TRIAL STABILISATION OF RUNNING BIOMECHANICS WITH SHOE FAMILIARISATION IN TRAINED DISTANCE RUNNERS

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Appropriate trial sizes for biomechanical studies examining running shoe functionality are important to ensure valid insights into injury prevention strategies. The study aimed to examine the influence of shoe familiarisation on trial stabilisation in trained distance runners. A sequential averaging analysis was used to define trial stabilisation of biomechanical measures obtained from two testing conditions (new shoe and familiarised shoe). Between condition group analyses suggested similar trial stabilisation irrespective of shoe familiarisation (group mean ±SD: new: 7.5 ±2.0 trials; familiarised: 7.0 ±2.0 trials). Within group analyses identified variations in trial stabilisation according to the participant, condition and measure. An eight trial protocol was advocated for participant-condition analyses in longitudinal studies examining shoe functionality.

KEYWORDS: foot-ground interaction, sequential averaging, longitudinal testing.

INTRODUCTION: The functionality of running shoes has been repeatedly implicated as an injury risk factor in distance running (Taunton et al., 2003; Sinclair, 2014). Biomechanics studies debating the diverse effects of foot-ground interactions, and explicitly shoe interactions, have accordingly been popular in recent years. As suggested by Bates et al. (1983), multiple trials are recorded during biomechanical assessments to aid the stability of the variables being analysed and to achieve a representative mean value. The methodologies used in many shoe-related studies have recently been questioned, such that accurate responses made by runners while adapting to new footwear may not be portrayed (TenBroek et al., 2014). Since variability is an inherent characteristic of human movement, the selection of an appropriate trial sizes, which represent a stable biomechanical response (trial stabilisation), is necessary to ensure injury prevention programmes are informed by valid insights.

As suggested by James et al. (2007), trial sizes ascertained for individual participant responses influence the stability and validity of biomechanical studies, and should be objectively ascertained. The number of trials obtained from individuals in running gait studies has however, typically been fixed within a study, wide ranging and seemingly arbitrarily selected. In a cross-sectional study examining running shoe interactions, Bates et al. (1983) advocated the use of a minimum of eight trials to obtain stable participant-condition kinetic values. While contemporary studies of running biomechanics have similarly employed a fixed participant trial size irrespective of condition, less conservative trial sizes than advocated by Bates et al., (1983) have frequently been employed (e.g.Crowell & Davis, 2011; Kong et al., 2011; Nunns et al., 2013).

Trial stabilisation of important biomechanical measures of shoe functionality in running gait be compromised by shoe familiarisation over test-retest protocols such that fixed trial size designs may be unjustified. As a consequence of learning and adaptation, trained runners wearing a new shoe may hypothetically require a greater number of repetitions (less conservative trial sizes) to achieve within-collection trial stabilisation compared to latter testing sessions in which shoe familiarity is achieved. The use of arbitrarily selected fixed sample sizes may subsequently be unjustified for longitudinal studies examining shoe functionality. The aim of this study was to subsequently examine the influence of shoe familiarisation on trial stabilisation of important biomechanical gait measures in trained distance runners. The overall purpose of the research was to inform protocols for future large scale longitudinal studies aiming to develop biomechanical insight for injury prevention strategies centred on shoe functionality.

METHODS: Three healthy, trained distance runners (age: 32.3 ±7.4 years; mass: 60.8 ±11.6kg; height: 1.67 ±0.11m) completed multiple sub–maximal over ground running trials in an indoor athletics arena during repeated data collection testing sessions. The study protocol was ethically approved by the University's Research Ethics Committee and participants provided written informed consent.

During the first session, participants performed running trials along a 30m runway at a self-selected, sub-maximal running speed using a new pair of neutral running shoes (Nike Lunar Flyknit 2). A second testing session was conducted following 50 miles of road running training within the respective shoe. The 50 miles were accumulated by the runners across multiple training runs over a four week time period. The repeat testing session was performed at 50 miles to facilitate shoe familiarisation without simultaneous and prominent shoe degradation.

