Quantifying Bivariate Plots in Sports Biomechanics

PROF DAVID MULLINEAUX

The British Association of Sport and Exercise Sciences

HUMAN KINETICS

About Today's Webinar

Today's webinar is being produced jointly by the British Association of Sport and Exercise Sciences (BASES) and Human Kinetics.

It is scheduled to last for about an hour and will be recorded and made available for download and playback. You will receive an email containing a link to the recording when it is available.

All microphones and phone lines are muted so we ask that you submit questions by using the question box located in the lower right corner of your screen

We'll collect any questions sent throughout the presentation for David and he will answer as many as possible during the Q&A segment at the end.

Join the conversation through Twitter

@HumanKineticsEU

@BASESUK

About Today's Presenter

Professor David Mullineaux is a Professor in Sports Science at the University of Lincoln.

He has made several transitions between academia and industry in the UK and USA. His research interests are in using realtime biofeedback to alter technique, and on applying analytical techniques in biomechanics.

He has experience of applying this expertise to research in Sport and Exercise Science, Sports Medicine, Orthopaedics, Biomedical Engineering, Athletic Training and Physical Therapy.

David has co-authored the 'Sample Size and Variability Effects on Statistical Power' chapter in the 2017 BASES book 'Biomechanical Evaluation of Movement in Sport and Exercise'.

BASES
The British Association of Sport and Exercise Sciences

HUMAN KINETICS

Presentation Aim

- PROVIDE AN INSIGHT INTO SOME BIVARIATE ANALYSES
  - Brief background
  - Need / types of data preparation
  - Quantification of bivariate
  - Future directions

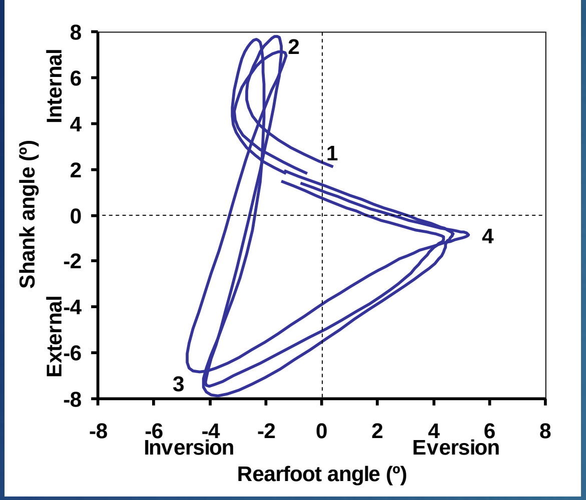
Background

- WHY BIVARIATE?
  - Theoretical
    - General: based on ‘relationship’, ‘coordination’ or ‘coupling’ between 2 variables
    - Specific: many from biomechanics and motor control
  - More comprehensive information when data are
    - Bivariate (v univariate)
    - Time-series (v discrete values, e.g. maximum)

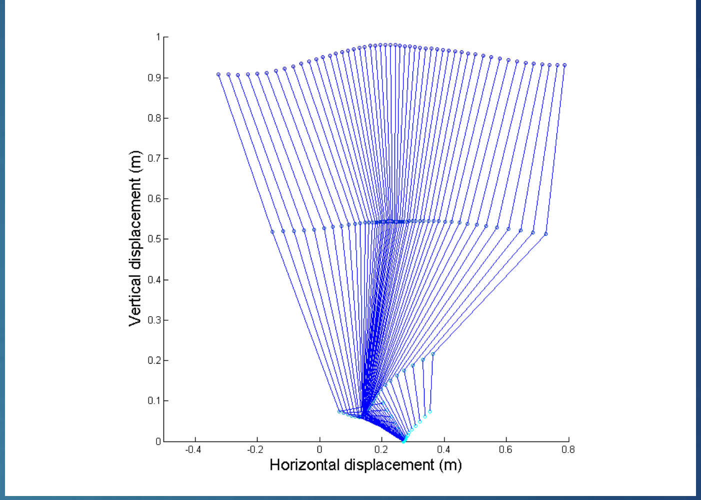
- LIMITATION
  - Greater analysis complexity
    - Fewer methods
    - Published methods harder to validate

