and asymmetries of 5–15% (or even higher) typically do not increase the likelihood of injury. Assessing inter-limb asymmetries is a complex matter.

Practitioners should select tests aligned with sports demands and track changes over time, rather than relying on single time point data. Ongoing temporal assessments help distinguish meaningful trends from natural fluctuations. Measurement error should also be considered to ensure changes exceed the minimal detectable change and reflect genuine performance or shifts in injury risk. Intra-individual analysis is recommended over averages across groups, as they can obscure meaningful variations. Arbitrary thresholds for what may be considered "normal" asymmetries oversimplify a continuous variable, potentially leading to misleading conclusions. Focusing on ranges (e.g., confidence intervals) instead of point values (e.g., mean) provides a more nuanced view. In addition, interpreting raw limb data alongside asymmetry metrics is crucial, as similar asymmetry percentages may arise from different limb strength profiles. Tracking raw data ensures that interventions improve performance, even if asymmetries persist. We provide a framework to help guide practitioners' decisions. Task specificity and context, temporal stability, measurement quality, and raw performance data are key pieces of the puzzle. Before implementing "asymmetry-correcting" programs, practitioners should answer key questions, for which we provide a user-friendly decision tree. Not all asymmetries are likely to yield meaningful benefits if corrected, and intervening in asymmetry should result from a carefully reasoned process that requires establishing relevance, ensuring measurement quality, gathering appropriate data, and considering practical implications.

Keywords: asymmetry; inter-limb; human performance; thresholds; temporal stability; raw changes

1. Introduction

Inter-limb asymmetry is a misunderstood concept in sports and healthcare settings [1–3]. Supposing a continuum ranging from −100% (e.g., favoring the left limb) to +100% (favoring the right limb), perfect symmetry would be 0%, and asymmetry would reflect the magnitude of deviation from this 0% symmetry point. In reality, perfect symmetry is just a specific (and statistically unlikely [4]) case within a continuum of inter-limb asymmetry. Despite our natural, functional anatomical asymmetries [5], social networks flourish with misinformation and often promote inter-limb asymmetries as something to be 'corrected'. These misconceptions are not exclusive to social networks; even expert practitioners fall into these traps: a recent study showed that postural asymmetry (no specific definition or cut-off value provided) was considered a problem warranting inter-professional collaboration by over 60% of Dutch physiotherapists [6]. While craniocaudal and dorsoventral asymmetries are usually accepted unproblematically, inter-limb asymmetries tend to generate debate [2]. Although inter-limb asymmetries are of considerably smaller magnitude than craniocaudal and dorsoventral asymmetries, this fact should still help us reframe our perspectives.

A systematic review has shown weak to moderate quality evidence that some inter-limb asymmetries may be risk factors for sports injury [7]. In this review, many studies established injury risk based on surrogate measures (e.g., the Y balance test) and not on actual injury data (*i.e.*, reporting of injury occurrence, potentially combined with statistics such as injury incidence). Just to provide an example, one study concluded that exercises to reduce inter-limb asymmetry could help reducing injury risk, but the only outcomes were single-leg hop distance, triple-hop distance, and data from a single-leg drop-landing task [8]. The review authors recognized problems with the quality of the included studies and poor standardization of methods; they stated that: "The relationship between asymmetry and injury risk could not be conclusively established" [7] (p. 209). Another review raised awareness that empirical research often associates inter-limb asymmetries with injury risk despite lacking injury data [2], *i.e.*, the supposed relationship is primarily based on surrogate measures and not on injury occurrence data. A systematic review including 28 prospective cohort studies showed highly inconsistent findings, stating that no clear relationship could be established between inter-limb asymmetries and injury risk [9]. A more recent systematic review also showed no relationships between inter-limb strength asymmetries and non-contact lower limb injuries [10]. Even more recently, a randomized trial with over 800 recreational runners (male and female) showed that asymmetric gait kinematics and kinetics during treadmill running were unrelated to lower limb injury risk [3]. A prospective study with 415 taekwondo athletes suggested that certain inter-limb asymmetries could increase non-contact lower limb injury risk [11], but because the analysis was retrospective, and the cut-off value's fit was not tested with other samples, generalization is not advised. Regardless, in that study, the cut-off point was ≥ 15% [11]. Overall, the relationship between *putative* risk factors and injuries is complex and likely nonlinear [12], and inter-limb asymmetries of 5% to 15% (and possibly higher) do not seem to affect injury risk [2].

Likewise, reviews have shown that inter-limb asymmetries present inconsistent relationships with independent measures of athletic performance (e.g., jumping performance) [1,2,7,9,13,14]. A recent study with swimmers found stable asymmetries of up to 30% across a 16-week training period, despite improvements in swimming performance during that period [15]. In sports, inter-limb asymmetries are usually associated with differences in functional outcomes, such as force production during standardized performance tests [1]. These asymmetries are expected, as they represent the natural biological asymmetries, often exacerbated by natural fluctuations in performance variability and sport-specific demands [1,2,13,16] (e.g., volleyball players constantly spiking using the same upper limb, or baseball pitchers using the same throwing arm). The literature has vast discrepancies regarding how to best assess inter-limb asymmetries [1,7]. Inter-limb asymmetries are individual- and sport-specific, fluctuate in time, depend on the task and metric used to evaluate them, and often correlate poorly with performance measures [2,7,10,17,18]. Empirical investigations commonly evaluate asymmetry at a single point in time, which may result in idiosyncratic data and does not provide an understanding of natural variability in asymmetry indices over time [2,7,13]. Moreover, no clear thresholds exist to determine when (and for what tasks) inter-limb asymmetries may be detrimental [2,3,10,13,18].

