



2022 NSCA *NATIONAL* CONFERENCE

July 6-9, 2022 | New Orleans & Online
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› *ADVANCEMENT*
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CONFLICT OF INTEREST STATEMENT

I have no actual or potential conflict of interest
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MAKING SENSE OF ASYMMETRY IN SPORT PERFORMANCE AND S&C RESEARCH

Objectives

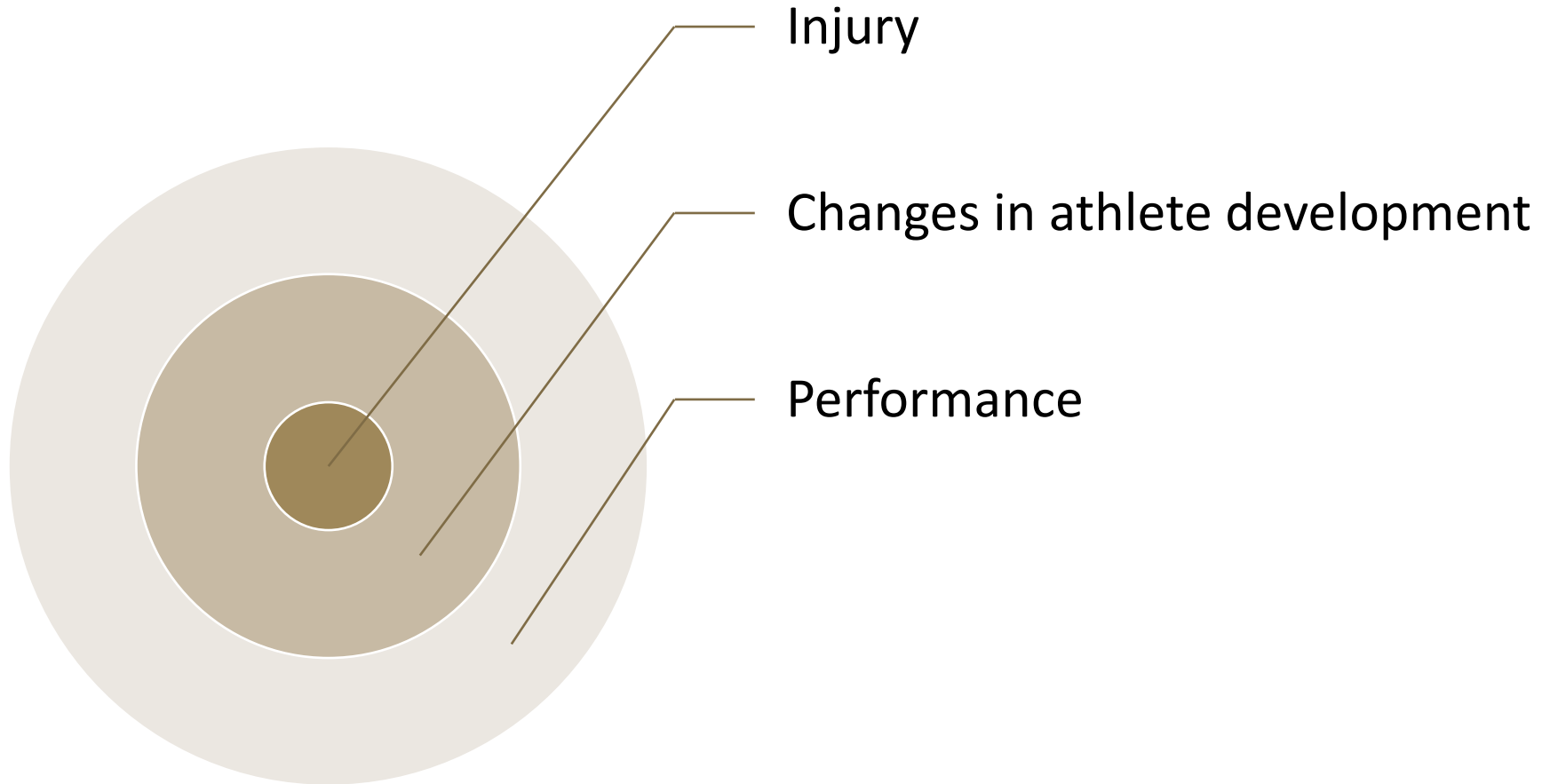
Is monitoring asymmetry important?

Reviewing relevant literature

Quantifying asymmetry

Issues & Solutions

Is monitoring asymmetry important?



Reliability



Is monitoring asymmetry important? – Performance



Strength



Jumping



Body Comp



Sprinting



COD

Is monitoring asymmetry important? – Performance

Strength

- Computer simulation demonstrated no statistical difference in JH between symmetrical and asymmetrical strength models when equated for overall strength - Yoshioka et al., 2011
- IMTP PF asymmetry is related to poorer performance in SJ and CMJ (JH $r = -0.52$ to -0.39 ; PP $r = -0.43$ to -0.28) - Bailey et al., 2013
- Leg strength and lean mass asymmetries may negatively influence kicking accuracy in Australian football - Hart et al., 2014
- Stronger individuals aren't as asymmetrical as weaker individuals - Bazyler et al., 2014; Bailey et al., 2015

Is monitoring asymmetry important? – Performance

Jumping

- Strength (measured during jumping) asymmetry assessment may help optimize sprint start (strong leg should be in the forward block) – Vagenas and Hoshizaki (1986)
- Functional asymmetry (SL CMJ) may inhibit short sprinting performance, but not longer distances – Sannicandro et al., 2011
- PF asymmetry influences both A/P & M/L COM displacement & RFD asymmetry influences M/L COM displacement – Bailey et al., 2015c
- Bishop C, et al. (2019). Drop jump asymmetry is associated with reduced sprint and change-of-direction speed performance in adult female soccer players.
 - JH and RSI

Is monitoring asymmetry important? – Performance

Jumping

- Bishop C, et al. (2021). Vertical and horizontal asymmetries are related to slower sprinting and jump performance in elite youth female soccer players.
 - SL CMJ asymmetry with vertical jump performance and triple hop for distance asymmetry with other horizontal jump tests
- Bishop et al., (2022c) found a few of statistically sig. correlations between unilateral DJ JH asymmetry and 10 m sprint time and 505 COD performance
 - But they weren't consistent across the season
 - and COD relationship was only in one direction

Is monitoring asymmetry important? – Performance

Body composition (lean mass asymmetry)

- Strength & power asymmetry is only partially explained by lean mass asymmetry
 - Thigh and shank lean mass asymmetry accounted for 20% of the variance in force asymmetry during CMJ - Bell et al., 2014
 - Pelvis, thigh, and shank lean mass asymmetry accounted for 25% of power asymmetry during CMJ - Bell et al., 2014
- Lean mass asymmetry weakly associated with jumping performance (JH, PP, Imp)
 - <10% of variance in jumping performance could be explained by lean mass asymmetry in NCAA Div. I Basketball players. - Bailey, Eusufzai, Wright, 2021
- Leg strength and lean mass asymmetries may negatively influence kicking accuracy in Australian football - Hart et al., 2014

Is monitoring asymmetry important? – Performance

Body composition (weight distribution)

- WtD asymmetry may result in barbell tilt and rotation in the squat – Sato & Heise, 2012
- WtD asymmetry may result in excess mediolateral COM displacement during the propulsive phase of jumps (Bailey et al., 2015c)

Is monitoring asymmetry important? – Performance

Sprinting

- More expensive to measure
- No practical relationship between sprint asymmetry and maximal velocity (all $r < 0.39$, $n = 344$, 11-16 yrs) – Meyers et al., 2017

Is monitoring asymmetry important? – Injury Prediction

- Very limited research connecting asymmetry to injury
- >15% in female collegiate athletes increased injury risk – Knapik et al., 1991
 - but only when the right side was stronger than the left (hip flexor and extensor)
- Issues with injury prediction research
 - Ethics
 - No way to ethically validate injury prediction models
 - Bad injury prediction models are correct more often than they aren't
 - e.g., Deciding there is no injury risk 100% of the time when an injury risk is 1 for every 1,000 exposure hours, would be correct 99.9% of the time.
 - Models will be complex and may not generalize well in different environments
 - Injury is multifactorial and injury prediction models likely won't be linear
 - Noise – there may be issues with asymmetry measurement reliability and stability (Bailey et al., 2021, Bishop et al., 2022c)
- The connection between force/strength asymmetry and injury is not well supported by science