Bivariate example 1

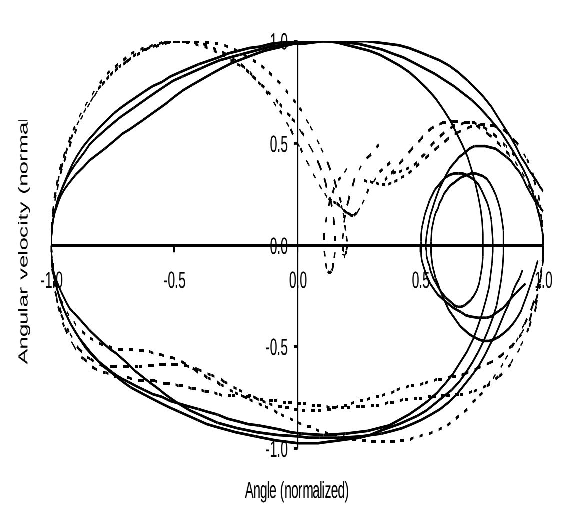
- Angle-angle



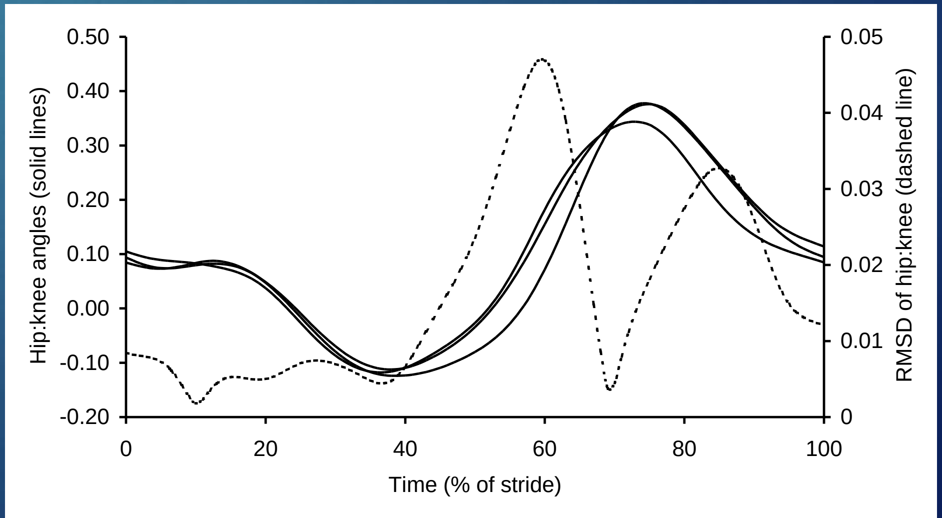
- Variable-variable



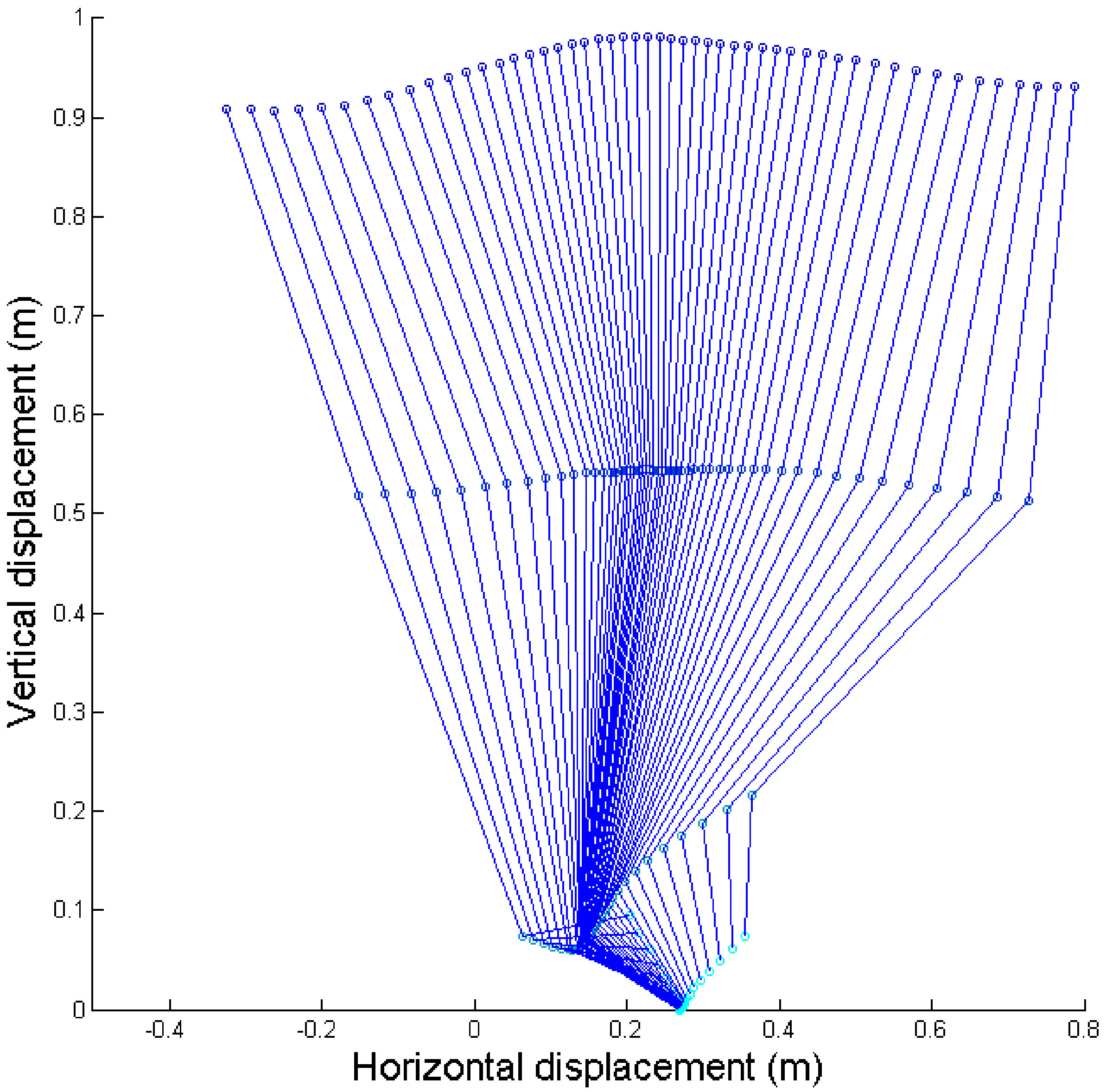
- Phase-plane portrait

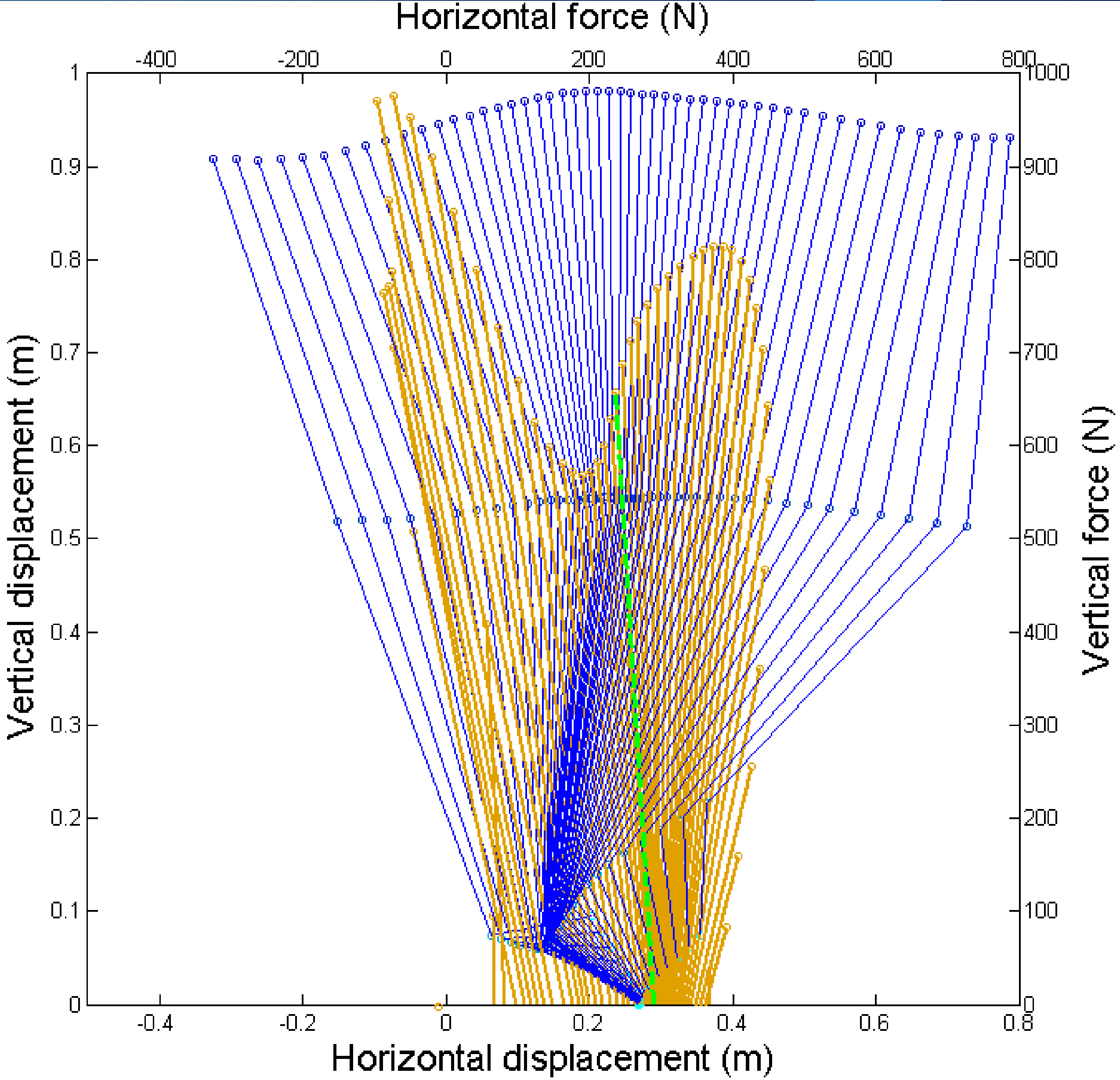


- Ratio-variable v time

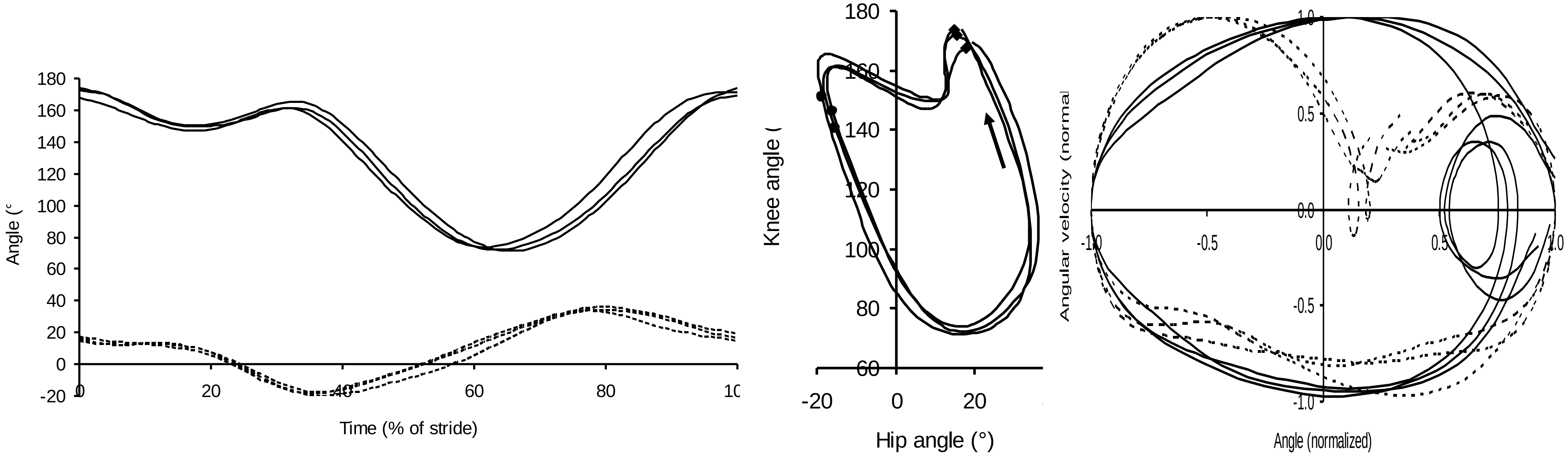


Bivariate example 2





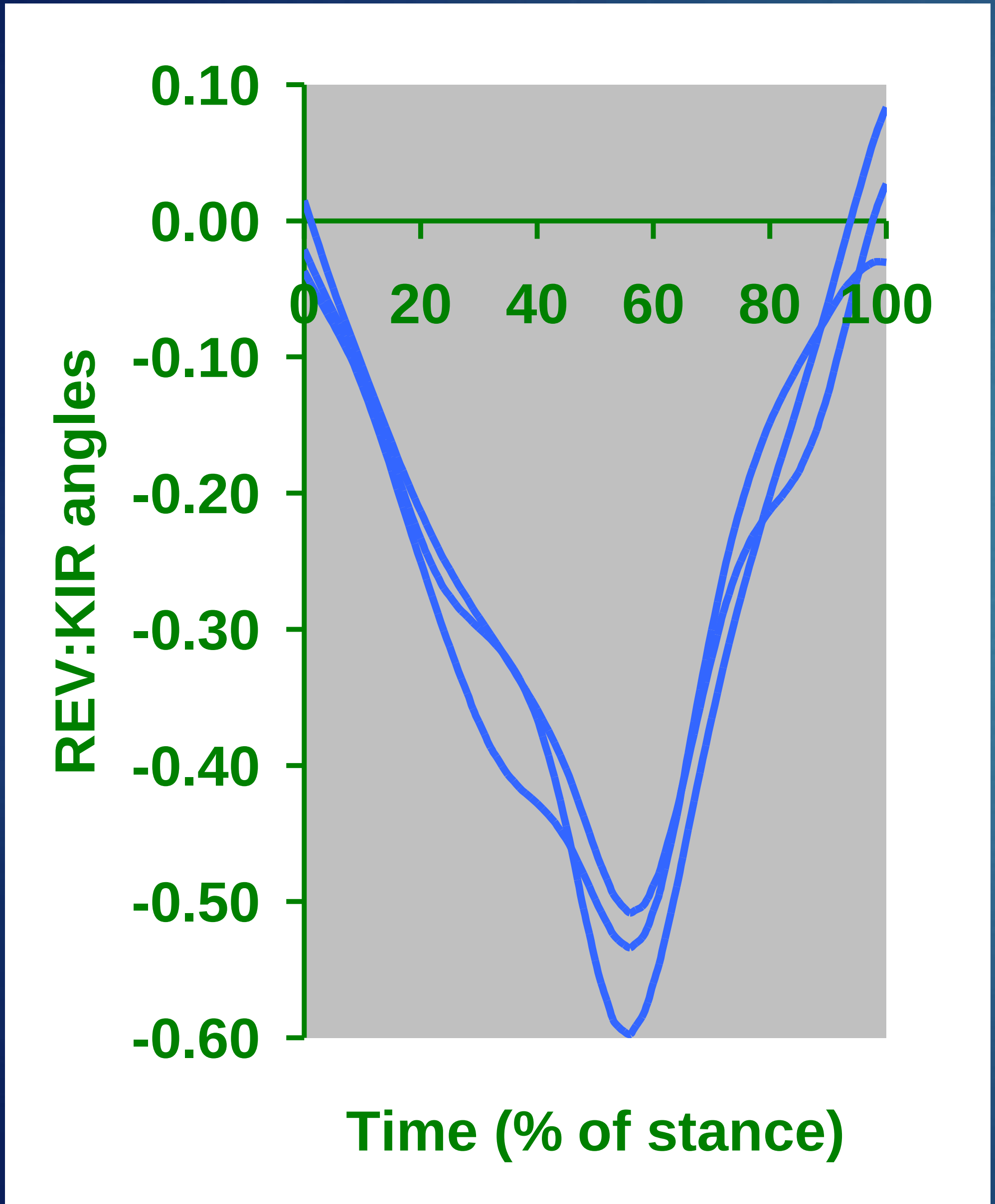
Bivariate example 3 – same data



Data preparation

- FOCUSING ON NORMALIZATION (E.G. TEMPORAL, MAGNITUDE, SPATIAL)
  - Often necessary to account for different trials
- PRINCIPAL BENEFITS
  - Reduces variability
    - Intra-subject (e.g. cater for inter-week marker placements)
    - Inter-subject (e.g. scale for different leg lengths)
- PRINCIPAL DISADVANTAGES
  - Alters data
  - May remove ‘real’ and important variability

Temporal normalisation - simple