During each testing session, three-dimensional coordinate data of active markers located on the lateral aspect of the left limb and right hip were obtained during the trials using four co-aligned CODA 6.30B-CX1 scanners (sample rate: 200 Hz). Synchronous ground reaction force data (sample rate: 1000 Hz) were also obtained for a single stance phase using two force plates (Kistler Instruments Ltd., Switzerland) embedded in series in the running track.

The first ten stance phases were exported from each of the two testing sessions for each participant. The coordinate data were reduced to two-dimensions and subsequently low-pass filtered (cut-off frequency: 12 Hz). Whole body (e.g. approach velocity) and localised kinematic measures (e.g. knee flexion-extension angle at initial ground contact) were subsequently defined using the filtered coordinate data. Whole body velocity was obtained from the first derivative of the average anterior-posterior location of the left and right hip markers preceding initial ground contact. The force plate data were used to derive kinetic measures, which included the maximum vertical ground reaction force and respective average loading rate.

A sequential averaging analysis, which was previously described by Bates et al. (1983), was used to ascertain trial stabilisation of the selected kinematic and kinetic measures. The mean participant-condition response in the selected measures was initially derived using the criterion ten trials. Mean responses were iteratively re-calculated using increasing trial sizes (n = two to nine trials). For each measure, stability was initially established when all sequential mean deviations were within one-fourth of the standard deviation of the ten trial criterion response. Trial stabilisation was subsequently ascertained as one trial greater than the smallest number of trials required to achieve measure stability.

Individual participant differences in the absolute mean response between new and familiarised conditions were tested using a paired t-test (α level of 0.05). The mean trial stabilisation was compared between conditions (new and familiarised shoe) for each measure using a participant and group analysis.

RESULTS: The participant-condition absolute responses and trial stabilisation for each of the kinematic and kinetic measures examined in the study are presented in Table 1. While participant-specific differences were identified between testing conditions for individual kinetic and kinematic measures for Participant A and B, similar between-condition responses were found for Participant C across all kinematic and kinetic measures.

When determined as a group mean across all measures, similar trial sizes were required to achieve stabilisation between the new (group mean ±SD: 7.5 ±2.0 trials) and familiarised conditions (group mean ±SD: 7.0 ±2.0 trials). Between-condition comparisons further identified an earlier trial stabilisation in the approach velocity (Vapp) and average loading rate of the maximum vertical ground reaction force (LFzmax) with familiarisation for all three participants. In contrast, a later stabilisation in the sagittal plane knee angle at initial ground contact (ICKFE) was achieved for all participants with shoe familiarisation.

Table 1 Absolute responses and trial stabilisation for kinematic and kinetic measures obtained for running trials performed in new and familiarised shoes by three trained distance runners (Participant A, B and C)

		New		Familiarised	
		Absolute Response	Trial Stabilisation	Absolute Response	Trial Stabilisation
A	Vapp* ($m.s^{-1}$)	3.26 ±0.10	9	3.10 ±0.10	6
	ICKFE* (°)	165.4 ±1.1	5	160.8 ±0.9	8
	FzmaxKFE* (°)	135.6 ±1.8	10	129.3 ±1.1	8
	Fzmax (BW)	2.46 ±0.04	8	2.44 ±0.04	9
	LFzmax ($BW.s^{-1}$)	20.2 ±0.81	4	20.50 ±0.84	3
	Participant Mean ±SD		7.2 ±2.6		6.8 ±2.4
B	Vapp ($m.s^{-1}$)	3.42 ±0.14	7	3.33 ±0.12	5
	ICKFE (°)	148.3 ±3.7	7	147.8 ±2.2	8
	FzmaxKFE* (°)	124.0 ±1.0	9	125.6 ±1.1	7
	Fzmax* (BW)	2.64 ±0.06	9	2.56 ±0.05	8
	LFzmax* ($BW.s^{-1}$)	26.19 ±1.15	10	25.18 ±1.37	8
	Participant Mean ±SD		8.4 ±1.3		7.0 ±1.2
C	Vapp ($m.s^{-1}$)	5.27 ±0.13	6	5.38 ±0.13	5
	ICKFE (°)	160.1 ±2.2	4	158.9 ±3.9	10
	FzmaxKFE (°)	151.3 ±2.3	8	149.2 ±3.4	10
	Fzmax (BW)	3.41 ±0.20	9	3.57 ±0.19	5
	LFzmax ($BW.s^{-1}$)	160.07 ±13.05	8	152.67 ±10.55	6
	Participant Mean ±SD		7.0 ±2.0		7.2 ±2.6
	Group Mean ±SD		7.5 ±2.0		7.0 ±2.0

