THE EFFECT OF INCREASING ISOMETRIC STRENGTH ON TECHNIQUE DURING THE FRONT FOOT CONTACT PHASE IN ELITE CRICKET FAST BOWLERS

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The study investigates the effect of increased isometric strength on technique in elite male cricket fast bowlers. A 16-segment forward-dynamics simulation model individualised to investigate optimal technique of the front foot contact phase of fast bowling for ten elite male bowlers was utilised. For each individualised model, isometric strength was increased by 5%, technique (initial body configuration and subsequent movement) re-optimised, and the differences between the original and strengthened optimal techniques analysed. Ball release speed increased by <1% (40.7 vs 41.1 ms^{-1}) with a delay in bowling arm circumduction the only technique difference observed. No differences were found when comparing kinetic parameters. This suggests isometric strength does not limit technique in elite bowlers, this knowledge could influence elite coach development and applied practice.

KEYWORDS: musculoskeletal modelling, strength and conditioning, performance

INTRODUCTION: Cricket fast bowlers utilise the speed at which they deliver the ball to reduce the reaction time of the opposing batter in an attempt to be successful. Previous research has traditionally focussed on identifying the link between fast bowling technique and ball release speed. A combination of technique parameters within the front foot contact phase (period between front foot contact and ball release) have been identified as optimal, these include: a more extended front leg, increased upper trunk flexion, and a greater delay in the flexion of the front arm and bowling shoulder (Worthington et al., 2013; Felton et al., 2023). From a dynamical systems perspective, however, individual movement patterns are determined by the process of self-organisation (Kelso, 1995) and the interaction of organismic, environmental, and task constraints (Newell, 1986). Despite this, little is known regarding how an individual's strength affects their fast bowling technique.

Previous research investigating the effect of strength on cricket fast bowling has commonly focused on its relationship with ball release speed rather than its effect on technique. The results from these studies, however, have been conflicting. Whilst studies have associated faster ball release speeds with increased lower limb (Kiely et al., 2021; Letter et al., 2022) and shoulder strength (Ramachandran et al., 2021), strength training intervention studies have found no link between improved strength and power measures and upper arm velocity (Hislen et al., 2023) and faster ball release speeds (Callaghan et al., 2021). Studies have also failed to find a relationship between greater lower limb strength and front foot ground reaction force characteristics (Callaghan et al., 2021). Whilst no relationships have currently been identified in the literature between strength measures and technique characteristics, it is likely that a lack of homogeneity in the sample population, research design, and different strength measuring methods within experimental research are the contributing factors to the conflicting results or lack of findings in this area. An alternative approach, which allows for the manipulation of a single variable whilst keeping all others constant, is to utilise a forward-dynamics musculoskeletal model (Yeadon and King, 2018). This approach has recently been adopted across multiple elite cricketers to determine the commonalities of optimal technique during the front foot contact phase during fast bowling (Felton et al., 2023).

The purpose of this research, therefore, was to utilise a forward-dynamics musculoskeletal model of the front foot contact phase of fast bowling to investigate the effect of increasing isometric strength on technique in elite male cricket fast bowlers when maximising ball release speed.

METHODS: A 16-segment planar torque-driven computer simulation model of the front foot contact phase of the cricket fast bowling action was utilised (Figure 1). The simulation model was individualised to 10 male members of the England and Wales Cricket Board Elite Fast Bowling Group (age: 20.7 ± 2.4 years; height 1.91 ± 0.08 m; mass: 86.9 ± 8.5 kg). All procedures were approved by Loughborough University's Ethics committee and each participants informed consent was obtained prior to the study commencing. Each of the individual-specific simulation models has previously been evaluated and utilised to investigate the optimal technique (initial body configuration and subsequent movement pattern) to maximise ball release speed (Felton et al., 2023). In this study, the maximum isometric torque parameters for the ankle, knee, hip, and shoulder flexor and extensors were increased by 5% in every model, with each model then re-optimised (by varying the joint torque activation parameters) to investigate the effect of increased isometric strength on the optimal technique to maximise ball release speed.

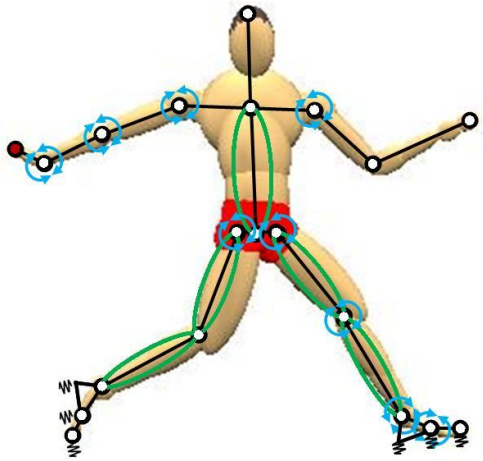

Figure 1 - Sixteen-segment simulation model with wobbling masses within the shank, thigh and trunk segments and spring-dampers at three points on each foot. Nine torque drivers at the joints with circular arrows and angle drivers at all other joints.