Is monitoring asymmetry important? – Athlete Development

- Bilateral strength training decreases IPF asymmetry in weaker ROTC cadets - Bazyler et al., 2015
 - But not in the stronger subjects who had less asymmetry to begin with
- Unilateral training and bilateral eccentric training decrease SL broad jump distance asymmetry - Sannicandro et al., 2014, Hammami et al., 2020
- “Core stabilization” training decreases SL CMJ PF asymmetry - Dello Iacono et al, 2015
 - Study reported very low variability in results compared to all other asymmetry research 
- SL CMJ JH asymmetry reduced following eccentric training (Gonzalo-Skok et al., 2019) and isoinertial training (Madruga-Parera et al., 2020) (small to large effect sizes)
- No statistical differences in unilateral and bilateral CMJ JH asymmetry following combined strength and power training - Pardos-Mainer et al. 2020
- Most studies show that asymmetry decreases as strength increases (regardless of training method) - Bettariga, et al., 2022

Is monitoring asymmetry important? – Athlete Development

- Adaptation is direction specific
 - Eccentric overload training in the horizontal direction may be superior to the lateral direction for reducing asymmetries - Gonzalo-Skok et al., 2022
 - Neither improved vertical jumping performance
- Order may impact adaptation with unilateral training - Moreno-Azze et al., 2021
 - Beginning with the weaker leg may lead to lower asymmetry
- Soccer match play doesn't impact asymmetry (pre/post 5 matches) - Bishop et al., 2022b
- Variable stability/reliability across a season may be a concern as poor agreement in asymmetry scores is present - Bishop, et al., 2022c

Asymmetry Quantification



Asymmetry Quantification

- Many options outlined by Bishop et al., (2016)
- Method chosen will impact the results
- Main concern is producing a reliable measure
- Simplicity is likely best for repeatability in monitoring and reporting

ARTICLE

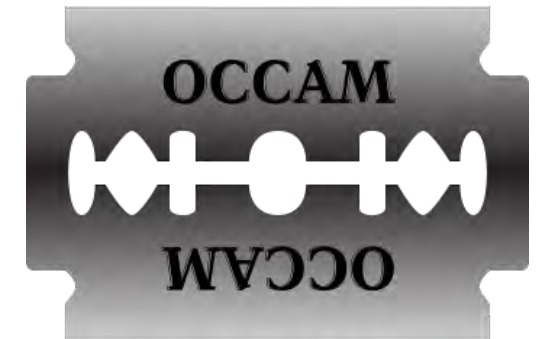
Asymmetries of the Lower Limb: The Calculation Conundrum in Strength Training and Conditioning

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[Author Information](#)😊

Strength and Conditioning Journal: December 2016 - Volume 38 - Issue 6 - p 27-32

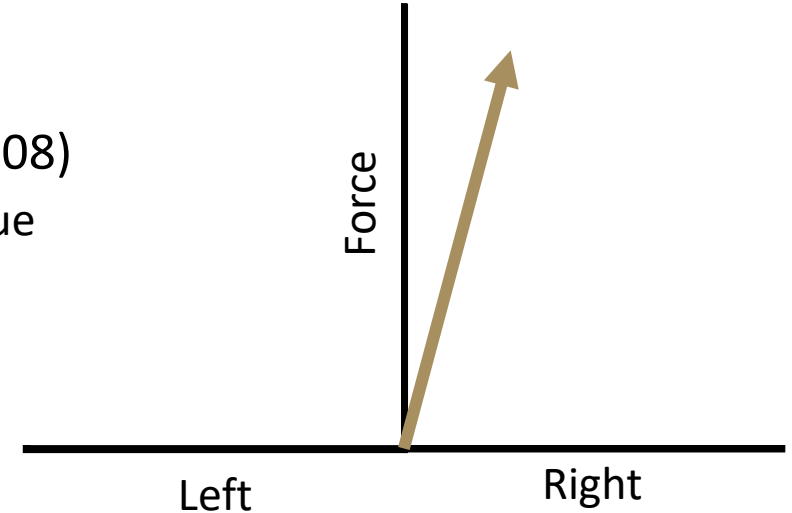
doi: 10.1519/SSC.0000000000000264



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Asymmetry Quantification

- It is important to remember that strength asymmetry is a vector
- Method chosen should reflect magnitude and direction (Bailey, Sato, McInnis, 2021)
- This likely negates any method that does not include direction
- Dominant limb/nondominant limb methods may be used depending on how limb dominance is defined
- Stronger/weaker limb methods should likely be avoided
 - Unless you know they won't switch
- Reference value methods may be population specific (Zifchock 2008)
 - Switching which limb is used for reference, produces a different value
- Method must include some sort of directional indicator
 - (+) or (-)
 - right or left



Asymmetry Quantification

- Methods that utilize a reference limb generally produce much higher asymmetry scores
 - For example,
 - Ceroni et al., (2012) (uses reference limb) - $\frac{\text{nondominant limb}}{\text{dominant limb}} * 100$
 - Shorter et al., (2008) (no reference limb) - $\frac{\text{higher value} - \text{lower value}}{\text{sum of values}} * 100$
- Reference limb methods will result in different values if the reference limb is switched
 - For example, Impellizeri et al., 2007
 - $\frac{\text{stronger} - \text{weaker}}{\text{stronger}} * 100$
 - $\frac{10-9}{10} * 100 = 10\%$
 - $\frac{10-9}{9} * 100 = 11.111\%$
- Potentially the most robust method (Zifchock, 2008)
 - Deals with inflated asymmetry scores by not using a reference limb
 - Sets perfect symmetry at 45°

$$\text{Symmetry Angle} = \frac{45^\circ - \arctan\left[\frac{\text{left value}}{\text{right value}}\right]}{90^\circ} * 10$$

Asymmetry Quantification: Small differences magnify as asymmetry increases

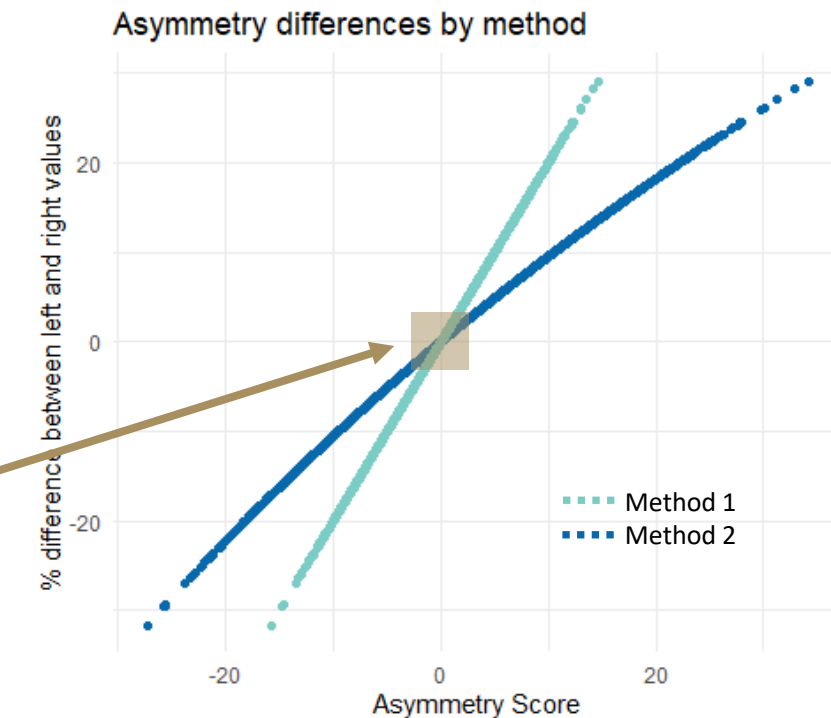
- Simplest vector-based method with easiest interpretation and application
 - Bailey et al., (2015) used a modification to the SI score by Shorter et al., (2008)
 - $(\text{left value} - \text{right value}) / \text{sum of values} * 100$
- Most commonly vector-based used method in recent publications
 - Bishop et al., (2018 (step 1), step 1 & 1 in 2022)
 - Step 1: $(100 / [\text{max value}] * [\text{min value}] * -1) + 100$
 - Step 2: Use an if statement in MS Excel or other
 - `=*IF(left>right,1,-1)`