Basis

- Make trials same length (e.g. 101 points)

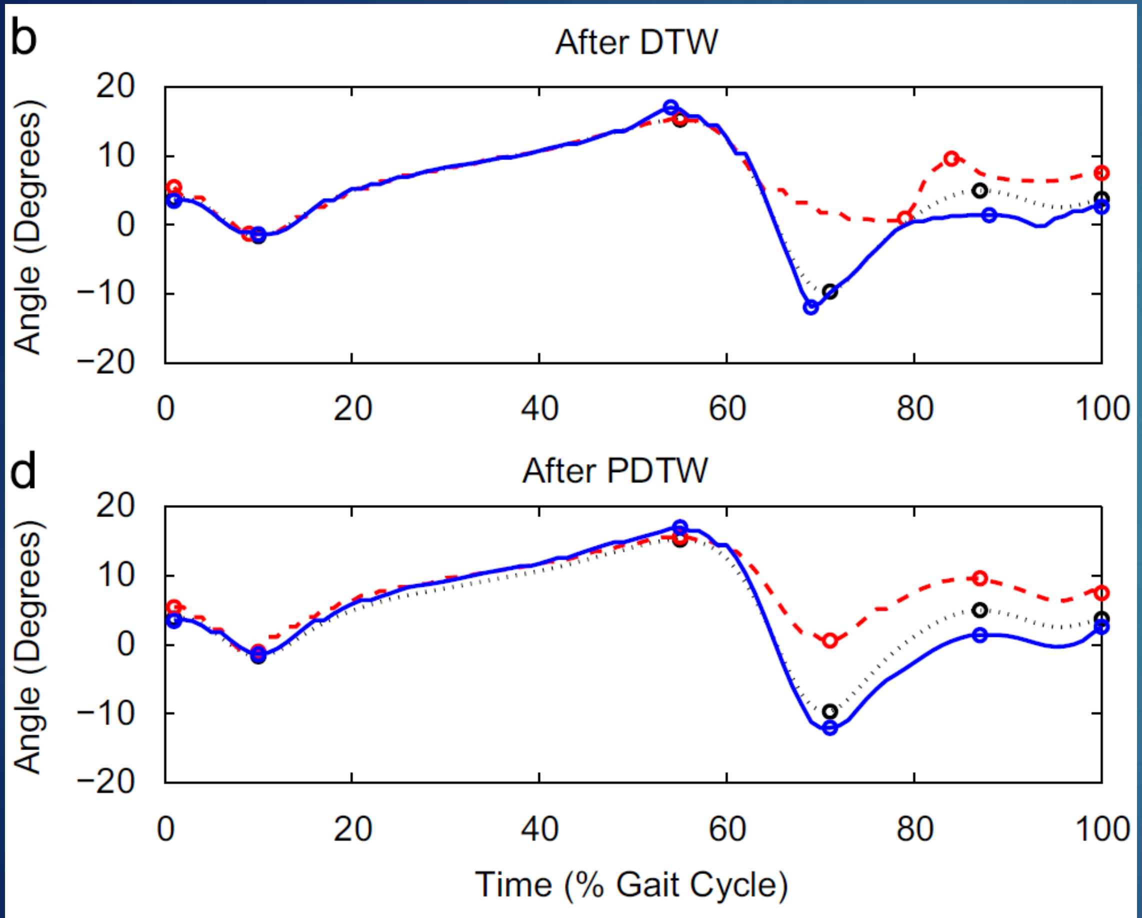
Benefits

- Often required to facilitate comparisons between trials
- Present time as percentage of movement (e.g. 0 to 100%)

Cautions

- Adds more smoothing
- Changes sampling rate
  - Often 101 points used
  - Instead choose points close to trial length (e.g. trials range 146-152 points, resample to 150)

Temporal normalisation - complex



Basis

- Align key features of curve
- Several methods (e.g. Dynamic time warping, DTW; Piecewise DTW, PDTW)

Benefits

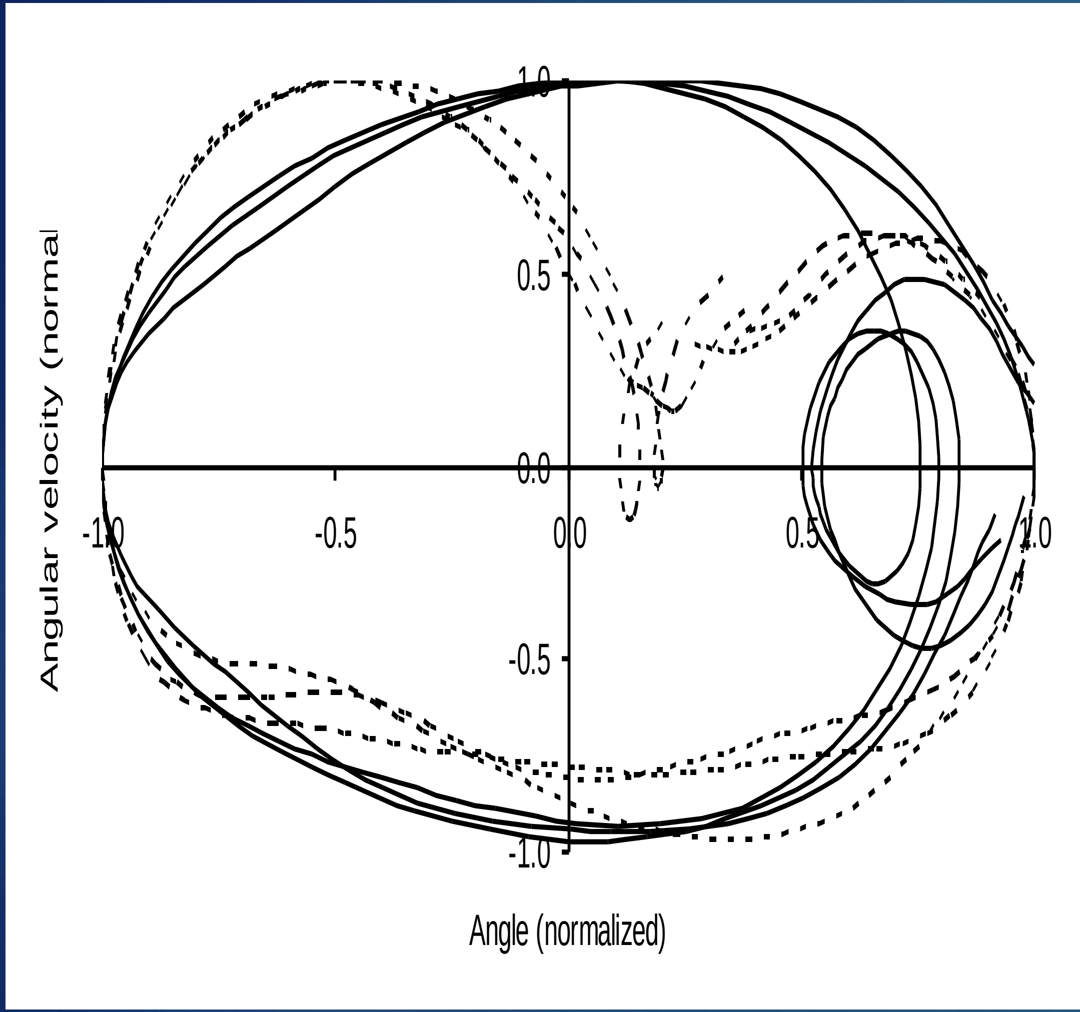
- Facilitates comparisons between trials

Cautions

- Alters shapes
- Smooths data
- Alters descriptive statistics

Helwig et al. (2011). Methods to temporally align gait cycle data. Journal of Biomechanics, 44, 561-6.

