COMPARING TIBIAL ACCELERATIONS BETWEEN DELIVERY AND FOLLOW-THROUGH FOOT STRIKES IN CRICKET FAST BOWLING

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The kinematics of the fast bowling follow-through are often reported, yet the follow-through is unassessed. This study compared magnitudes of tibial accelerations across the delivery and follow-through foot strikes in fast bowlers. Fifteen sub-elite male fast bowlers performed 24 deliveries during training. Tibial accelerations were measured using tibial-mounted inertial measurement units. Peak tibial acceleration magnitudes were recorded at the foot contacts of the delivery and follow-through strides. A linear mixed model showed statistical significance between foot strike events (p < .001) with the greatest magnitude of tibial acceleration occurring at back foot re-contact. The tibial acceleration peak reported at back foot re-contact may have implications for load quantification and injury risk, therefore representing an important avenue for future fast bowling research.

KEYWORDS: inertial measurement units, kinematics, objective assessment, team sport

INTRODUCTION: A hypothesized link between large peak ground reaction forces (GRFs) at the initial front-foot ground-strike (FF1) and injury (Bartlett et al., 1996) has led to a research focus on delivery stride biomechanics in cricket fast bowling (Hurrion et al., 2000; Worthington et al., 2013). Whilst research has demonstrated that large GRFs occur at both initial back-foot ground-strike (BF1) and FF1 (Hurrion et al., 2000; Worthington et al., 2013), current fast bowling research has afforded little consideration to the follow-through foot strikes that occur after ball release.

Studies in golf and baseball pitching show that decelerations occurring in the follow-through phases of those actions are likely responsible for high muscle and joint loading, contributing to injury incidence in athletes of those sports (Pappas et al., 1985; Steele et al., 2018). Due to the requirement for cricket fast bowlers to decelerate their centre of mass (COM) after ball release and change direction to avoid running down the pitch, it is possible that the tibial accelerations in the follow-through may be equal to, or larger than those at the delivery stride. If tibial acceleration is greater during the follow-through, this needs to be considered alongside other load measures collected during the delivery stride, to evaluate the entire biomechanical load of fast bowling.

Previous research has used inertial measurement units (IMUs) to measure tibial acceleration across the fast bowling delivery and follow-through strides and through principal component analysis, found that tibial acceleration at each foot ground-strike across the delivery stride and follow-through represented unique aspects of fast bowling performance (Epifano et al., 2021). Based on these findings, further research into the magnitude of peak tibial acceleration across the delivery stride and follow-through is warranted.

This study aimed to compare the peak resultant tibial accelerations at BF1, FF1, the back foot re-contact strike in the follow-through (BF2), and the front foot re-contact strike in the follow-through (FF2). It was hypothesised that the magnitudes of tibial acceleration at the follow-through foot ground-strikes would be similar to those in the delivery stride.

METHODS: Fifteen injury free, amateur male fast bowlers (mean ± SD; age 21.0 ± 3.8 years; height 1.8 ± 0.1 m; mass 80.1 ± 8.6 kg) provided written consent before participating in this study. All procedures conformed to the Declaration of Helsinki and were approved by the La Trobe University's Science, Health and Engineering Low-Risk Human Ethics Subcommittee (HEC20021). Participants completed 24 deliveries towards a batter in outdoor turf-pitch cricket nets. Measures of tibial acceleration were recorded using tibial-worn 1600 Hz IMUs (Blue Trident, Vicon Motion Systems, Oxford, UK). Time-stamped raw acceleration data were saved locally on each device and later downloaded using proprietary software that also captured synchronised video of each delivery using a mounted tablet (Capture.U, Vicon Motion Systems, Oxford, UK). Raw acceleration data was exported into MATLAB (v. R2021a.2, MathWorks) where resultant acceleration was calculated using the three-dimensional Pythagoras' Theorem formula. Resultant accelerations were plotted in MATLAB and the peak values at BF1, FF1, BF2, and FF2 for every trial were recorded using the time-synchronised video for data integrity. The R program (R core Team, 2021) with the lme4 package (Bates et al., 2015) was used to perform a linear mixed analysis, where trials were clustered by participant to examine the main effect of foot ground-strike.

RESULTS:
A significant main effect of foot strike event ($F(3, 1580) = 97.1$, $p < .001$) was identified in the linear mixed model. The largest magnitude of tibial acceleration was observed at BF2, followed by FF1, FF2, and BF1 (Figure 1), with only FF1 and FF2 not being significantly different to each other ($p = .417$).