Therefore, researchers and practitioners should shift their focus from inter-limb asymmetries to changes in raw limb data from which asymmetry is born. In fact, some inter-limb asymmetries may be morphologically determined and stable in time (e.g., bone structure), meaning they are, by and large, non-modifiable. But even for inter-limb asymmetries that are "functional" and more easily modifiable (which represent at the core of this manuscript), it may not always be advisable to attempt to change them (or even possible, given their inherent variability). This methodological paper starts by exploring the challenges behind assessing and interpreting inter-limb asymmetries and then explores how to improve upon those limitations. Practical applications for regular training and return-to-play scenarios are also provided.

2. Challenges and solutions to improve analysis of inter-limb asymmetries

Inter-limb asymmetry indices may inform about right-to-left differences in strength, power, or functional performance. An example is the limb symmetry index (LSI), which divides the performance of the weaker limb (or injured limb) by that of the stronger limb (or non-injured limb) (and then multiplied by

100), with values closer to 100% indicating greater symmetry [19–21]. Confusion may arise because the same formula (without multiplication by 100) has been termed asymmetry ratio [22,23]. In contrast, in other studies the asymmetry ratio has been defined as ((stronger limb – weaker limb)/(stronger limb + weaker limb)) × 100 [24] or as ((stronger limb – weaker limb)/stronger limb) × 100 [25]. A good summary of different formulas is provided in a table elsewhere [26]. So, consensus may not exist on the technical terms and the formulas used for their calculation, inviting readers to be careful when comparing different studies [26,27]. Regardless, what tests are being implemented to assess such inter-limb asymmetries? How are data being analysed? How do we assess if the inter-limb differences are meaningful? We may test each limb separately, then measure the difference, or measure inter-limb differences in bilateral tasks [27]), but relevant challenges should considered. Some widespread practices may not provide the best scientific assessment of inter-limb asymmetries.

2.1. Choose your tests wisely

The expression "inter-limb asymmetry" is potentially misleading and could be replaced with "inter-limb asymmetries", as inter-limb asymmetry is not a monolithic, generalizable concept, but instead highly specific. The choice of a particular test (e.g., unilateral countermovement jump [CMJ]) and, within it, a specific metric (e.g., jump height) impacts the asymmetries that are observed, and, in the absence of monitoring multiple tests and/or metrics over time, may provide a biased account of performance [28]. In fact, test-specificity means that the choice of one-legged *vs.* two-legged CMJ will require differential data analysis, including different formulas to calculate the percentage difference [27]. For example, a study with 28 men and 30 women assessed impulse asymmetry between the one- and two-legged CMJs, showing no correlation for men ($r = 0.06$, $p = 0.76$) and only a moderate correlation for women ($r = 0.45$, $p < 0.05$) [29]. The magnitude and direction of inter-limb asymmetries are task- (*i.e.*, single- *versus* multi-joint) and velocity-dependent [16]. Therefore, we should ensure that test protocols are relevant: they should be intentionally selected to reflect sport-specific demands and/or provide specific information related to injury risk. The decision to monitor specific metrics (e.g., inter-limb asymmetries) should follow a clear understanding of their importance and role in the broader context of performance or injury prevention [2,30]. Data collection should not be the starting point but instead driven by a well-defined purpose within the chosen paradigm. Monitoring inter-limb asymmetries (or similar metrics) is recommended only if their measurement aligns with the overarching goals of relevance (such as improving performance). This should consider the sport-specific demands and individual characteristics, among other factors. Otherwise, we may risk choosing a test just because it provides a measure of asymmetry, regardless of its relevance. In fact, needs analysis is highly relevant in sports sciences in general [31]. Information from multiple tests and metrics should be collected to avoid enforcing a decision based on a single piece of information [28], relevance should play a key role in these decisions.

2.2. Ongoing data collection to assess temporal trends

Natural intra- and inter-day variability is expected to occur in asymmetry indices, as are seasonal variations [2,3,7,13,17,18], so the interpretation of data from an isolated point in time is ill-advised. Regular assessments provide multiple data points that allow discerning noise from information [2,13], while providing the grounds for assessing temporal stability [32]: without multiple data points, there is no way to known what “normal” is and whether there is a deviation from “normal”. Practitioners can interpret a value as putting the athlete at high risk of injury, when it reflects the athlete’s standard, healthy, functional value. Alternatively, these values can reflect noise, but this cannot be determined due to insufficient quantity of measurements. Some tests deliver inter-limb asymmetry values that fluctuate in time and magnitude but often also—and importantly—in direction [33,34], so regular monitoring is paramount to better discern real change from normal variability; it is conceivable that in some cases that range is broad. Only data collection across multiple time points can provide a good understanding of a normal or typical range of variability.