Magnitude normalisation



Basis

- Re-scale trials to same range
- e.g. min 0 to max 1, or -1 to +1)

Benefits

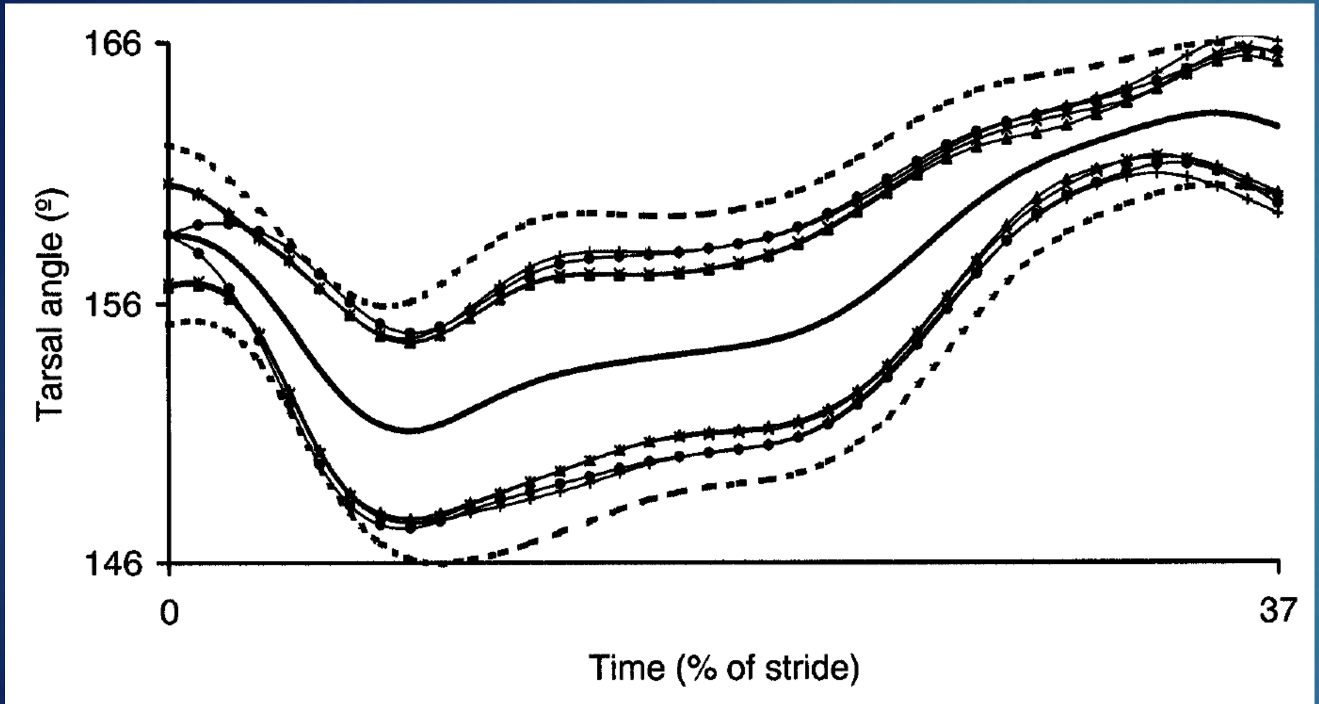
- Facilitate comparisons between different ranges of motion

Cautions

- Can require spatial normalization (e.g. data centred with mean of 0,0)
- Removes magnitude information

Mullineaux, D.R. and Wheat, J. (2018). Research methods: sample size and variability effects on statistical power. In Biomechanical Evaluation of Movement in Sport and Exercise: The British Association of Sport and Exercise Sciences Guide, 2nd Edition (edited by C.J. Payton and A. Burden). London: Routledge.

Spatial normalisation



Mullineaux et al. (2004). Effects of Offset-Normalizing Techniques on Variability in Motion Analysis Data. Journal of Applied Biomechanics, 20, 177-84.

Basis

- Aligns key features of curve
- Several methods (e.g. mean)

Benefits

- Facilitates comparisons between trials
- Mean changes negligibly
- Variability significantly reduces

Cautions

- Alters shapes
- Smooths data
- Alter descriptive statistics

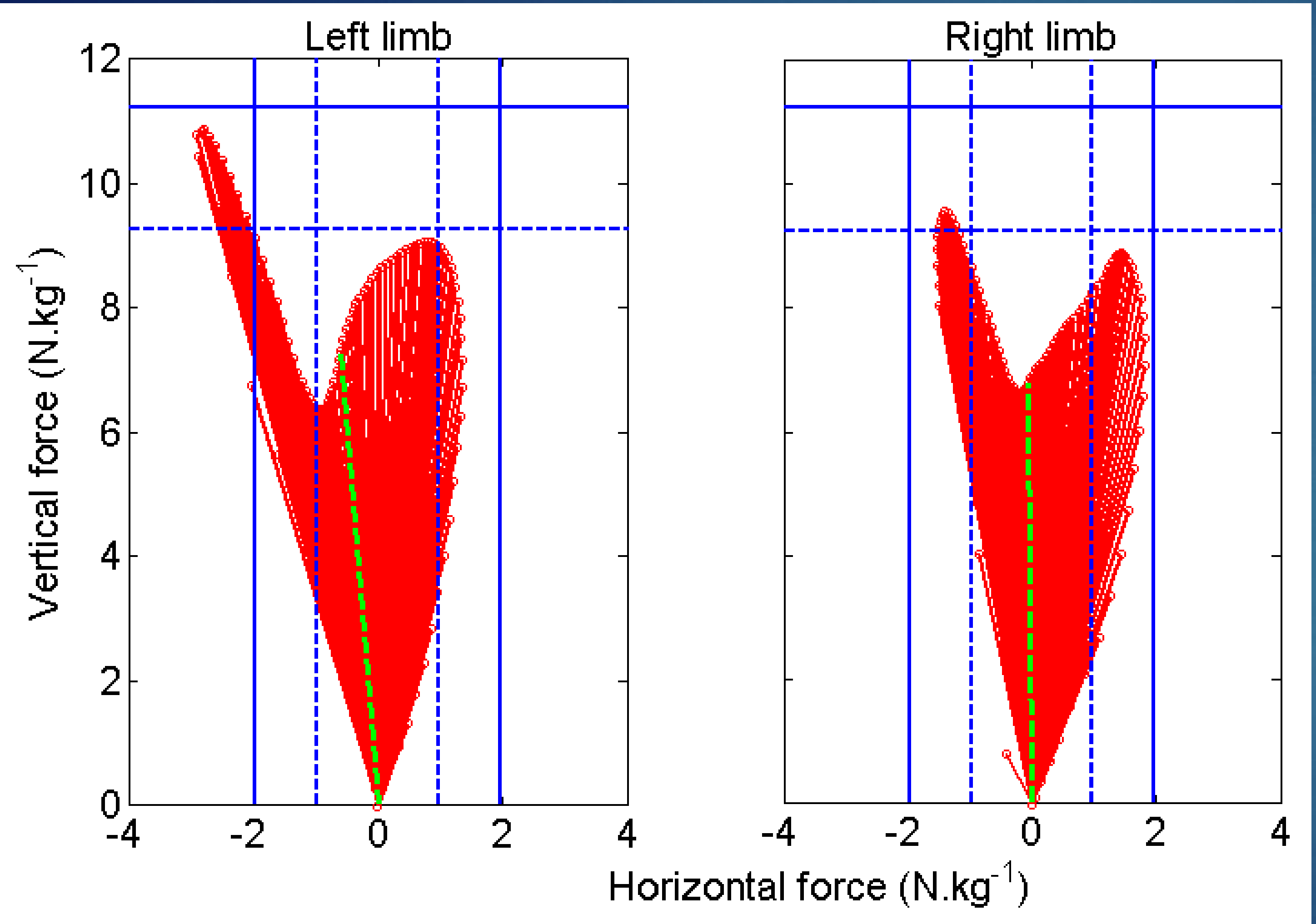
Statistical assumptions – normality

Stage	Settings			Cycles (count)		SD (°)		Normal (count)	
	$\alpha1$	$\alpha2$	b	Mean		Mean		Mean	
Raw				38.2		11.9		22.6	
				Reduction	Sig	Reduction	Sig	Reduction	Sig
Stage 1	0.01			12.3	Y	10.3	N	16.0	Y
	0.001			6.0	Y	10.0	N	13.0	Y
	0.0001			3.5	Y	9.7	N	10.6	Y