*Significant difference in absolute mean response (n = ten trials) between new and familiarised conditions at α =0.05. Vapp: Approach Velocity (Vapp); ICKFE: Initial contact knee flexion-extension angle; Fzmax: Maximum vertical ground reaction force; LFzmax: Average loading rate of the maximum vertical ground reaction force.

DISCUSSION: Trial stabilisation of important biomechanical measures of running gait were examined for three trained distance runners during new and familiarised shoe conditions. Shoe familiarisation was found to have a participant-specific effect on the respective biomechanical measures, which advocated the need for careful consideration of trial size selection in group analyses integrating individual-participant responses. Individuality in the biomechanical responses between conditions further supported the use of within-participant protocols in future longitudinal studies examining shoe functionality.

Trial stabilisation was hypothesised to vary between shoe testing sessions due to participant familiarity with the running shoe following the acclimatised training (50 miles) phase. Participant-specific and group trial stabilisation analyses between shoe conditions were subsequently examined using a previously advocated (Bates et al., 1983) sequential averaging analysis. In contrast to the study hypothesis, the combined group analyses suggested the use of similar trial sizes irrespective of shoe condition (familiarity) across all participants and measures. When considered relative to the nearest whole trial, a conservative eight trial individual-participant protocol was suggested for group and longitudinal analyses of shoe functionality. The use of the conservative eight trial protocol has previously been advocated for cross-sectional, single testing session protocols of shoe functionality (Bates et al., 1983). The similar conditional response identified for the repeated group analyses within this study further supported the use of a fixed trial size irrespective of shoe condition. The need for a cautious approach to implementing the use of fixed trial sizes for individual analyses in longitudinal research designs was however, also suggested. The

individual participant analyses demonstrated inconsistent trial stabilisations between conditions for localised kinematic and kinetic measures. The finding subsequently supports the suggestion of James et al. (2007) that the number of trials obtained from a participant influences the stability (test-retest reliability) and thus validity of the data obtained. The less conservative trial size obtained for the approach velocity for each participant with shoe familiarisation suggested that isolated running performance analyses may justifiably employ varied trial sizes between shoe conditions. In contrast, the maintained use of fixed trial sizes for more detailed examinations of localised kinematic and ground reaction force responses between shoe conditions was advocated. The diversity in trial stabilisation between performance and localised measures may partially reflect a functional mechanism in which trained runners accommodate changing performances by compensatory and inconsistent modifications to the localised kinematic and kinetic. While the study protocol examined a small sample of trained runners, the individual responses demonstrated the need for careful consideration of data reduction approaches for group analyses in future studies examining shoe functionality. Future considerations of trial stabilisation, which are dependent on the level (group or individual) and detail of analysis (performance or localised response) are suggested for studies examining shoe functionality and associated injury risk.

CONCLUSION: The number of trials required to achieve stable responses in important biomechanical measures of distance running gait may be specific to the individual and measure. When considering trial stabilisation for group-condition protocols for biomechanical studies examining shoe functionality in distance running, the collection of a conservative eight trial sample from individual participants is recommended. A fixed trial size for group analysis was recommended irrespective of shoe familiarisation in repeated testing sessions for longitudinal studies aiming to inform injury prevention strategies.

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