Left	Right	Method 1	Method 2
50.5	49.5	1%	1.98%
55	45	10%	18.18%
60	40	20%	33.333%
65	35	30%	46.15%

Method 1 is the modification to Shorter et al. (2008) by Bailey et al. (2015), Method 2 is from Bishop and colleagues (2018)

10,000 pairs of left and right force values
(mean = 3500 N, sd = 200 N) used to
create asymmetry measures

Most asymmetries
will be in this area



Plot created in R by author for this presentation

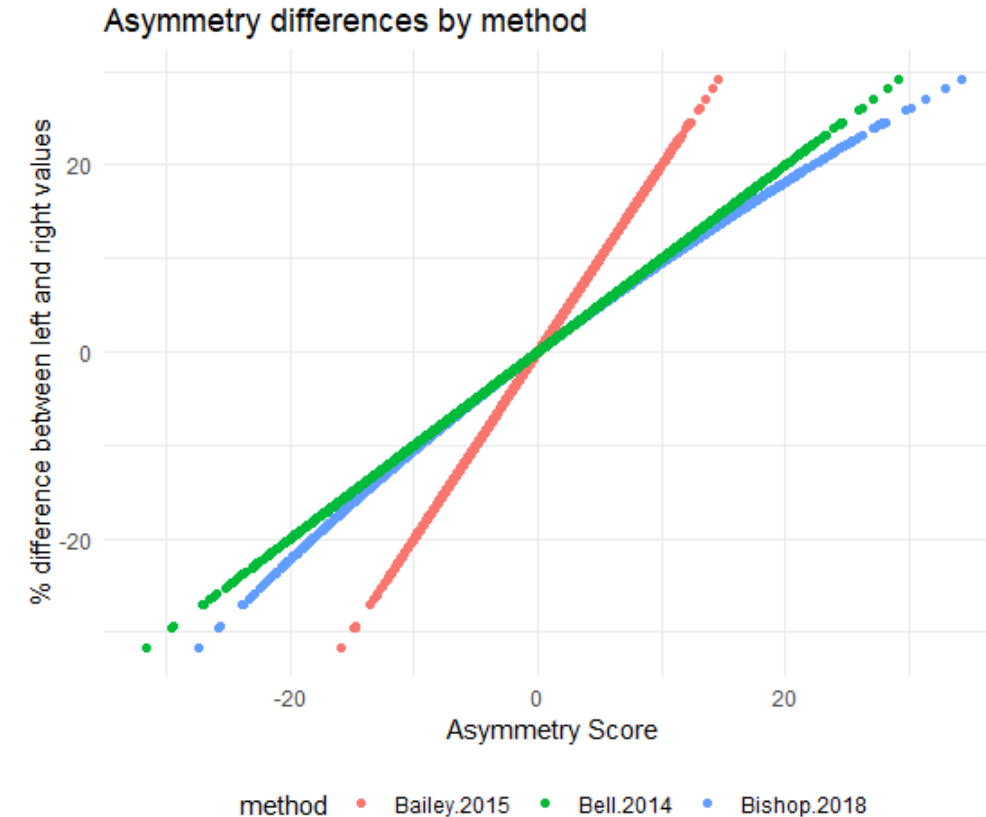
Asymmetry Quantification

- What are we really trying to measure?

- Percentage difference between while avoiding athlete reference limb
 $\% \text{ difference} = \text{difference in values} / \text{reference value} * 100$
- A simple modification would be to use what would be a theoretically perfectly symmetrical limb value as the reference (1/2 the total variable value)

$$\text{Percent difference} = \frac{\text{right value} - \text{left value}}{0.5 * \text{total value}} * 100$$

- A version of this method was first published in 1987 by Robinson, but others have used it since as a scalar asymmetry index (Bini & Hume (2014) and Marshall et al., (2015)), and absolute symmetry index (Karamanidis et al., 2003).
- Vector-based version described as limb symmetry index (Bell et al., (2014))
- But, asymmetrical athletes do not appear to become symmetrical by redistributing current levels of force production
 - The weaker side gets stronger, overall strength is increased, and symmetry is achieved (Bazyler et al., 2015).



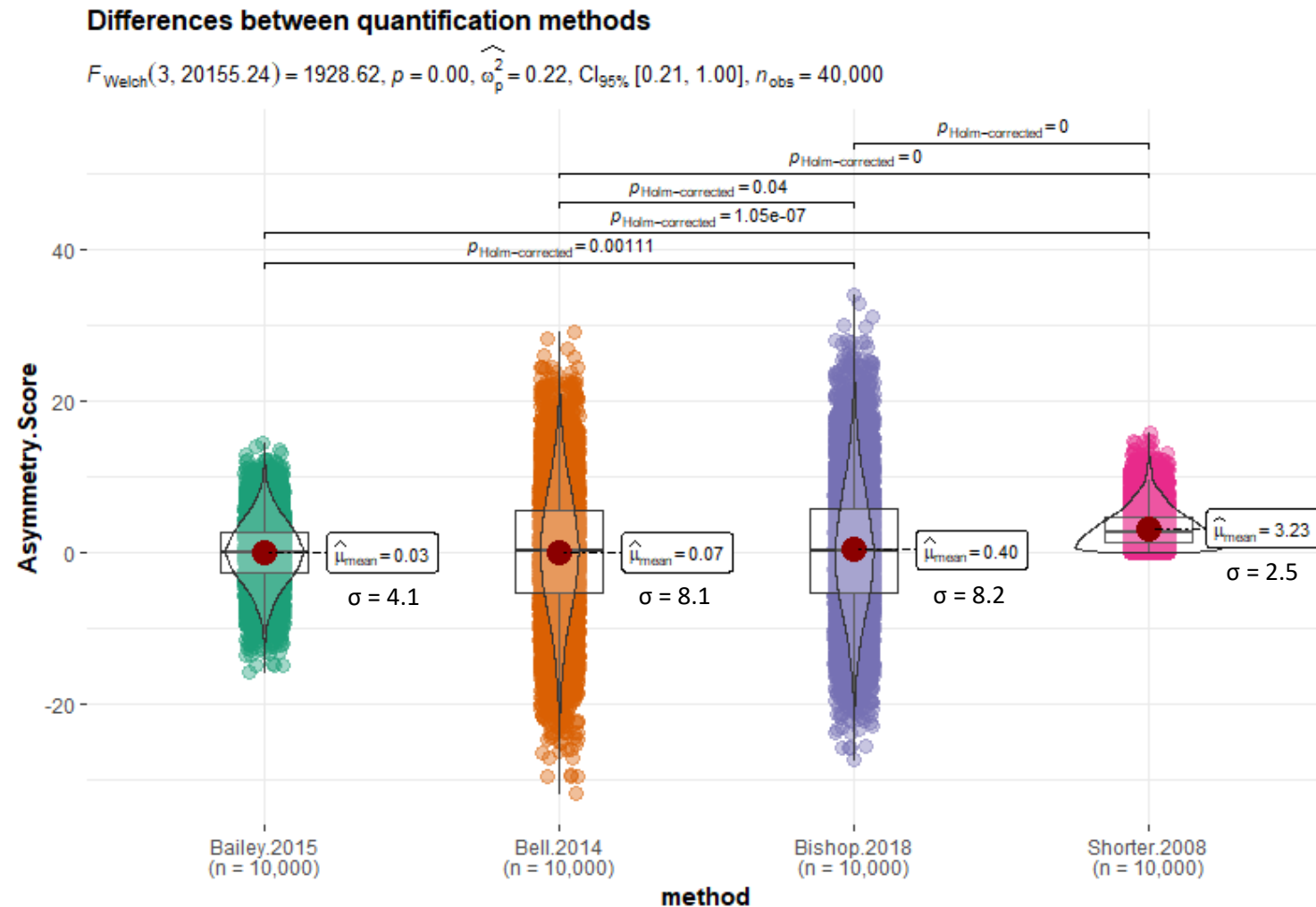
Plot created in R by author for this presentation
10,000 pairs of left and right force values (mean = 3500 N, sd = 200 N) used
to create asymmetry measures

Asymmetry

Quantification:

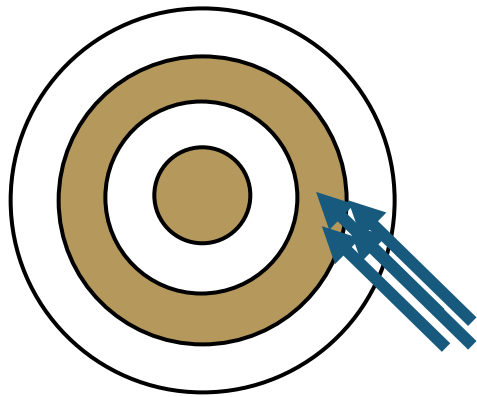
What's the difference?