- Cycles reduces (e.g. a1=.0001 then 3.5 cycles removed)
- SD decreases by 9.7 to 2.2, but non-significant!
  - SD weak measure in presence of outliers
  - Use other measures, e.g. Median Absolute Deviation
- Non-normal points reduces (e.g. a1=.0001 reduces by 10.6)

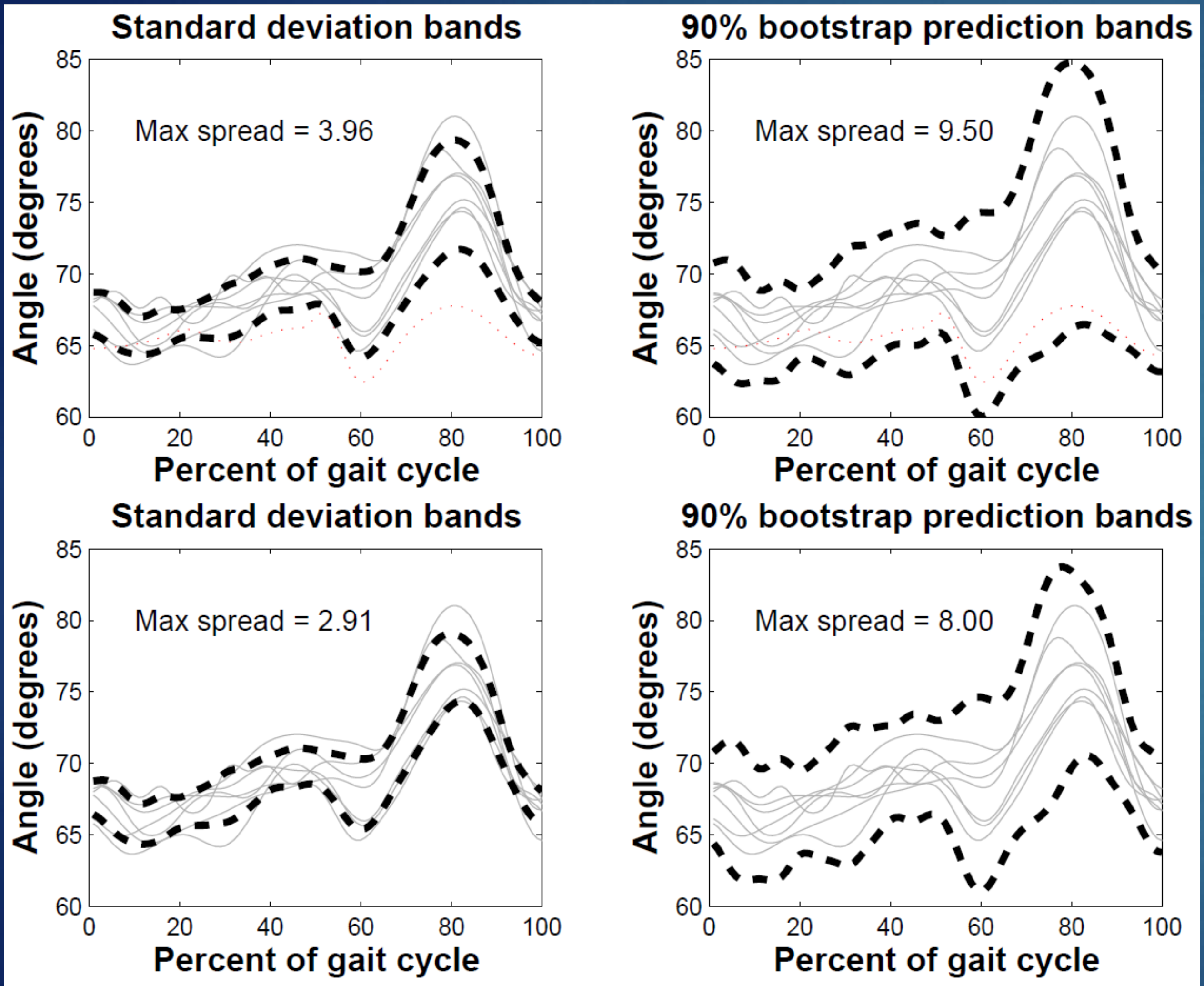
Mullineaux and Irwin (2017). Error and anomaly detection for intra-participant time-series data. International Biomechanics, 4, 28-35.

Quantification – normative



- Use:
  - Assess if peak ‘braking’ and ‘propulsive’ fall within healthy regions
- Pros:
  - Simple (good for clinical evaluation)
  - Visual (easy to make comparisons, e.g. L v R)
- Cons:
  - Need a data base (to generate ‘regions’)
  - Binary (e.g. healthy v injured) – low sensitivity

Quantification – Confidence Intervals



Apply to ratio bivariate data

Various approaches

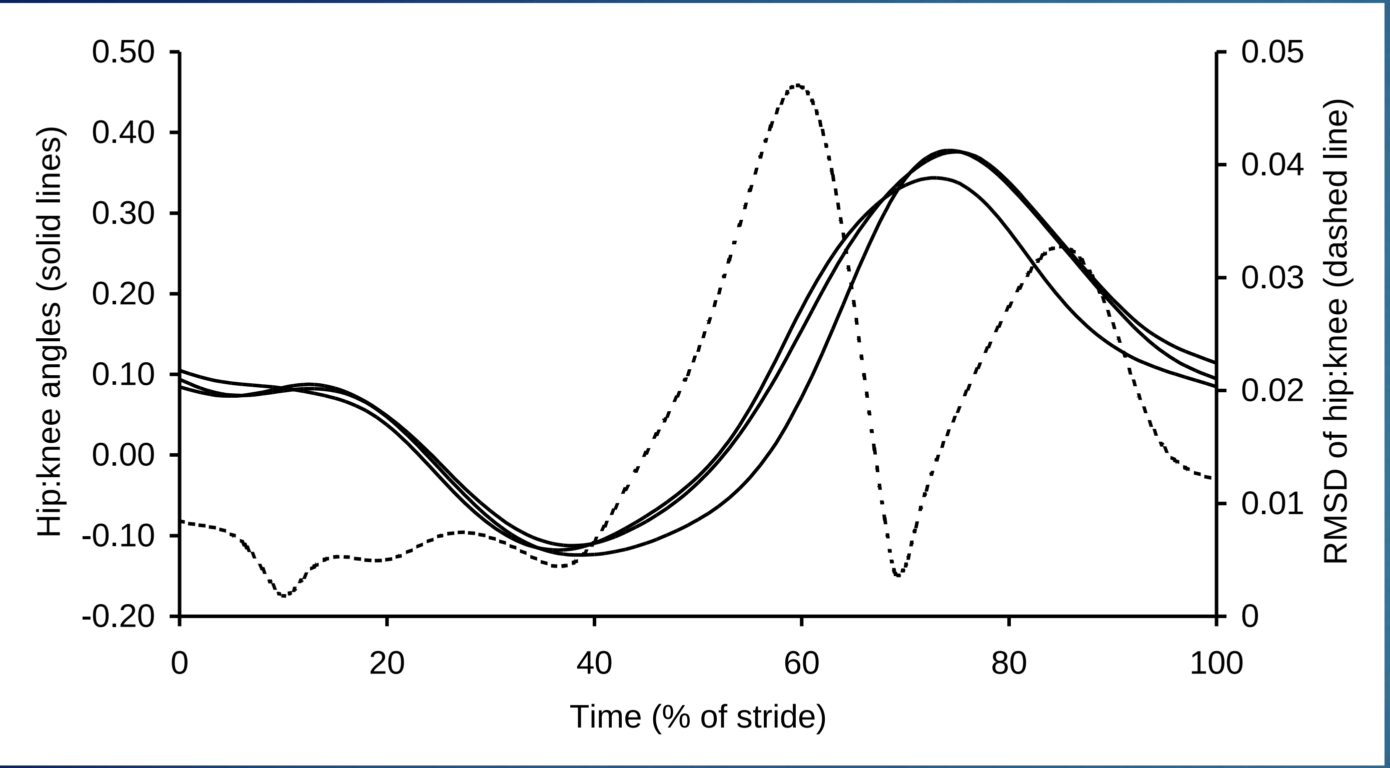
- Descriptive (e.g. SD, 95%CI)
- Descriptive bootstrapped

Example here

- Compares SD v 90%bootstrapped
- Shows effects of outliers

Chau et al. (2005). Managing variability in the summary and comparison of gait data. Journal of NeuroEngineering and Rehabilitation 2005, 2:22