Assessing and interpreting multiple metrics can be overwhelming and increase the likelihood of false positives (see also literature on multiple testing and family-wise error rate correction [35,36]). Ultimately, we must choose carefully which tests and metrics (a single test such as the CMJ can provide several metrics, such as jump height, flight time, and positive and negative impulse, among others) offer relevant inter-limb asymmetries data over time [37,38]. Otherwise, we may incur in *p*-hacking [39]. There is also a particular challenge to define a meaningful change and factor measurement error, both of which are discussed in the subsequent section.

2.3. Meaningful change and measurement error

An appropriate interpretation of changes in data must account for measurement error [7,18,28,40,41]. Inter-limb asymmetries are usually reported in percentage, so the coefficient of variation (CV) is likely appropriate for comparisons, as both values are in the same unit (*i.e.*, %) [42,43]. However, regardless of the specific metric used (e.g., CV, typical error of measurement), it must be factored in before jumping to conclusions. Otherwise, any ‘significant’ change may be due to measurement error alone. For example, in a study with elite youth male volleyball players, significant relationships existed between the analyzed variables (e.g., ball and arm speed during the serve). Still, the authors highlighted that the measurement error of the instruments used could explain most “statistically significant” relationships [44].

Therefore, meaningful changes would need to (at least) surpass typical measurement error [28,40], and even that might not suffice (*i.e.*, it may not have a real practical or clinical impact). In this context, a minimal detectable change would result from changes greater than measurement error, while the minimally clinically important difference (MCID) would indicate changes that have important practical consequences [41]. Determination of the MCID or the smallest worthwhile change (SWC) involves considerable reasoning and judgment, and it may not be possible to establish a genuinely objective threshold [40]. Still, attempts can be made. For example, previous work has suggested that inter-limb asymmetries should be considered meaningful only if they are larger than normal intra-limb variability [45].

Alternative proposals suggested using SWC values specific for each asymmetry test [46], and a thumb rule of 0.2 × between-subject standard deviation (SD) may be used [47]. But are the values scientifically grounded? Suppose measurement error and regular daily or weekly fluctuation (*i.e.*, normal variability) were accounted for. How large is a change on top of that to be considered an MCID or SWC? And is the MCID/SWC value for a given metric relevant for overall performance? For example, will a SWC in a CMJ test result in performance benefits in the field? Moreover, is the SWC for performance the same as a SWC for injury prevention, or may there be trade-offs, such as a SWC that benefits performance at the cost of increasing injury risk? Within performance, is the SWC for raw performance data comparable to the SWC for inter-limb asymmetries? These questions likely have no easy answers but should make us ponder before proceeding with data analysis and jumping to conclusions.

Practitioners, who are experts in their domains, could help to improve this decision-making process by offering practically relevant input. This is not to suggest that data-driven research and applications are ignored but instead complemented. For example, a survey could assess the magnitude of the gap between scientific knowledge and expert knowledge [48]. This could raise a discussion on how to better communicate scientific findings and translate them into practical contexts. Conversely, it could provide nuances and pragmatic concerns that future research should incorporate. After all, some (but not all) scientific research is performed in highly controlled environments, likely to differ from real-world contexts in several key parameters. Understanding how the real-word training contexts operate may help to deliver more relevant, contextualized, and nuanced research. Similarly, case studies could help to understand the complexities of interventions in real training contexts [49].

2.4. Focus on intraindividual analyses

In typical performance metrics (e.g., jump height, sprint time), the SD (when considering all the participants) usually represents ~10–30% of the mean, or even less (e.g., [50,51]), implying that sample-level data are probably a good enough indicator of individual data. However, the SD for inter-limb asymmetry metrics is often ~50–90% of the mean (e.g., [34,37]). Consequently, interindividual variability is too large and attempting to detect changes based on mean values will likely result in trivial or small effect sizes due to the very large SD. This could be circumvented by recruiting very large samples, but in sports sciences the norm is to have very small sample sizes [52,53]. Of course, knowing the normal or typical range of inter-limb asymmetries for a given population (e.g., swimmers, basketball players) may provide a sufficient starting point to interpret inter-limb asymmetries in a specific person, which may be particularly relevant when few (or no) data points are available for that person. Some sports may present *similar* inter-limb asymmetry profiles, at least for some tests (e.g., handball and basketball [54]; canoeing and kayaking [55]), which could provide a helpful starting point when individualized data is not available. However, other sports may present completely different asymmetry profiles (e.g., soccer and cricket [56]; basketball, cricket, netball, soccer [57]), requiring caution when generalizing results. It is also conceivable that there are different within-sport asymmetry profiles, given the demands of each specific function or positional role.

Given the presented limitations, inter-limb asymmetry assessments should perhaps prioritize intra-individual comparisons over time rather than relying on average values across populations, especially when we have access to multiple data points for the same person. This approach accounts for the inherently individualized nature of asymmetry, where each athlete's baseline and response to training or rehabilitation can vary significantly [58]. Averaging values across groups may obscure meaningful trends or fluctuations specific to an individual [59,60], particularly given the substantial natural variability in asymmetry indices. Indeed, inter-individual variability may cancel out relevant asymmetry values, delivering low average asymmetry values, in contrast with larger values obtained when analysing individual data [61,62]. By monitoring temporal changes within the same athlete, practitioners can better discern whether observed differences represent actual performance improvements, injury risk markers, or simply normal physiological variability [60]. In contrast, comparisons to average benchmarks may misclassify an athlete's normal functional asymmetry as problematic or overlook unique deviations that warrant attention.