- Several statistical differences ($p \leq 0.001$) (due to large sample size)
- No practically meaningful differences between Bailey (2015), Bell (2014), and Bishop (2018) (all Cohen's d effect sizes were less than 0.01)
- Some equations produce more variation (noise) than others
 - When we begin with the same values, any increase in variability is noise (Khaneman et al., 2021)

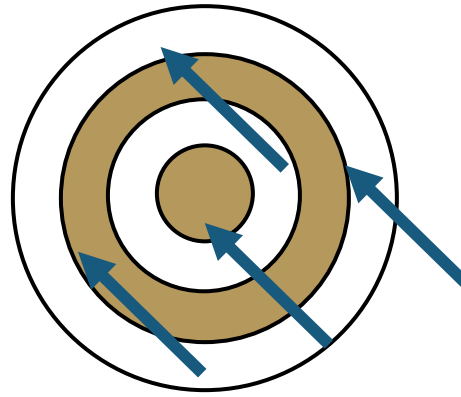


Asymmetry Quantification and Variability (noise)

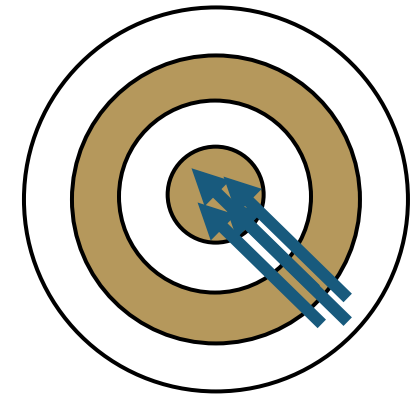
- Noise can be identified without knowing the criterion (Khaneman et al., 2021)



Reliable, but
biased



Unreliable, noisy



Valid

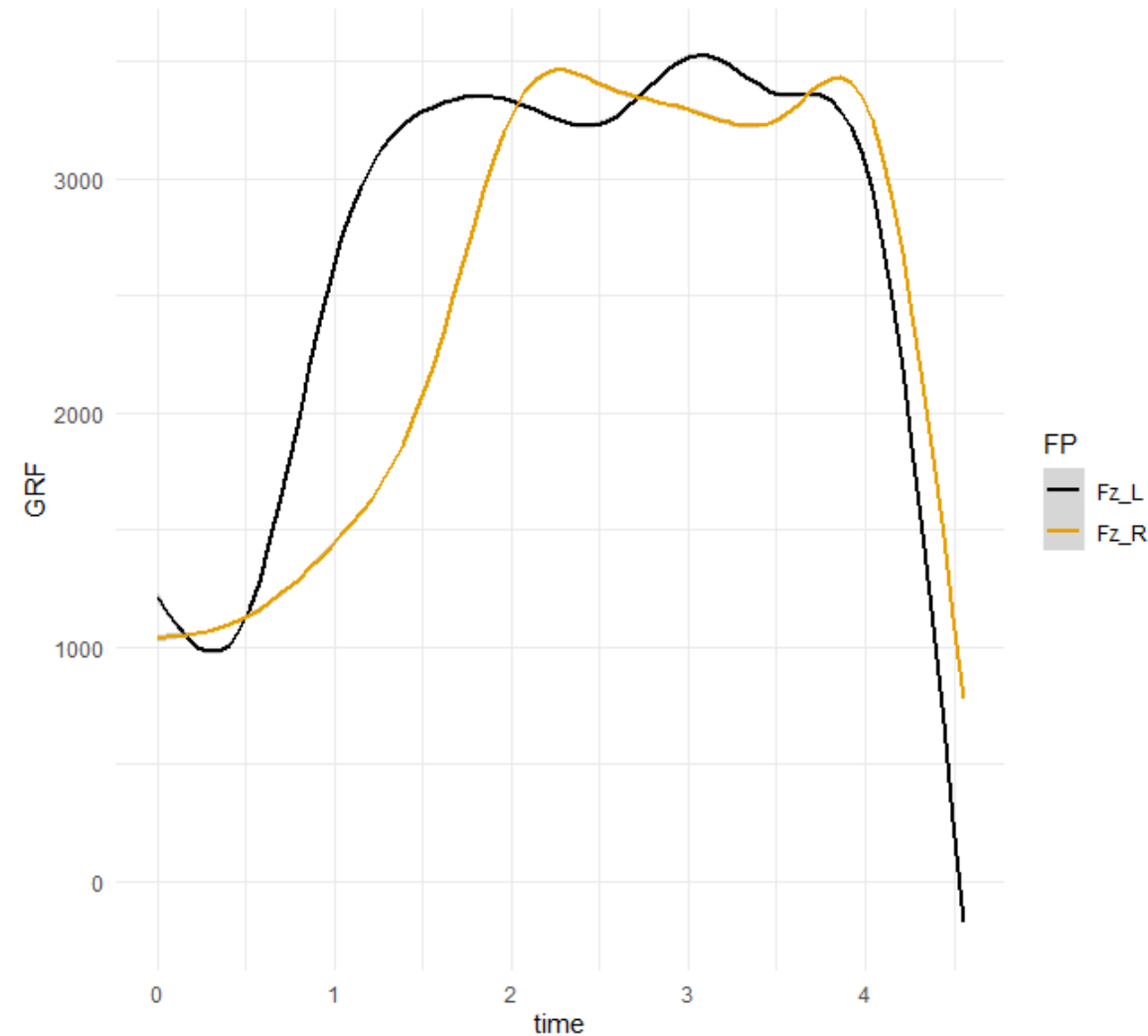
What variables should be measured?

What variables to measure?

- What variables should be used to quantify asymmetry?
- This will depend on what is important to your sport and what equipment/budget you are working with.
- JH asymmetries aren't necessarily what it seems to be
 - Unilateral JH asymmetry likely makes more sense than bilateral
 - JH asymmetry may be misleading when JH is calculated via takeoff velocity obtained via force plate measurement
 - Remember the impulse-momentum equation $f * t = m(v_f - v_i)$
 - Δv is caused by $\Delta \text{impulse}$, so this would actually be impulse asymmetry
- PF is easy and has been shown to be related to jump performance
 - But it has issues related to it being an instantaneous measure
- Instantaneous (uni-dimensional) measures versus multi-dimensional measures
 - Some of both should likely be included