Quantification – RMSD



Basis

- Ratio of two variables
- RMSD at each time point

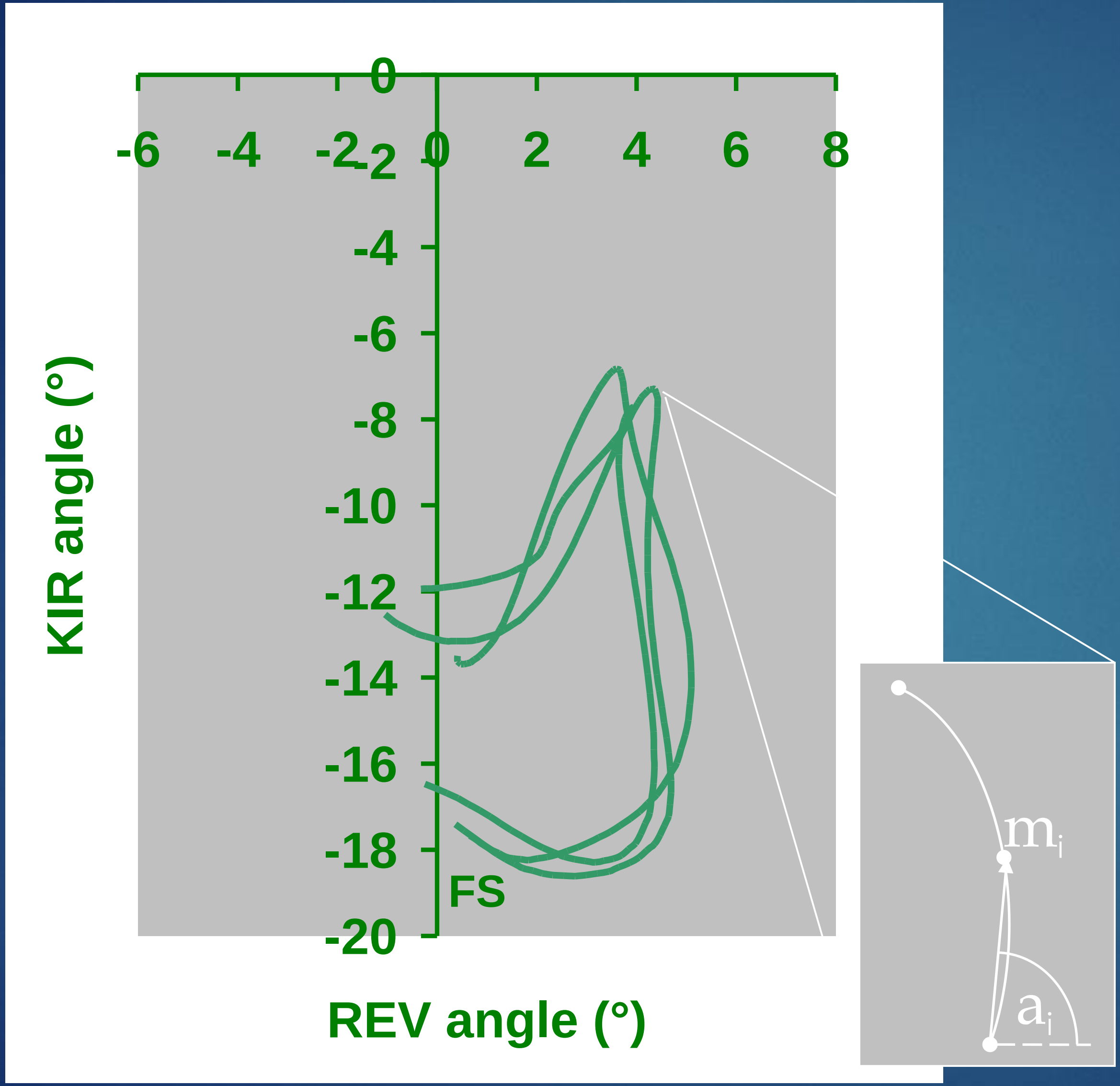
Benefits

- Two variables presented as a variable-time graph
- Easier to analyse where only one axis varies (i.e. time is fixed)

Limitations

- Loses information

Quantification –Vector Coding



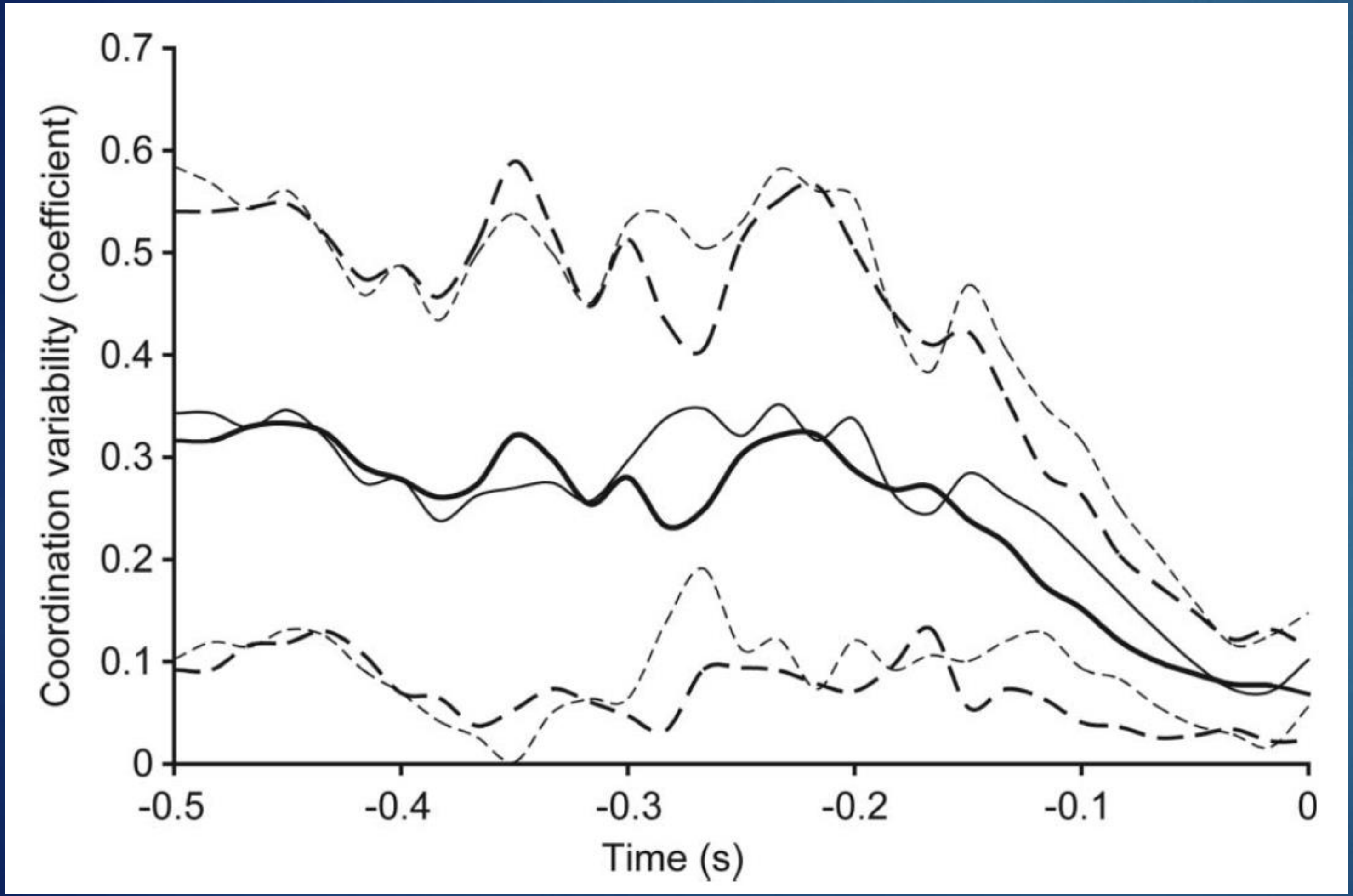
Calculation:

- Two methods
  - Angles and Magnitudes (Tepavac and Field-Fote 2001).
  - Angles (Heiderscheit et al. 2002)
- Output 0 (none) to 1 (most) [or vice versa]

Limitations

- Artefact at turning points (Heiderscheidt et al. 2002)

Vector Coding – example

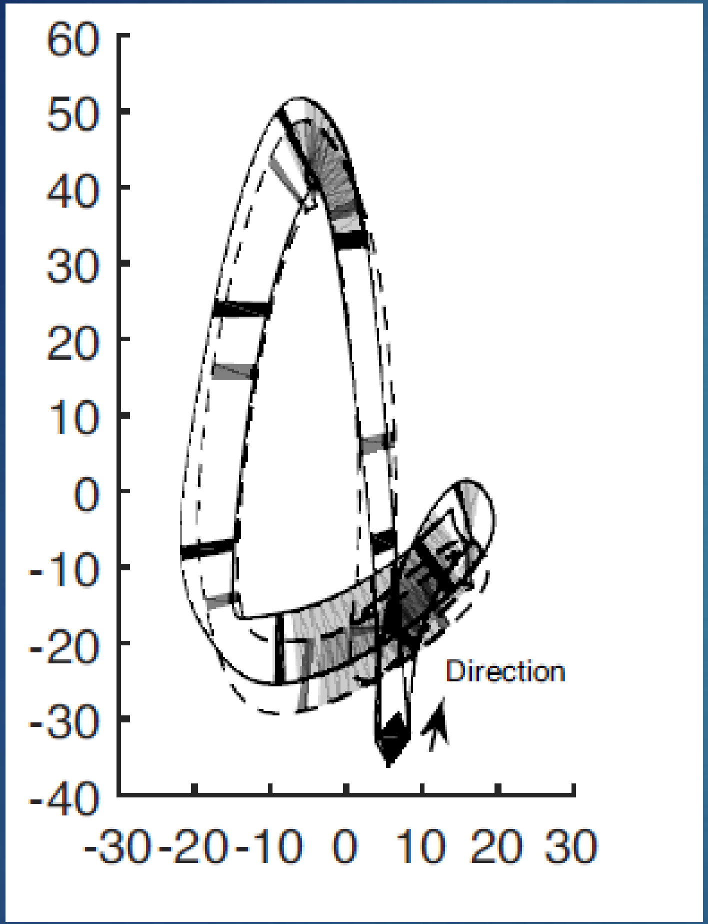


Wrist-elbow angles basketball free-throw

'Swish' (thick); misses (thin) – significant at final time point

Mullineaux, D.R. and Uhl, T.L. (2010). Kinematic variability of misses versus swishes of basketball free throws. Journal of Sports Sciences, 28, 1017-1024.