2.5. Perform continuous analysis and avoid arbitrary thresholds

In the study of inter-limb asymmetries, the literature has underlined the arbitrary, non-data-driven nature of established thresholds [2,18]. More generally, setting thresholds off continuous variables alongside complex processes (e.g., sports injury) is ineffective and warrants little to no predictive value [63]. Moreover, using arbitrary asymmetry thresholds to discretize a continuous variable and classify athletes into symmetrical or asymmetrical results in information loss and potentially biases the results [7,42]. In general, dichotomizing (or categorizing in general) a continuous variable results in reduced statistical power, biased effect size and loss of information [64,65]. The adoption of arbitrary thresholds in sports sciences affects multiple fields of study. This practice has been criticized in relation to running speed [66], acceleration and deceleration [67], most demanding periods [68], and inter-limb asymmetry [2,18]. Perhaps the recruitment of very large sample sizes, with cohorts sharing common characteristics, could provide better support for creating thresholds that would be useful as a starting point. Still, as previously mentioned, most studies in sports have the opposite problem of having very small sample sizes. In addition, generalizability is low given the heterogeneous competitive levels, age ranges, specific sports, fitness statuses, among many other factors.

Asymmetry values are continuous and thus then can assume any numerical value, so why create artificial thresholds that falsely dichotomize a continuous phenomenon, resulting in loss of power and informative value? Although such thresholds could potentially provide a rough normative guide at the population level (and a starting point for when no assessment is available), they may also be misused to interpret individual data. The use of arbitrary thresholds to, for example, determine who is at high risk of injury, often lacks a solid biological rationale and is seldom generalizable to different samples [69]. An illustrative example that conjugates the problem or arbitrary thresholds including test of inter-limb asymmetries is provided by the Functional Movement Screen®: the literature has shown that cut-off values are sample-specific [70–72], and the test battery presents low values of specificity and sensitivity, and overall reduced predictive ability [70,73–75].

2.6. Ranges over point values

Focusing on point values (e.g., mean, median) should be replaced with a focus on ranges (such as confidence intervals [CIs]). The benchmark against which to compare and interpret changes over time would be an interval, not a single value. Statistical analyses prioritizing ranges over point estimates enhance interpretability by providing a measure of uncertainty, reflecting the variability inherent in data collection and sampling [76]. This approach avoids the pitfalls of over-reliance on single-value estimates, which can misrepresent the reliability or robustness of results, especially in studies with limited data or high variability [77]. Additionally, presenting ranges promotes transparency and more accurate conclusions by revealing the precision of estimates and allowing readers to gauge the likelihood of various potential true values within the specified interval [78].

Based on previous sections, ranges over point values could also have a double application: (i) for each specific assessment, interpret the point value in the context of the range (in case there are no intraindividual data points to compare to, at least frame the point value of each individual within the range of variation amidst the whole group); and (ii) over time, try establishing a range of reasonable, “normal” values for each individual (hypothetical example: instead of considering that 17% is the standard value for that individual, maybe consider a range from 13–21%). Still, ranges may provide a mixture of normal inter- and intraindividual variability and measurement error. A discussion about the relevance of range and dispersion measures in general can be found elsewhere [79].

2.7. Consider raw data in addition to asymmetry values

Interpreting inter-limb asymmetries without considering raw data for each limb can be misleading. Asymmetries are ratios [26,27,42] that hide information and potentially overshadow the analysis of its component parts. For instance, a 10% inter-limb asymmetry could arise from a strong right limb and a weaker left limb or from a weak right limb and an even weaker left limb. Without the raw strength values, the relative magnitude of the asymmetry cannot be contextualized within an athlete's overall strength profile, limiting its practical application. Thus, integrating raw data alongside asymmetry metrics allows practitioners to understand whether the focus should be on "correcting" imbalances, improving overall strength, or both. Tracking changes in raw data over time is crucial to evaluate the effectiveness of training interventions [15,32–34,37,38]. If an athlete reduces their inter-limb asymmetry but both limbs become weaker, the improvement in balance will not necessarily translate to enhanced performance or reduced injury risk. Weaker strength levels have in some scenarios been associated with increased injury risk [80–82]. Conversely, an increase in strength in both limbs, even with maintained or slightly increased asymmetry, may still reflect meaningful progress. At the end of the day, the focus should be on improving limb performance, regardless of asymmetries. In some cases, performance can improve over time even with inter-limb asymmetries of up to ~30% [15]. Figure 1 shows an example of how misleading it may be to focus on inter-limb asymmetries alone. Players 2 and 4 are more symmetrical but have inferior peak force, and so players 1 and 3 will potentially be capable of performing at a superior level.