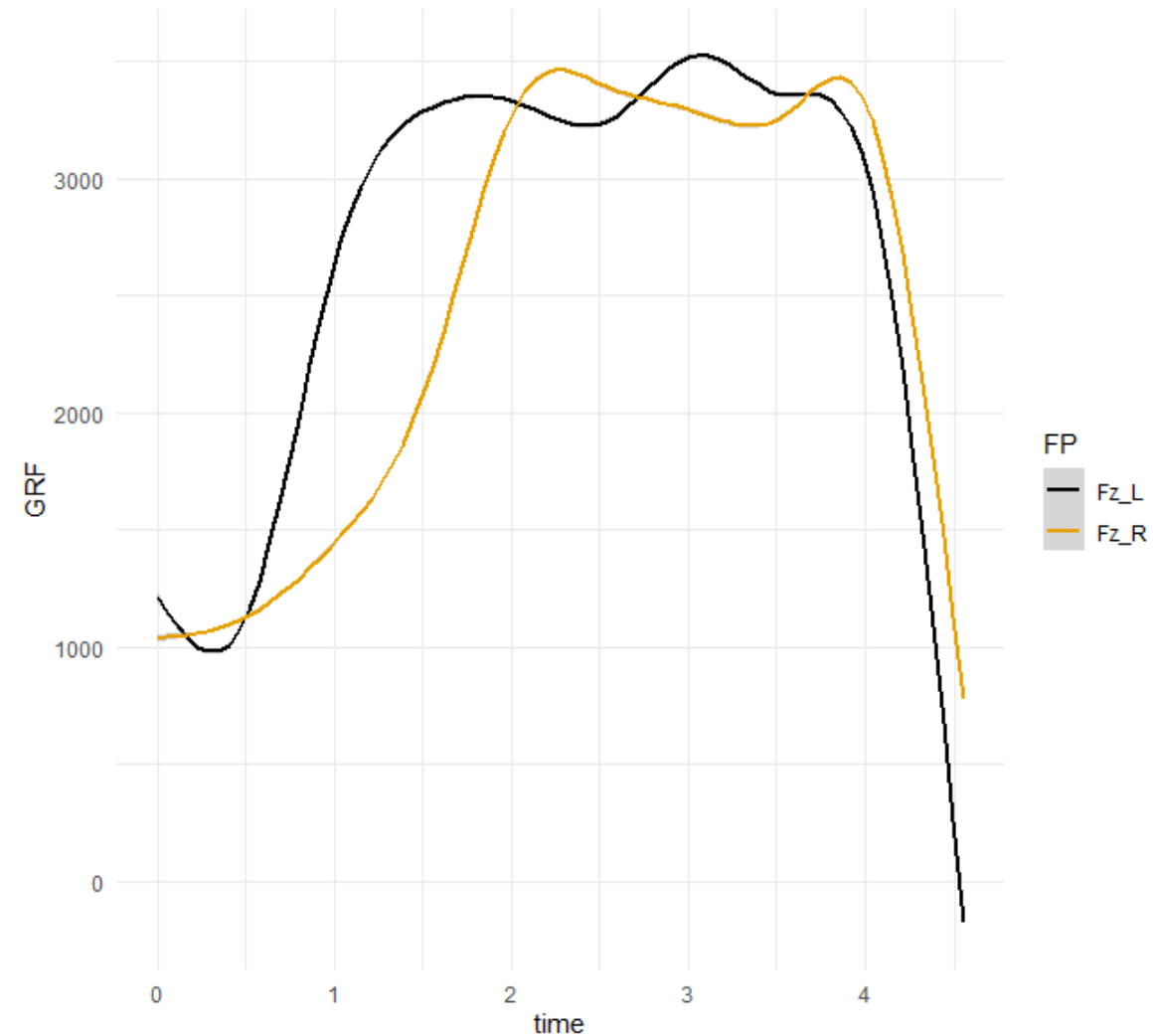
What variables to measure?

- Peak Force
 - Peak force neglects time (uni-dimensional)
 - Example PF asymmetry score from 0.008% to 0.02% depending on equation used
- Forces @ specific time points
 - They are instantaneous, but the times are matched
 - Forces at 50, 90, 200, 250 ms may be better predictors of performance since many of our sports won't allow for PF to be reached.
- Mean force
 - Easy to measure using force & time (multi-dimensional)
 - Example mean force asymmetry score between 4.07% and 8.14 % depending on eq. used
- Impulse
 - Force * time (multi-dimensional)
 - Example impulse asymmetry score between 4.07% and 8.14 % depending on eq. used



What variables to measure?

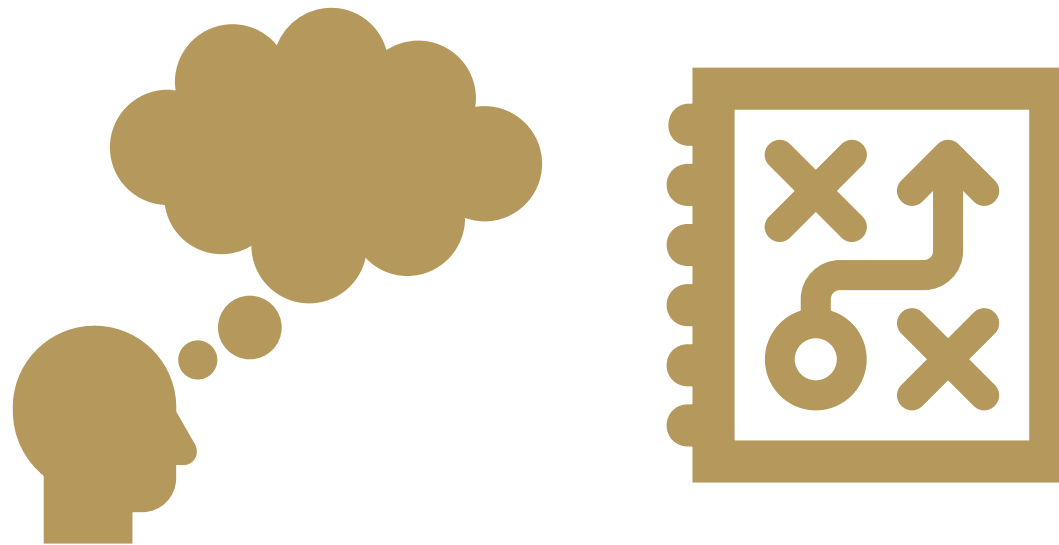
- Velocity
 - Displacement/time, doesn't work with isometric example
 - Can be instantaneous or average
 - Average velocity will be similar to impulse due to impulse-momentum relationship
- Power
 - Doesn't work with isometric example
 - Force * Velocity (multi-dimensional) and may be a better indicator of performance than either on their own for many sports (due to lack of time to develop PF and/or lack of room for displacement)
- RFD
 - The slope of the line (multi-dimensional)
 - May have issues with reliability
 - Example impulse asymmetry score 19.9% to 39.9%



What variables to measure

- Bishop et al., (PAP, JSCR (2022a)) “Seasonal variation of physical performance, bilateral deficit, and inter-limb asymmetry in elite academy soccer players: which metrics are sensitive to change?”
- Examined seasonal variability in asymmetry measures of 19 elite U-20 soccer players jump performance
- Asymmetry in JH, RSI_mod, Time to Takeoff, and CM depth decreased throughout the season
 - JH asymmetry – decreased throughout the season
 - but this may be a better indicator of change in impulse asymmetry based on how it was calculated
 - RSI_mod asymmetry – (JH/TTO) no statistical or practical differences
 - Authors recognize that this may be due to asymmetry and RSI_mod measures producing noise and recommend only using one proportional measure to limit introduced noise
 - TTO asymmetry – decreased throughout the season
 - CM depth asymmetry – (minimum COM displacement) decreased throughout the season
 - This may be indicative of loading on a specific leg and/or mediolateral pelvic tilt (needs further research)
- DJ RSI related to 10 sprint and 505 COD performance ($r > 0.5$) - Bishop et al., 2019

Issues and Solutions



Issue #1: Reliability

- Reliability in asymmetry research (if reported), is often done so inappropriately.
- The trend of poor reliability reporting is not specific to asymmetry research.
 - From 2008 – 2021, only 31.8% of JSCR studies report reliability findings (Smith, Hinojosa, Cripe et al., 2022)
- Many report reliability on the constituent measures instead of the asymmetry measure
 - This avoids a level of error/noise introduction due to asymmetry quantification and produces far more favorable results in terms of reliability (CV 10.4–15.7% vs. 63.2–1,497.1%) (Bailey, Sato, McInnis, 2021)

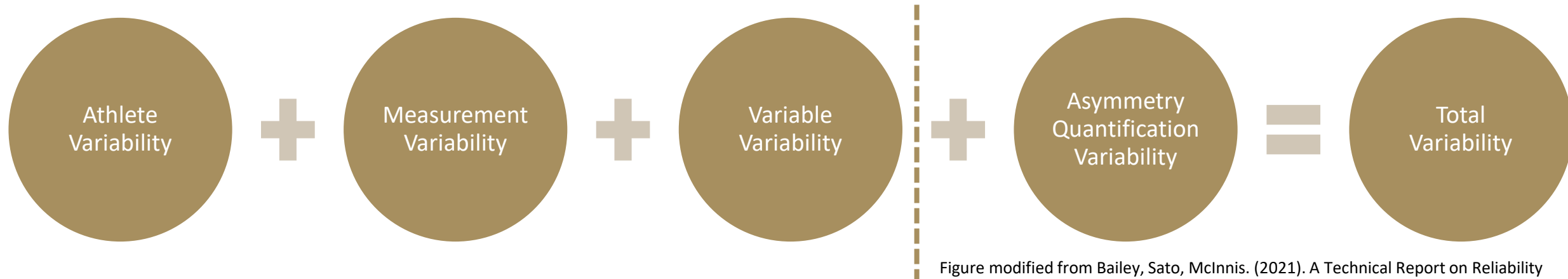


Figure modified from Bailey, Sato, McInnis. (2021). A Technical Report on Reliability Measurement in Asymmetry Studies. *J Strength Cond Res*, 35(7):1779-1783.