Quantification – CI2

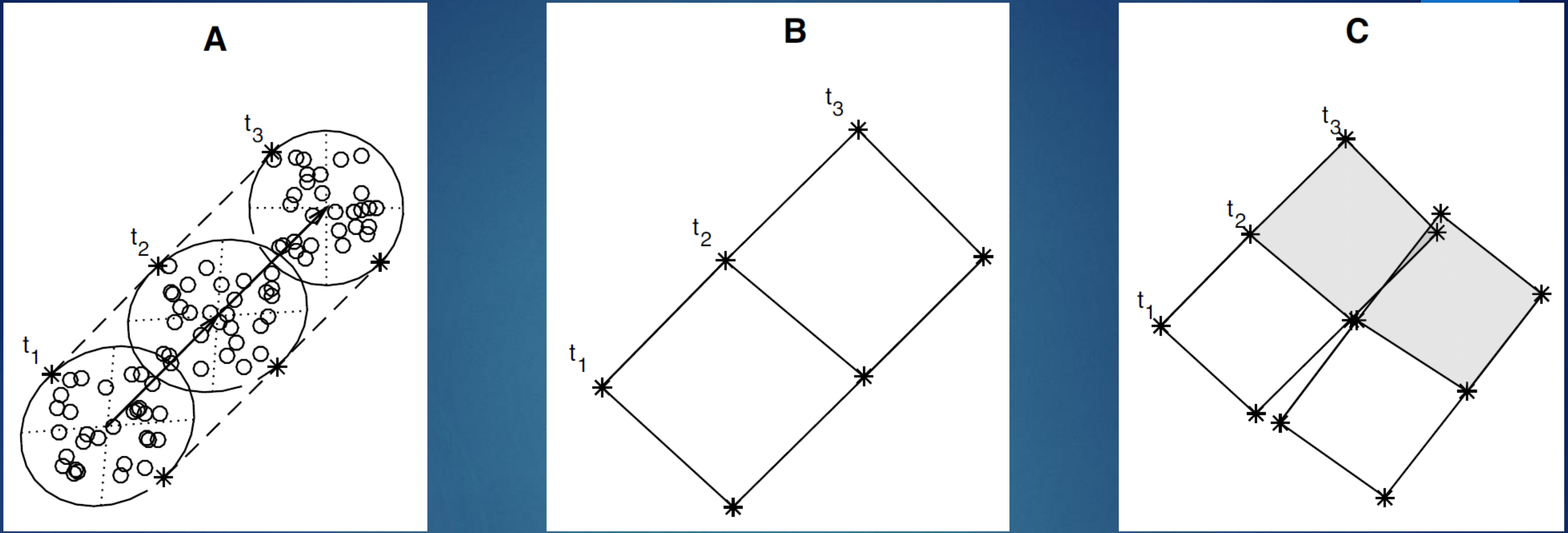


Mullineaux, D.R. (2017). CI2 for creating and comparing confidence-intervals for time-series bivariate plots. Gait and Posture, 52:367-373.

Key features

- Applies to variable-variable plots
- Calculates bivariate confidence intervals
- Compares two conditions (dashed v solid boundaries)
- Includes analysis of:
  - spatial (overlap of 2 conditions)
  - temporal (periodic filled polygons)
- Output: no-overlap (white) or overlap (shaded) spatially or temporally

Quantification – Basis of CI2

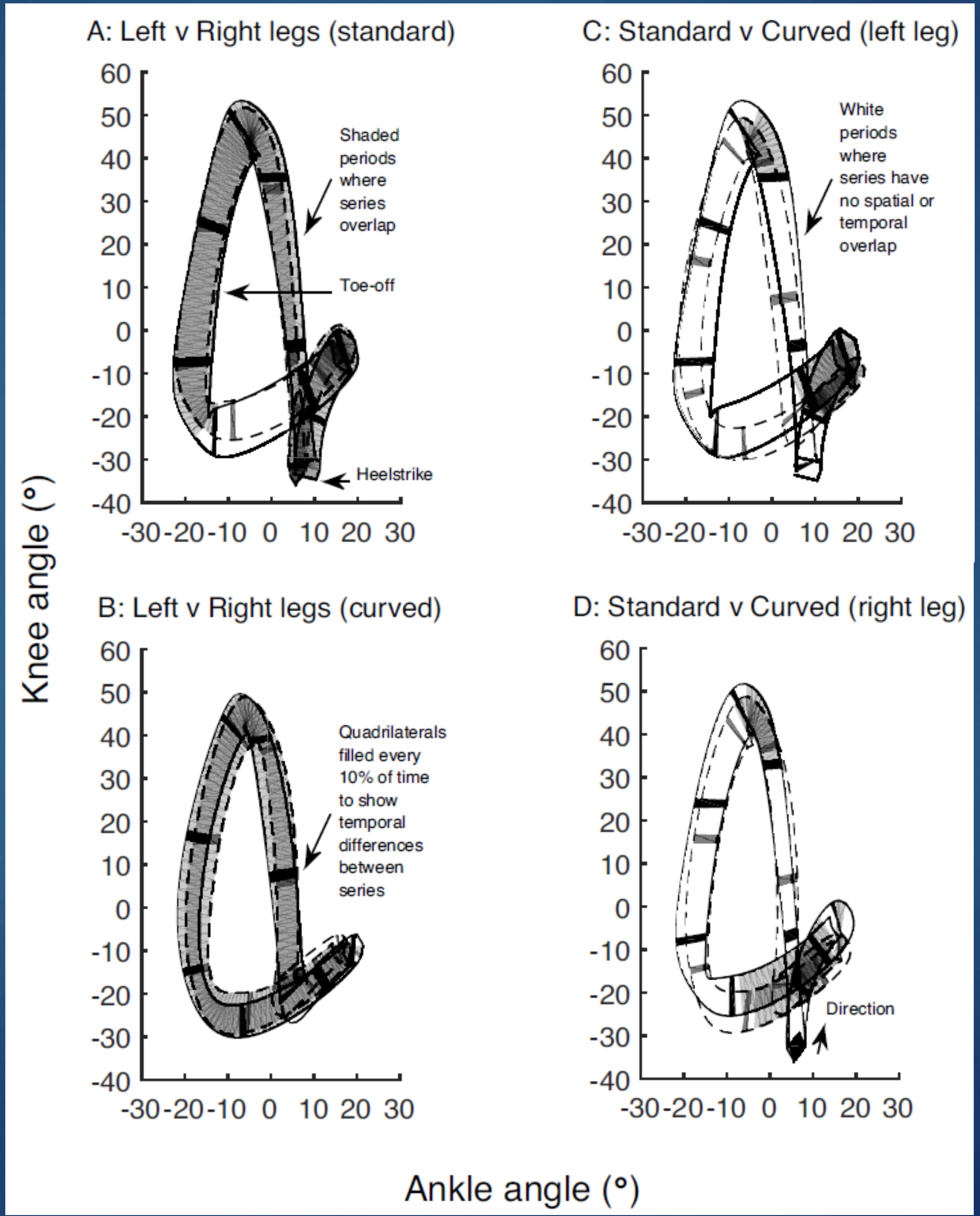


- Ellipses at each time point
- Determine direction
- Identify edges of ellipse parallel to direction