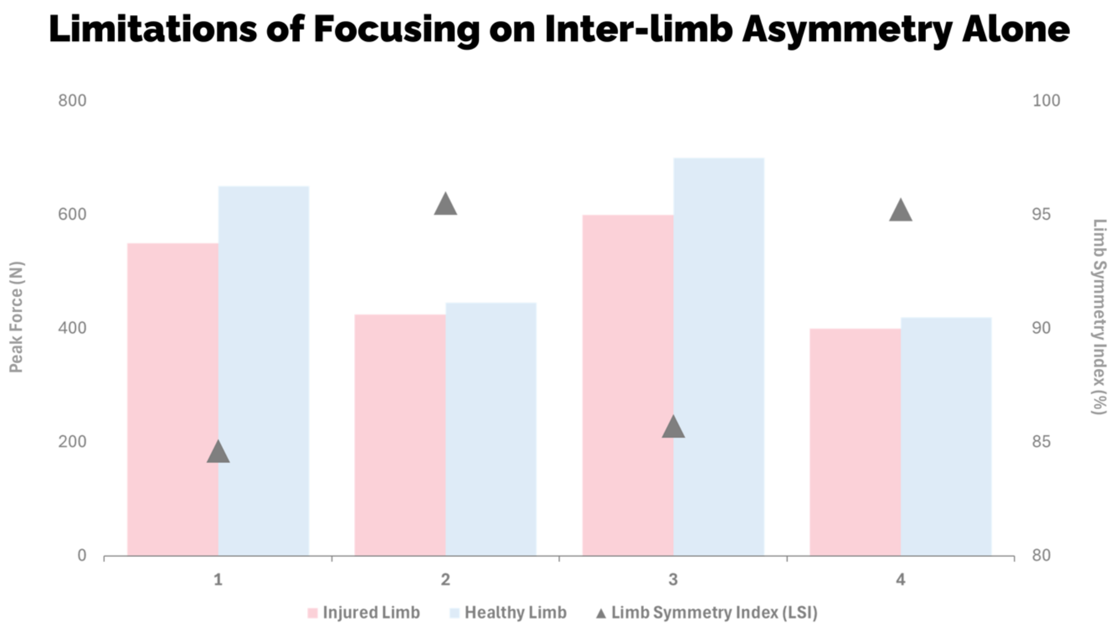

Figure 1. The limitations of focusing on inter-limb asymmetries alone. Legend: LSI – Limb Symmetry Index. Players 1 and 3 have larger raw inter-limb differences in peak force (and, consequently, lower LSI), but they also have superior peak force values in comparison to players 2 and 4.

3. Practical applications

Understanding and assessing inter-limb asymmetries requires a nuanced, evidence-based approach that moves beyond simplistic thresholds or universal rules. Our framework provides practical guidance for medical professionals, strength and conditioning coaches, and sports scientists working with athletes. First and foremost, practitioners should recognize that inter-limb asymmetries of 5–15% (and potentially higher) typically do not impair performance or increase injury risk. Recent evidence demonstrates that inter-limb asymmetries up to 30% can coexist with performance improvements. This understanding should shift the focus from automatically "correcting" asymmetries to carefully evaluating their functional relevance. We propose a mind map for a comprehensive assessment framework (Figure 2) to help guide practitioners regarding what to consider when assessing inter-limb asymmetries. The key takeaway is that asymmetry assessment is not a simple, one-dimensional measurement, but a complex interplay of multiple factors that must all be considered for meaningful interpretation. The framework is built upon four key dimensions:

(1) *Task specificity and context* considers how asymmetries manifest differently across movements and sports. For instance, volleyball players consistently spiking with one arm represent a sport-specific adaptation rather than a deficit requiring correction. Competition level, role in the team, and individual movement patterns all influence how asymmetries should be interpreted. What might be a problematic asymmetry for one athlete may be perfectly functional (maybe even advantageous) for another.

(2) *Temporal stability* acknowledges that asymmetries naturally fluctuate across different timescales. Single-point measurements often provide misleading information. Regular monitoring helps distinguish meaningful changes from normal biological variation, training adaptations, and environmental influences. Practitioners should establish baseline ranges of variation for individual athletes rather than relying on population averages.

(3) *Measurement quality* emphasizes that reliable assessment requires more than just consistent measurements. Tests must demonstrate relevance to performance or injury risk in specific contexts. Multiple metrics often provide more complete information than any single measure. Error quantification (both random and systematic) is essential for interpreting changes meaningfully. Practitioners should resist the temptation to assess asymmetry across numerous metrics without theoretical justification for their relevance. Like *p*-hacking in research [39], examining enough variables will inevitably reveal some 'significant' asymmetries purely by chance. For instance, a jumping assessment might yield data on take-off velocity, peak force, rate of force development, impulse, and various temporal parameters—analyzing asymmetry in each metric increases the likelihood of finding 'problematic' differences without necessarily indicating meaningful functional limitations. Instead, practitioners should first establish which specific variables are most relevant to the sports demands and injury risk factors, then focus their asymmetry assessment on those theoretically justified metrics.

(4) *Raw performance data* provides crucial context for asymmetry values. For example, a 10% strength asymmetry could reflect either a strong dominant limb with a moderately strong non-dominant limb or two relatively weak limbs. These scenarios demand different interventions despite showing identical asymmetry percentages.

Combined, these features advise practitioners to avoid relying on simple thresholds or universal rules when assessing asymmetries, instead undertaking a holistic, multi-factorial approach.