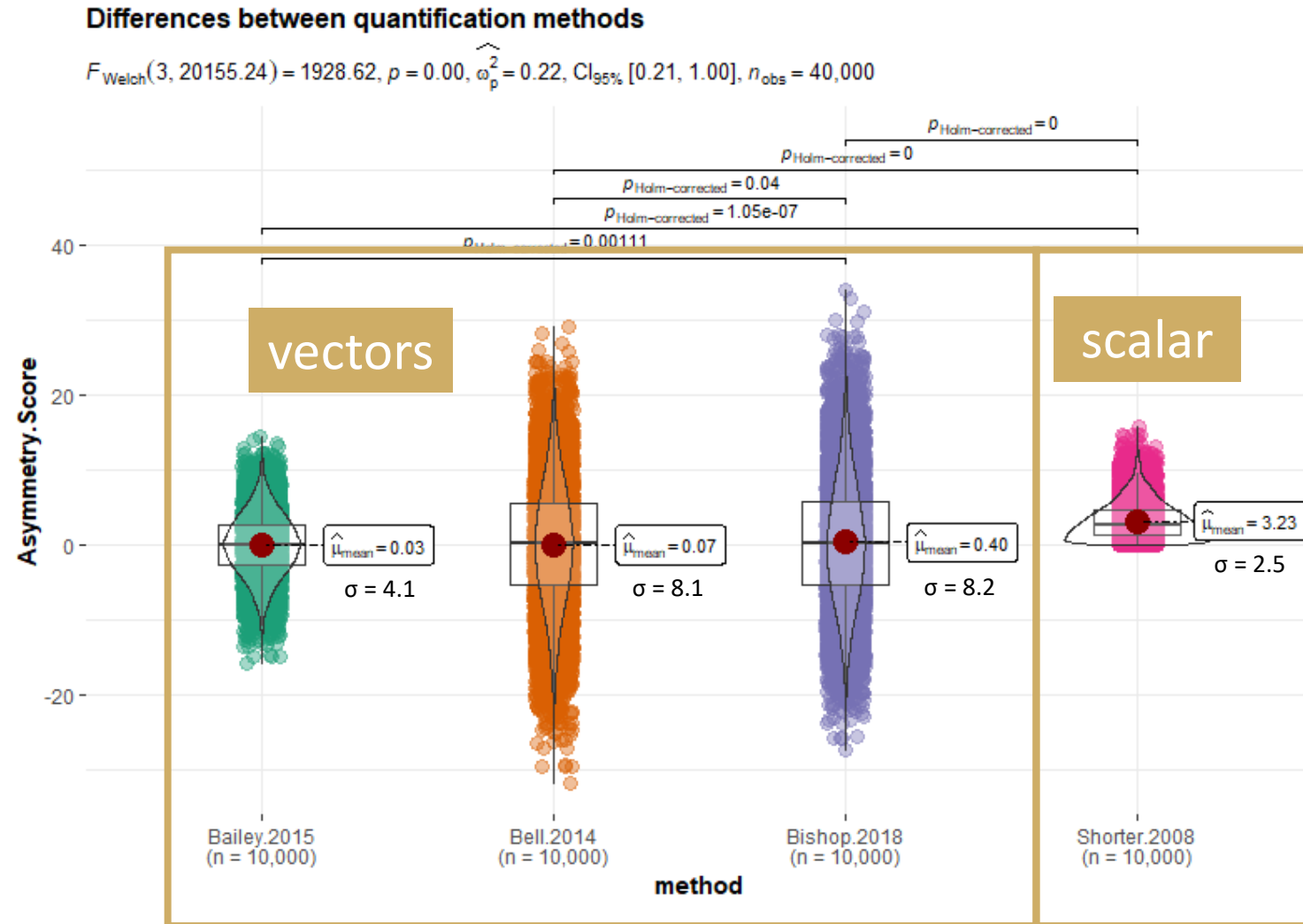
Issue #1: Reliability

- Many absolute reliability measurements have assumptions, and they likely are not evaluated.
 - Coefficient of variation (CV)
 - Assumes heteroscedasticity (Atkinson & Nevill, 1998, Bailey, Sato, McInnis, 2021, Bailey 2019)
 - I've never found asymmetry data to meet this assumption
 - Is contraindicated with vector data it is only meant to be used with ratio data (data with a true zero point) (Mitchell, 1986, Ospina, Marmolejo-Ramos, 2019, Bailey 2022)
 - Standard error of measurement (SEM)
 - Assumes homoscedasticity (Atkinson & Nevill, 1998, Bailey, Sato, McInnis, 2021, Bailey 2019)
 - Despite opposing assumptions, some report both CV and SEM “_(ツ)_/”
 - CV should never be reported with asymmetry measures

Temp	F	C	K
Value 1	98	36.7	309.8
Value 2	83	28.3	301.5
Value 3	67	19.4	292.6
mean	82.7	28.1	301.3
sd	15.5	8.6	8.6
CV	18.8	30.6	2.9

Issue #1: Reliability

- Quantifying reliability on scalar (magnitude only) instead of vector asymmetries (magnitude and direction) alters reliability findings as vector values can vary on both sides of zero (Bailey, Sato, McInnis, 2021).
- The decision to use asymmetry measures as scalar instead of vector may be due to the research question
 - But for the purposes of monitoring both the magnitude and direction are important, thus a vector should be used



Plot created in R by author for this presentation

Issue #1: Reliability

- Agreement instead of test-retest reliability
 - Bishop et al., (2022a) “Seasonal variation of physical performance, bilateral deficit, and inter-limb asymmetry in elite academy soccer players: which metrics are sensitive to change?”
- Kappa evaluates agreement (which is a special case of reliability and not what we commonly think of as test/retest reliability)
- Bishop et al., (2022) reported values at pre, mid, and post season
 - Tests would be too far apart to evaluate reliability
- Kappa evaluates agreement in dichotomous values (de Vet et al., 2006, Bailey, 2021)
 - Force asymmetry (and other vectors) are not dichotomous
 - Evaluating agreement with Kappa will tell us if they maintain direction, but it ignores magnitude
 - For example, asymmetry values of 0.02% and 47.56% agree, but 0.01% and -0.01% do not agree
- Bishop and colleagues reported poor to fair agreement
 - Also reported some negative kappa values which indicates that more of the agreement is coming due to chance occurrence

Issue #1 >> Solutions

Standardize your methods very strictly

- Pick the quantification method that works best for you, while limiting noise introduced

Evaluate your own reliability

- Appropriately

There are many free statistical options to do this (e.g. R, JASP, Python)

Evaluate relative and absolute reliability

- Appropriately

Evaluate intra and inter session reliability

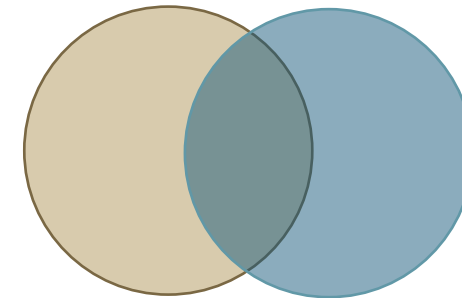
Reliability is a part of validity, so...