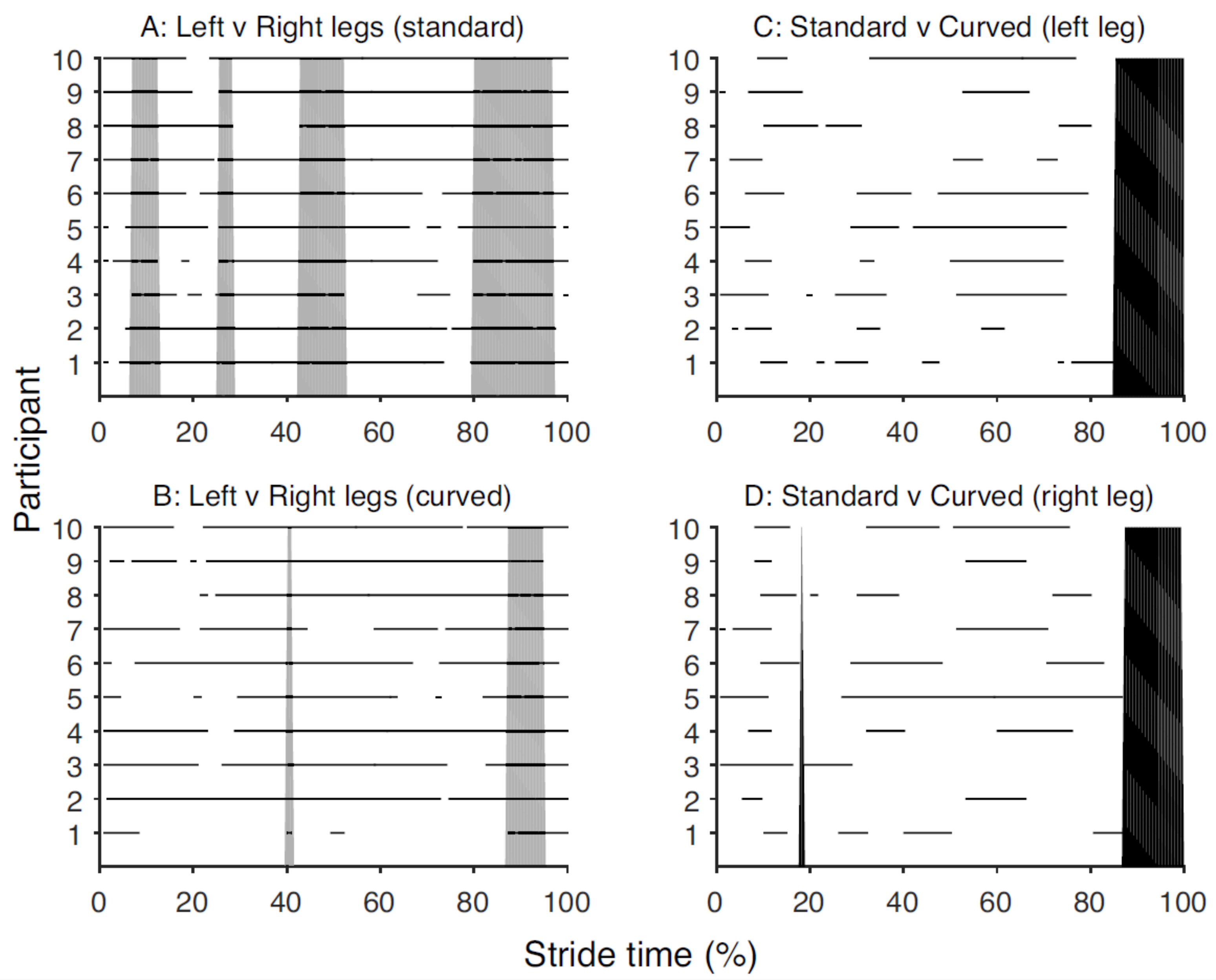
- Uses edges to create polygons

- Repeat with second condition
- Where 2 conditions overlap, shade polygons

Quantification (intra) – CI2



Quantification (inter) – CI2



Interpreting:

Solid horizontal line
- Overlap

Light shaded region
- X% subjects overlap (e.g. 100%)

Black shaded region
- X% subjects no-overlap (e.g. 100%)

Summary – presenting data

- Visually (2D or 3D)
  - Stick diagrams, butterfly, trajectories
- Comparisons
  - Left v right, injured v non-injured
- Graphs
  - Bivariate (or variable-variable), e.g.:
    - Angle-angle; phase plane portraits (velocity v displacement)
- Animations
  - Virtual reality

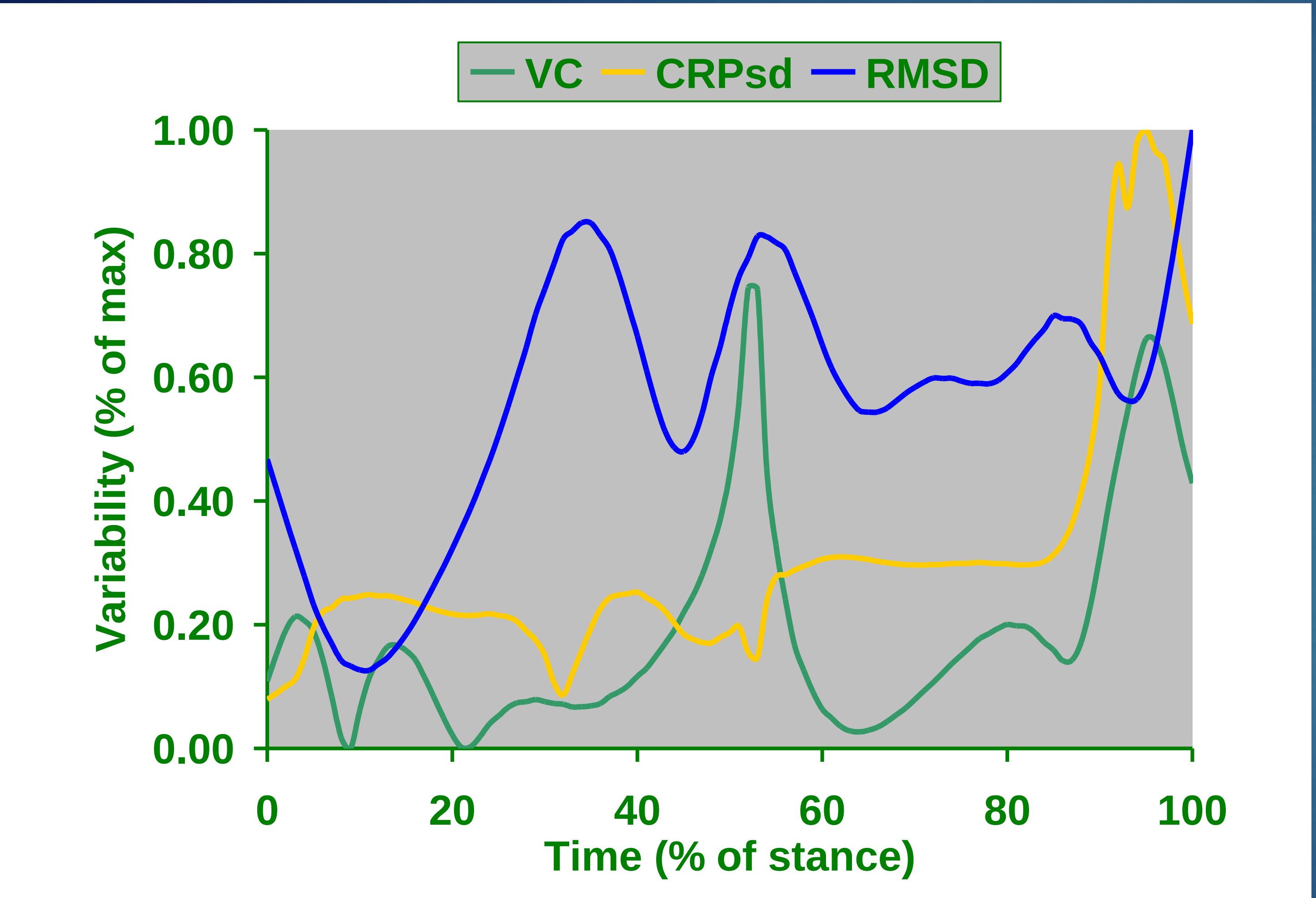
Summary – quantification

- Discrete points or phases (e.g. maximum)
- Variable-time graph (variable, ratio of variables)
  - SD, RMSD, 95%CI (largest to smallest)
  - %CV, %RMSD
- Variable-variable (including angle-angle plot and phase-plane portrait)
  - Vector coding, NoRMS, cross correlation
  - CI2
- Phase plane portrait (when comparing two plots)
  - Continuous Relative Phase, CRP
  - CRP standard deviation, CRPsd

General considerations

- Theories
  - Basis for investigating bivariate
- Assumptions
  - ‘Beliefs’ about the bivariate relationship to the theory
- Delimitations
  - ‘Relevant’ variables
  - ‘Appropriate’ analyses
- Limitations
  - Removing variability (to compare trials)
  - Number of trials (e.g. 10 trials proposed for CI2)

Finally – future considerations



Reliability poor
- CRPsd (phase-plane portrait)
- RMSD (ratio)

(Mullineaux 2007)

Validity – concurrent
- All different (Figure; Mullineaux 2008)

Validity – ecological
- Unknown
- Vector coding reliable
- CI2 (and CI2-area) untested

Any Questions?

Please submit any questions using the box in the bottom right hand corner of your screen.

We'll try fit in as many as possible in the time remaining.

BASES

The British Association of Sport and Exercise Sciences

JOIN BASES NOW

Receive exclusive member benefits

BECOME A MEMBER OF THE UK'S LARGEST PROFESSIONAL SPORT AND EXERCISE SCIENCES NETWORK

WWW.BASES.ORG.UK/HOW-TO-JOIN

@BASESUK /BASESUK

BASES_UK BASESUK

What's coming up?

We have some great webinars coming up:

- **Psychosocial considerations in sports injury risk and prevention** By Adam Gledhill
  Date: Wednesday 21st March 2018
  Time: 15.00 GMT
- **Sleep & Performance: Time to wake up!** By Ian Dunican
  Date: Wednesday 18th April 2018
  Time: 15.00 GMT

Registration for these webinars are open so please join us.

Further details on: www.humankinetics.me

@HumanKineticsEU

BASES
The British Association of Sport and Exercise Sciences

HUMAN KINETICS

Thanks from us!

Thank you to everyone for joining us today and thanks also to David for the presentation.

Please take a few moments when your webinar window closes to complete a short survey on today's presentation – we appreciate your feedback as it helps us continually improve our webinars.

Earn your BASES credits with our endorsed CE courses.

We will email everyone a link to the recording of today's presentation, so you can view it yourself or pass it along to friends or colleagues.

Thank you again for your participation, enjoy the rest of your day.