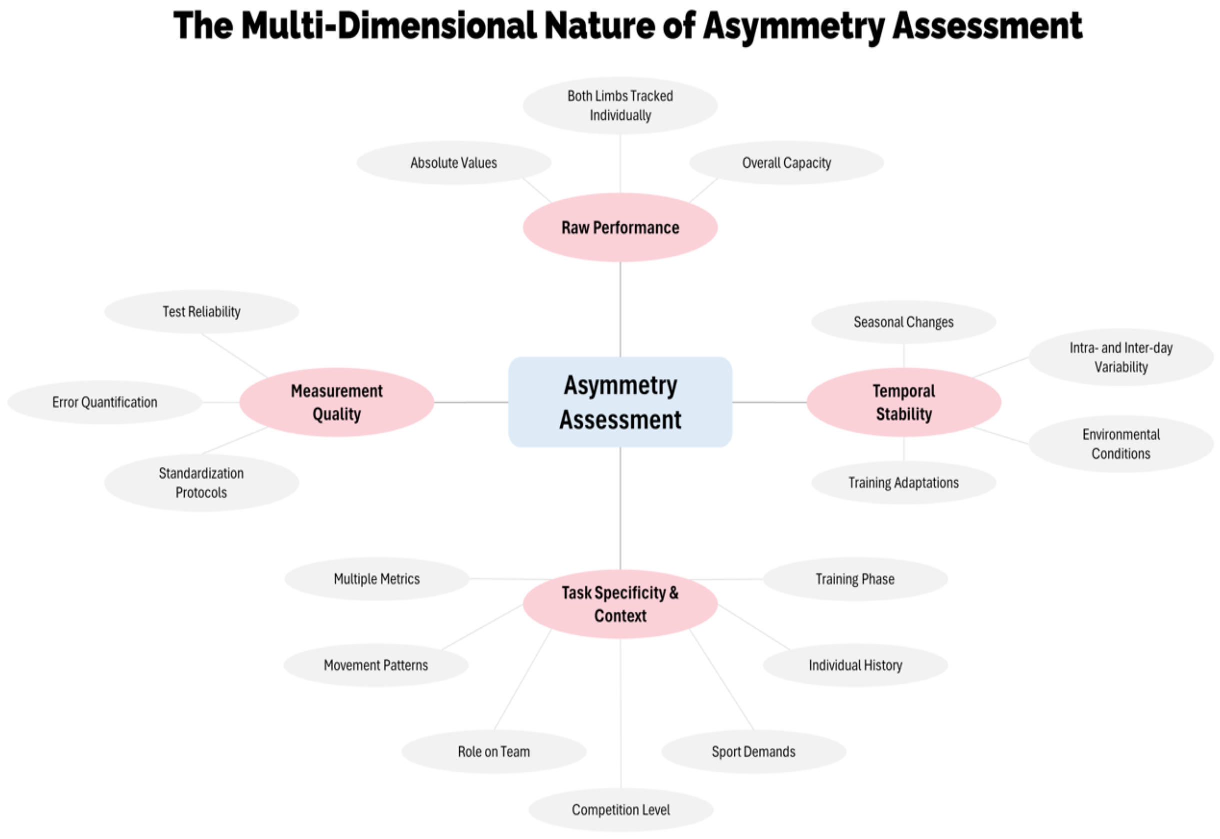

Figure 2. Mind map to help guide practitioners regarding what to consider when assessing inter-limb asymmetries.

Overall, inter-limb asymmetries are natural and do not clearly impair performance or increase injury risk [1–3,10,17,18]. These asymmetries may be unstable (*i.e.*, their magnitude and direction fluctuate in time) and are specific to the individual, sport, task, and metric chosen [2,3,7,10]. More importantly, inter-limb asymmetries should be framed within a broader picture of health and performance. Athletes often undergo various assessments, many of which provide no information on inter-limb asymmetries (e.g., 20 m linear sprint time, bilateral countermovement jump height). Inter-limb asymmetries are just one piece of a complex puzzle and should not be considered in isolation. Finally, practitioners should avoid overreliance on metrics of what they can measure (based on available equipment, time, and money, for example) and instead carefully reflect upon what they deem relevant and why [28]. With emergent technologies and metrics, losing track of what matters is easy. By trying to analyze "everything" practitioners may eventually find something outside a "normal range" and try to act upon it…even if it is not truly relevant.

To support evidence-based decision-making, we developed a systematic evaluation process (Figure 3) that helps practitioners determine when intervention is warranted. This decision tree addresses several critical questions:

(1) Is the assessment sport/task-specific and validated for the intended outcome? For example, are inter-limb asymmetries in a one-legged CMJ relevant for golf?

(2) Does theoretical and empirical evidence support a link to injury or performance? Following the previous example, is there evidence that a one-legged CMJ correlates with better golf performance and/or decreased injury risk during golf? And, if so, do we have follow-on evidence for causality?
(3) Have meaningful change thresholds been established? For example, does a 15% inter-limb asymmetry increase injury risk? For all injuries or just for some specific injuries? Is that threshold generalizable or sample-specific?
(4) Does the asymmetry exceed normal biological variation? By gathering population data, we can better understand what the normal lower and upper limits of inter-limb asymmetry are.
(5) Are raw performance levels below expected standards? Ultimately, if performance is at or above the expected level, perhaps inter-limb asymmetries are not necessarily of concern.
(6) Can intervention occur without compromising overall performance? If an intervention effectively reduces inter-limb asymmetries, but at the expense of performance, perhaps it should not have been implemented in the first place.