If your data aren't reliable, they aren't valid either

Issue #2: Conjunction Fallacy

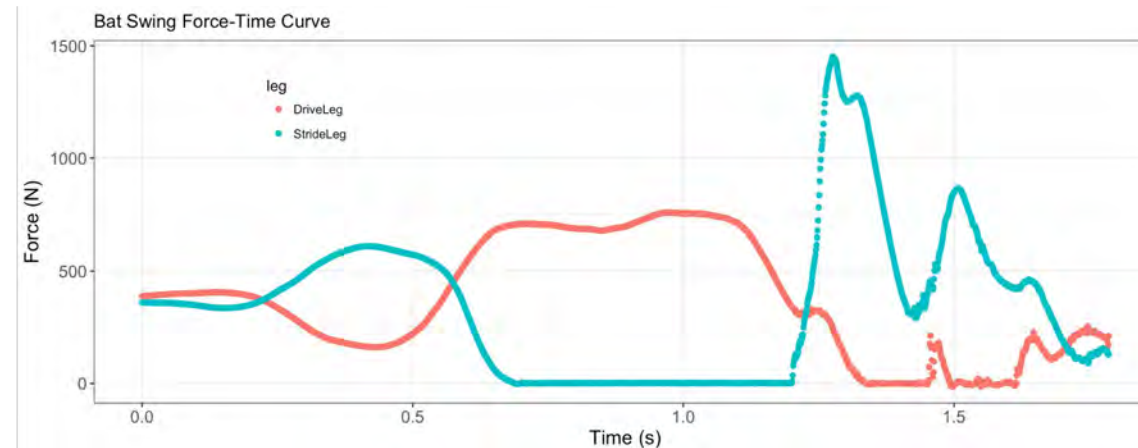
- Sara eats fast food for at least one meal everyday of the week and never exercises. Which of the following is more likely?
 - A. Sara is a computer scientist
 - B. Sara is a computer scientist and is overweight
- The conjunction fallacy occurs when we falsely believe a combination of events is more likely than a single one of the events happening alone
 - Originally explained by Amos Tversky and Daniel Kahneman (1983)
- Adding an additional quality/requirement doesn't increase the odds for occurrence, it shrinks it.
- We may make the same mistake with asymmetries

$$\Pr(A) \geq \Pr(A \wedge B)$$



Issue #2: Asymmetry may be task dependent

- Force production asymmetries during the CMJ are not necessarily related to force production asymmetries during bat swings in collegiate baseball players (Bailey et al., 2018, n = 13).
 - Peak Force SI $r = -0.240$
 - Impulse SI $r = -0.002$
 - Rate of force development $r = -0.518$ ($p < 0.01$)



Plot created in R by author for Bailey et al., 2018 NSCA Poster Presentation

Issue #2: Asymmetry carry-over between tasks is likely influenced by strength

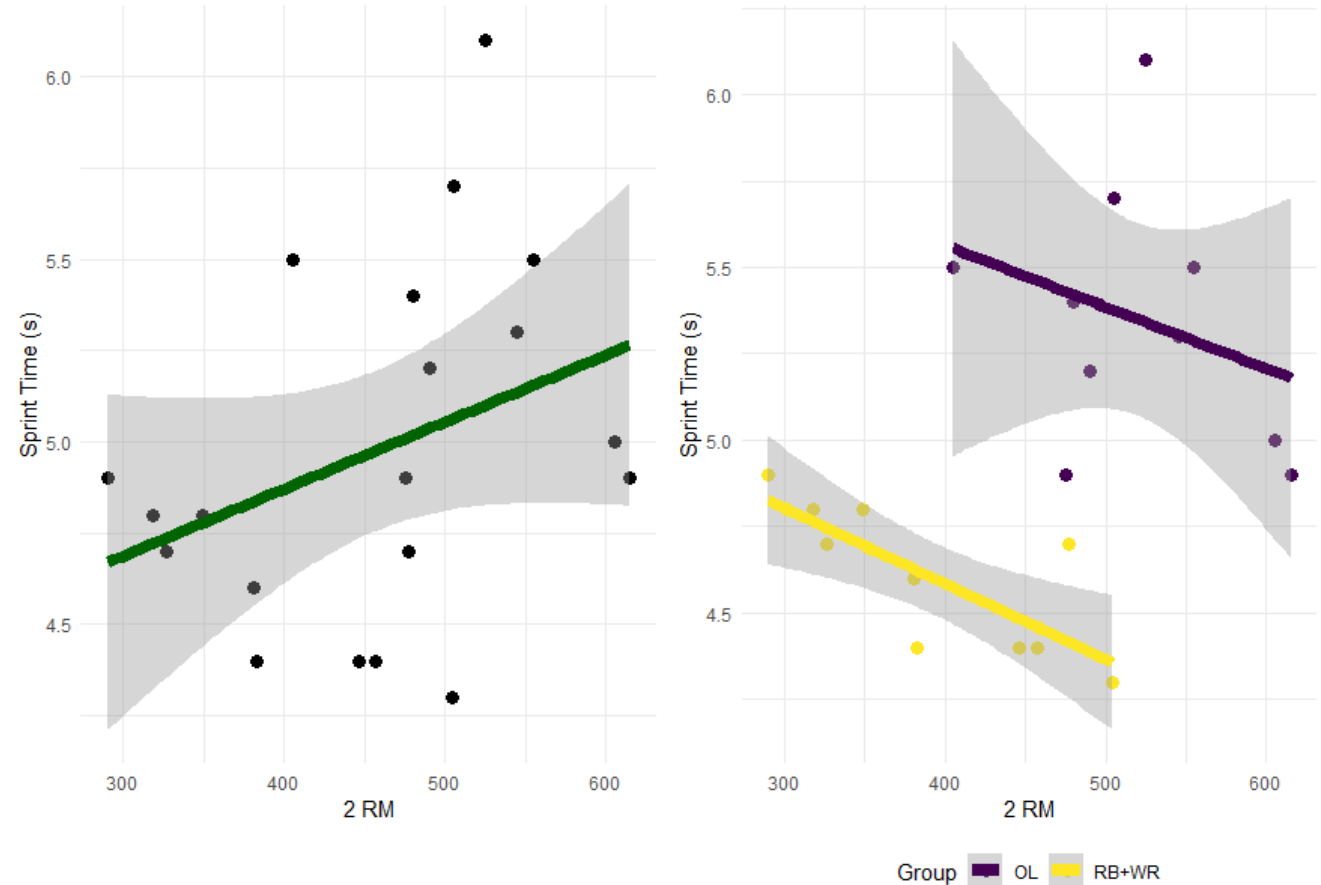
- Stronger athletes are less asymmetrical than weaker athletes during standing (weight distribution) and jumping performance (PF, PP, NI) ($p < 0.01$, $d > 0.8$)
 - Bailey et al., 2015(a)
- Asymmetry may decrease while strength increases, and this is more evident in weaker individuals
 - Bazyler et al., 2014
- No asymmetry measures carried-over between different tasks (SJ, CMJ, & IMTP (PF, TtoPF, NI, RFD*))
 - *Asymmetry measures of explosive strength (RFD) may carry-over between IMTP and jumping, but only in stronger athletes
 - Bailey, et al., 2015(b)

Issue #2: Strength asymmetry is only partially explained by lean mass asymmetry

- Strength & power asymmetry is only partially explained by lean mass asymmetry
 - Thigh and shank lean mass asymmetry accounted for 20% of the variance in force asymmetry during CMJ - Bell et al., 2014
 - Pelvis, thigh, and shank lean mass asymmetry accounted for 25% of power asymmetry during CMJ - Bell et al., 2014
- Lean mass asymmetry weakly associated with jumping performance (JH, PP, Imp)
 - <10% of variance in jumping performance could be explained by lean mass asymmetry in NCAA Div. I Basketball players. - Bailey, Eusufzai, Wright, 2021
- This likely indicates that there are some neural factors playing a role as well