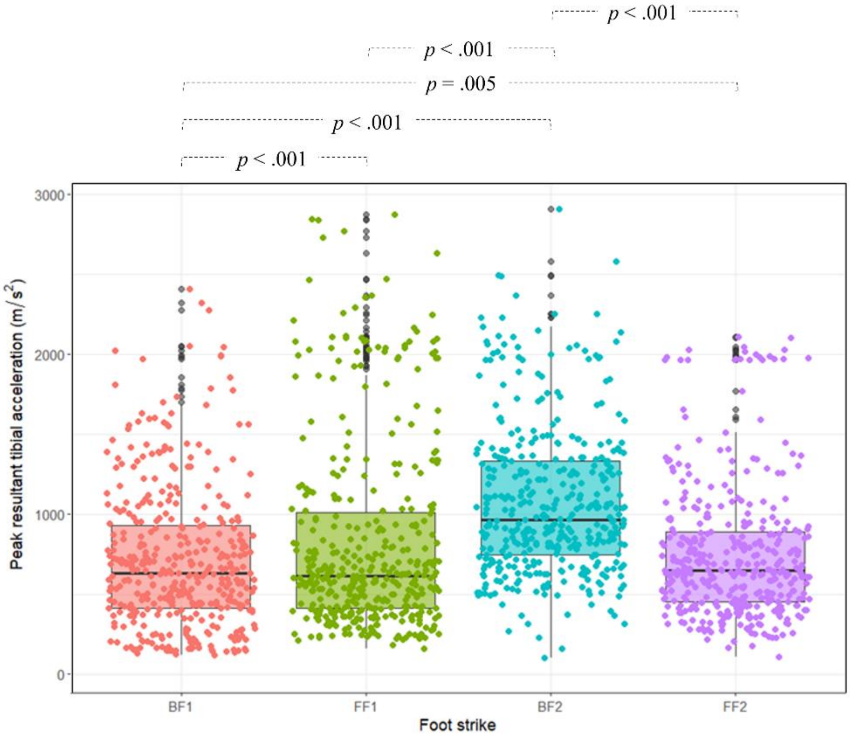

Figure 1. Box and whisker plot representing magnitudes of peak resultant tibial acceleration between foot strikes. Boxes convey second and third quartiles representing half of the data set. Vertical whisker lines demonstrate the first and fourth quartiles of data. Horizontal black lines within boxes signify the median value for each data set. Scatter plots represent peak resultant tibial accelerations from every trial and are categorised based on foot strike type. *Abbreviations:* BF1, tibial acceleration at back foot contact of delivery stride; FF1, tibial acceleration at front foot contact of delivery stride; BF2, tibial acceleration at back foot re-contact of follow-through; FF2, tibial acceleration at front foot re-contact of the follow-through.

DISCUSSION: This study investigated differences in peak resultant tibial accelerations across the foot strikes of the fast-bowling delivery stride and follow-through. The greatest magnitude of peak resultant tibial acceleration was reported at BF2, followed by FF1, FF2, and BF1.

Prior fast bowling research has focused mainly on the impacts of the delivery stride foot strikes (Alway et al., 2021; Callaghan et al., 2021; Callaghan et al., 2020; Portus et al., 2004; Worthington et al., 2013), with little consideration afforded to the follow-through. Epifano et al. (2021) was the first study to assess both the delivery and follow-through foot strikes and reported that foot strikes of the follow-through may represent a unique aspect of the fast bowling delivery. In the current study, the greatest magnitude of resultant tibial acceleration across both the delivery and follow-through foot strikes occurred at BF2. This may be due to the kinematics of the trunk and lower limbs following FF1. Fast bowlers typically deliver a ball with a rapidly flexing trunk from the beginning of the delivery stride through to ball release (Ranson et al., 2008). This is a function of linear-to-angular momentum transfer from the lower-limb segments involved in the run-up, to the trunk and upper-limb segments (Ferdinands et al., 2010; Zhang et al., 2011). At BF1 of the delivery stride, the fast bowler's rear leg is passive, whereby the knee flexes to dissipate GRF, rather than actively extending to generate a 'thrust' and maintain linear momentum (Ferdinands et al., 2014). Ferdinands et al. (2014) suggests that after the moment of FF1, when the back foot leaves the ground, flexion of the back knee and hip continue the linear momentum of the body's COM. After ball release, the bowler's linear momentum would continue forward and downward due to the flexing trunk, whilst the back leg trails behind the COM. To regain balance and produce a stable deceleration in the follow-through, the trailing leg must rapidly accelerate ahead of the COM and strike the ground, likely leading to the higher tibial acceleration at BF2. Given the proportionate relationship between force, mass, and acceleration (Newton's Second Law), it is likely that the greater magnitude of tibial acceleration at the BF2 strike is representative of larger tibial load, which may contribute to injury development.

As the tibial acceleration at FF2 was not significantly different to FF1, there is likely similar tibial loads at those foot strikes. This suggests that in disregarding FF2, prior research has potentially overlooked half of the total front-leg load through the cricket fast bowling action. When assessing or monitoring bowling loads, it would be prudent for researchers and practitioners to measure tibial acceleration through both the delivery stride and follow through.

CONCLUSION: This study compared peak resultant tibial accelerations across the delivery and follow through foot strikes of the cricket fast-bowling action. The greatest magnitude of resultant tibial acceleration occurred at BF2, while tibial acceleration at FF2 was not significantly different to FF1. Future research should aim to quantify GRFs during the follow through and further investigate the relationship between tibial acceleration and GRFs across the delivery stride and follow through.

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