Only when these criteria are met should practitioners consider targeted intervention. This approach helps avoid unnecessary interventions on functional asymmetries and missed opportunities to address genuinely problematic imbalances. When monitoring asymmetries, practitioners should:

(1) Track raw performance values for each limb independently. For example, collect raw performance peak force for each lower limb separately (e.g., isokinetic knee extensors and flexors testing).
(2) Collect longitudinal data to establish individual variation patterns. Each individual is expected to present fluctuating values of inter-limb asymmetries. Assessing the normal range of variation is only possible through multiple data points over time.
(3) Consider multiple assessment methods when feasible. Because different tests and/or methods may provide different information regarding inter-limb asymmetries, we should avoid trusting in a single assessment method, as it will likely provide a very incomplete and potentially biased account.
(4) Account for measurement error when interpreting changes. This goes beyond assessing intra- and interday reliability. In the presence of large but systematic errors, typical reliability indices (e.g., intraclass correlation coefficient [ICC]) may still provide "excellent" values. Therefore, metrics such as the mean absolute percentage error (MAPE) are needed to assess measurement error [83,84] and ensure that observed changes are real, and not simply an artifact of measurement error.
(5) Evaluate asymmetries within the broader context of performance and injury risk. Assess how well detected inter-limb asymmetries correlate with performance and injury risk, while ensuring causal directionality. Is the asymmetry increasing the injury risk, or are injuries increasing asymmetries?

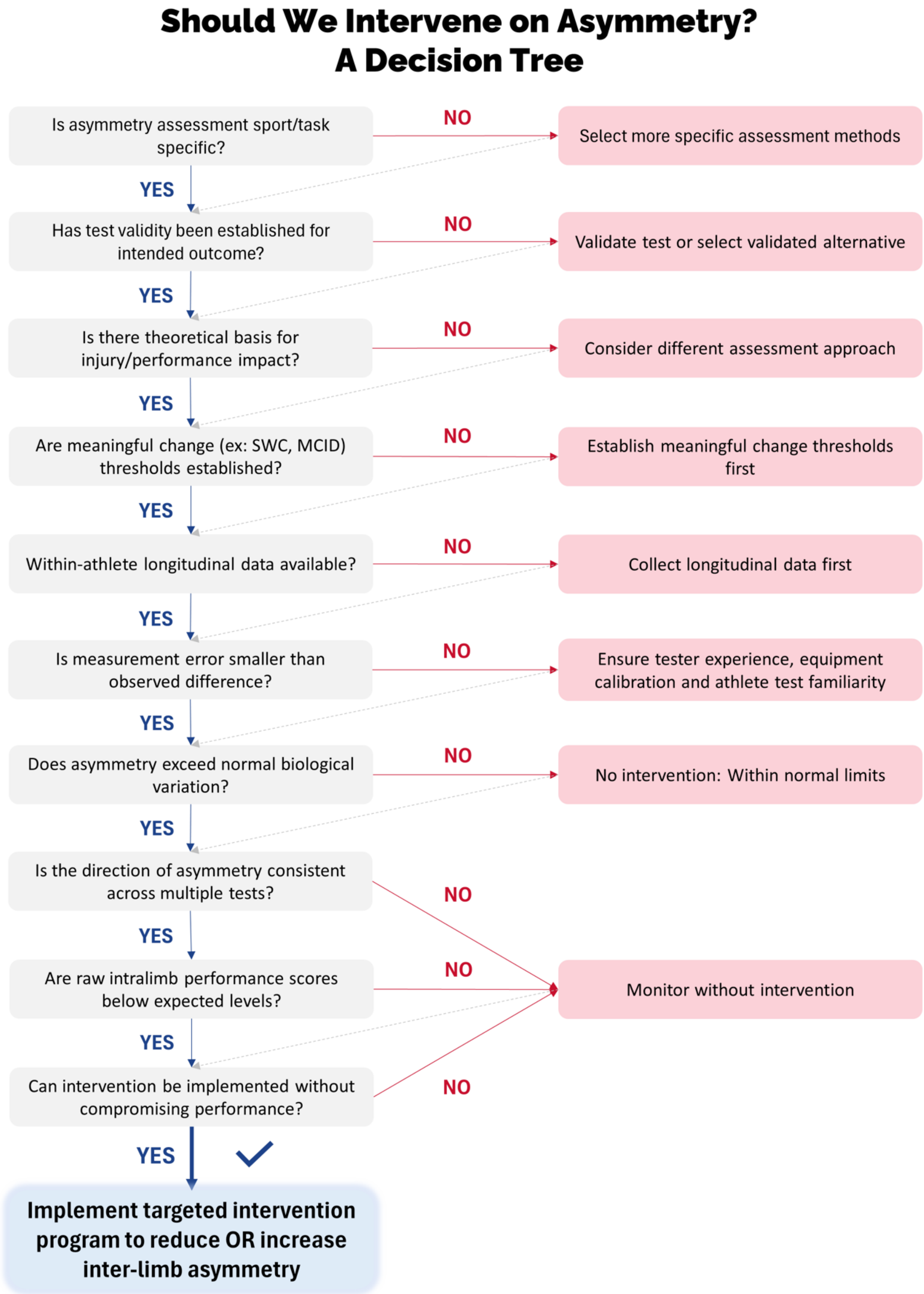

Figure 3. Decision-tree to help guide practitioners on whether an intervention is advised.