Issue #3: Simpson's Paradox

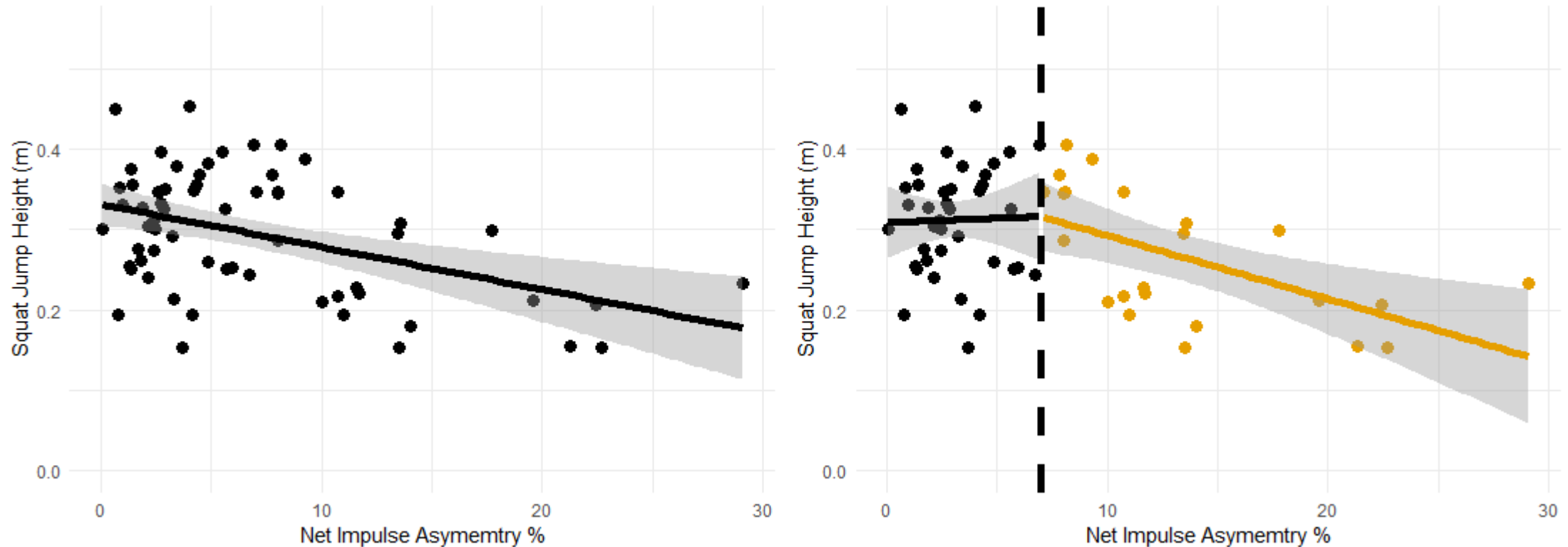
- Simpson's Paradox occurs when a negligible relationship differs dramatically when controlling for one or more other variables.
- The example on the right demonstrates this with the sprint time and a 2 RM squat before and after controlling for position



Plot created in R by author for this presentation

Issue #3: Simpson's Paradox

- Could this be present in asymmetry data? What variable should be controlled for?



Plot created in R by author for this presentation with data from:
Bailey, Sato, Sands, Burnett, Stone, 2014

Issue #2 & Issue #3 >> Solutions

Don't let your previous knowledge lead you down the wrong path

- Update your priors when you get new results

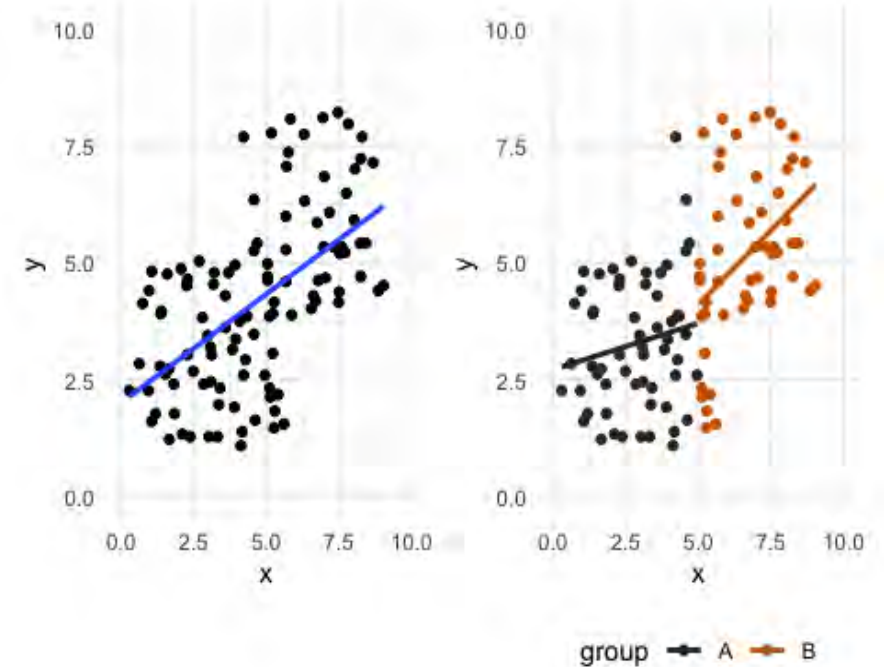
Evaluate asymmetry in the tasks that matter to your sport

- Your assessment may differ from what is seen in research

Consider other variables that might be influencing your results and investigate them

Create scatter plots for every correlation you produce and visually inspect them for grouping

- r values are heavily impacted when we consider multiple independent groups as a single group



Bailey (2021) (CC BY-SA 3.0)

Issue #4: Selection Bias

- Asymmetry test needs to be population specific
- Research sample needs to be the same as your population in order to generalize the results to it
 - Sport, sex, fitness level, training age, etc.
- Application of results should also be population specific
 - e.g, isometric PF (IMTP) asymmetry impairs jumping performance (JH & PP) in a sample of *collegiate baseball players* (mean asymmetry score was 6.6%)
 - Bailey, Sato, Alexander, Chiang, Stone. (2013). Isometric force production symmetry and jumping performance in college athletes. J Trainol, 2(1): 1-5.
 - More than many sports, baseball produces situations where athletes repetitively produce forces in asymmetrical patterns (i.e. throwing and hitting right-handed) and likely produce more asymmetrical athletes as a byproduct.
 - If your sport doesn't have as many asymmetries, correlation results will be different
- Results cannot be blindly applied to every population
 - even though this is often how results are discussed in all research areas

Issue #4 >> Solutions

ALWAYS check the subject information in articles

If the sample characteristics differ from your population, you can't assume the results will apply

You can always repeat the same studies yourself for your population

- YouTube is a great resource if you don't understand the statistical methods used with the statistical software of your choice

Possible for ≈\$800 (USD)



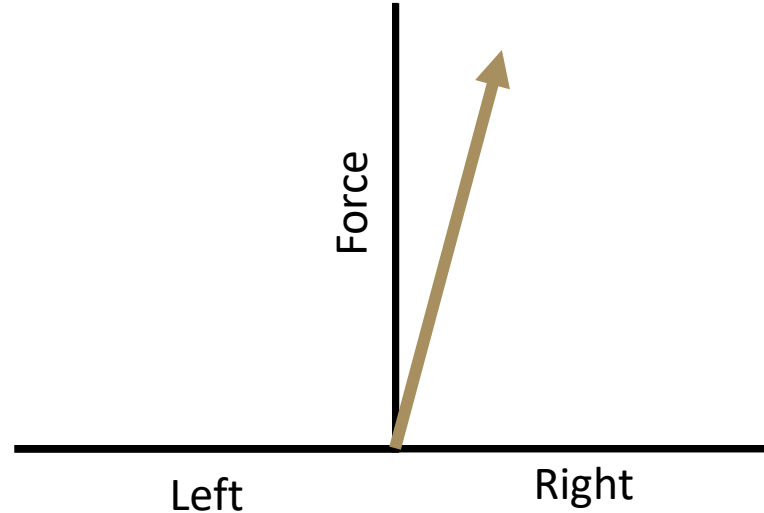
Image taken by author

You don't necessarily need 2 force plates

- A single large force plate that produce vertical and m/l force-time data will work
- Simply produce the resultant vector to give you the magnitude and direction

$$A^2 + B^2 = C^2$$

+ Basic trigonometry



Conclusion

Force production asymmetry may be a detriment to performance in some tasks, but...

- This seems to be task specific
- The associations between asymmetry and performance may not be consistently observed

Force asymmetries generally decrease as athletes get stronger

- Evaluating asymmetries along with other markers of development should be a target for future research

While the connection between asymmetry and injury is of interest to many, it isn't well supported by science

The chosen method for asymmetry quantification will introduce noise, thus it would be wise to choose a method that limits noise introduction

- Some methods introduce more noise than others

Conclusion

Measurement reliability may be the largest concern in asymmetry research and interpretation.

- Reliability is a part of validity and results can't be valid if they aren't reliable
- Special effort should be given to evaluate your own reliability in a way that is statistically appropriate
- Standardize methodology very strictly and limit opportunities for variability to be introduced (athlete, measurement, variable quantification, etc.)

Don't make assumptions based on single asymmetry value

- Include instantaneous and multi-dimensional variables

Utilize asymmetry tests that are specific to the athlete

If you have the means to evaluate force asymmetry, you can also replicate many of the published asymmetry studies

- Don't assume that published results will apply to your population

References

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Questions??

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