The decision tree shows that several critical stages should be considered before intervening upon inter-limb asymmetries. Not all asymmetries need to be "fixed". The overarching message is that intervening in asymmetry should result from a carefully reasoned process that requires establishing relevance, ensuring measurement quality, gathering appropriate data, and considering practical implications. This structured decision-making process safeguards against over-intervention (trying to fix asymmetries that do not need fixing) and under-intervention (missing asymmetries that genuinely require attention). It is a framework that promotes thoughtful, evidence-based practice rather than reactive intervention. Figure 4 provides additional visual guidance for interpreting asymmetry-related data. While this framework is evidence-informed, ideally future research should attempt to validate it.

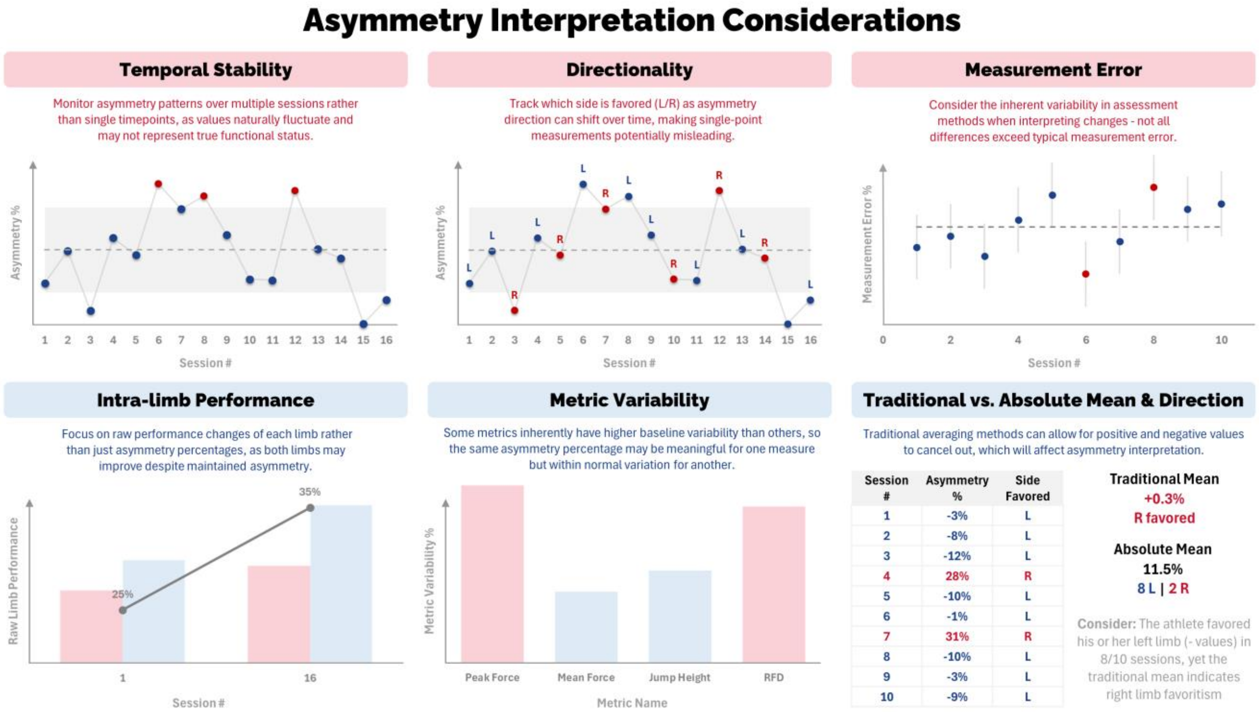

Figure 4. Visual guidance to assist the interpretation of asymmetry-related data.

4. Conclusion

Asymmetry is a ubiquitous phenomenon and may even be enhanced by sports-specific participation. Practitioners should resist the urge to "correct" asymmetries or to infer they are automatically prejudicial to performance or injury risk. Throughout this paper, we provided guidance regarding what, why, and how to consider sports-related asymmetries. An in-depth discussion of the conceptual and methodological premises supporting asymmetry assessments is paramount to guide how we act upon such information. Importantly, intervention decisions should never rely solely on arbitrary thresholds or normative data. Many asymmetries represent positive adaptations to sports demands or individual characteristics. Even when asymmetries appear large by conventional standards, intervention is warranted only when careful analysis demonstrates an apparent performance deficit or injury risk and when correction can occur without compromising overall athletic capability. This enhanced asymmetry assessment approach acknowledges human movement's complexity while providing practical, evidence-based guidelines for clinical decision-making. It encourages practitioners to move beyond simplistic symmetry targets toward more sophisticated and individualized evaluation methods.

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Conflicts of interests

The authors declare there are no conflicts of interest.

Authors' contribution

Conceptualization, J.A., A.V. and C.B.; methodology, J.A., A.V. and C.B.; writing—original draft preparation, J.A.; writing—review and editing, J.A., A.V., J.P., A.G.A., M.S. and C.B.; figures, A.V. and C.B.; supervision, J.A. and C.B.; project administration, J.A.; funding acquisition, not applicable. All authors have read and agreed to the published version of the manuscript.

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