To investigate the effect of increasing isometric strength on technique, the differences between the original (Felton et al., 2023) and strengthened techniques were analysed. Discrete parameters comprising ball release speed and total time of the front foot contact phase, and six ground reaction force parameters were determined for the original and strengthened optimised techniques. Ten continuous parameters comprising: four kinematic angle time histories (front ankle, front hip, front shoulder, and bowling shoulder); four joint torque time histories (front knee, front hip, front shoulder, and bowling shoulder); and two ground reaction force time histories (horizontal braking and vertical ground reaction force) were also extracted and time normalised for the original and strengthened optimised techniques. To compare the differences, paired t-tests were performed to compare the discrete (SPSS) and continuous (SPM1D) parameters, with an alpha value of 0.05 used to determine significance. Effect sizes (Cohen's *d)* were also calculated for the discrete parameters.

Table 1: Means, standard deviations, and differential statistics for the discrete parameters

parameter	optimised	optimised with strength increase	*p*	Cohen's *d*
ball release speed (m/s)	40.7 ± 1.6	41.1 ± 1.6	0.002	0.22
time (ms)	102 ± 6.0	102 ± 6.0	0.411	0.05
peak horizontal braking force (BW)	3.94 ± 0.4	3.83 ± 0.6	0.362	0.22
peak vertical force (BW)	5.68 ± 0.8	5.62 ± 1.0	0.630	0.06
horizontal braking loading rate (BW/s)	128 ± 45	132 ± 48	0.552	0.08
vertical loading rate (BW/s)	172 ± 70	195 ± 75	0.227	0.31
horizontal braking impulse (BW/s)	0.16 ± 0.05	0.15 ± 0.05	0.566	0.02
vertical impulse (BW/s)	0.29 ± 0.06	0.29 ± 0.07	0.522	0.05

RESULTS: The optimised techniques of the ten elite male bowlers with a 5% increase in isometric strength were significantly faster than the previously determined optimised techniques (Table 1), but only demonstrated an average increase in ball release speed of 0.8% (40.7 vs. 41.1 ms^{-1}). No significant differences were observed in the time between front foot contact and ball release, or the kinetic parameters (Table 1).

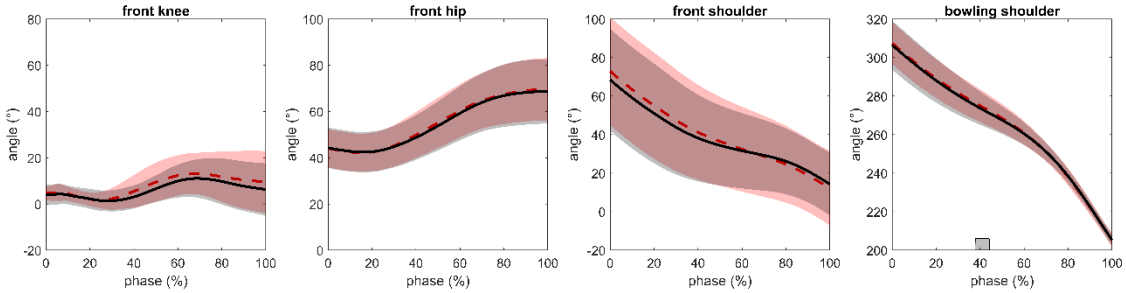

Figure 2: Mean and standard deviation of the joint angle time histories for the optimised techniques with 5% isometric strength increase (red dashed line) and without (black solid line). Statistically significant difference regions (p<0.05) are highlighted by a grey bar on the x-axis.

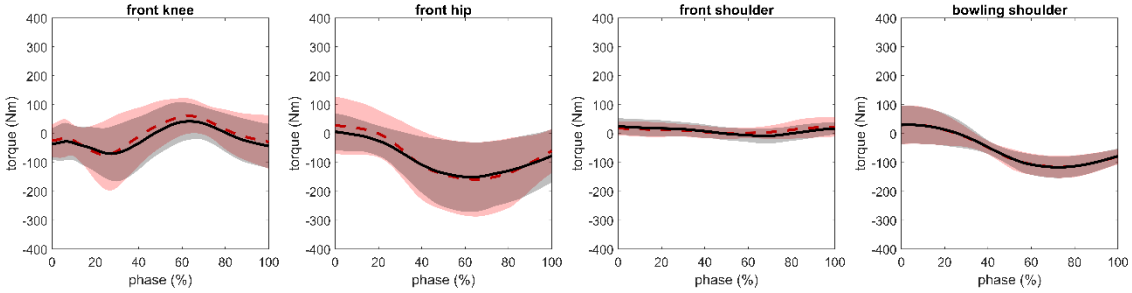

Figure 3: Mean and standard deviation of the joint torque time histories for the optimised techniques with 5% isometric strength increase (red dashed line) and without (black solid line). Statistically significant difference regions (p<0.05) are highlighted by a grey bar on the x-axis.

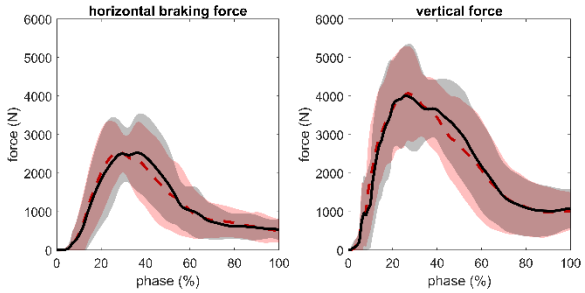

Figure 4: Mean and standard deviation of the ground reaction force time histories for the optimised techniques with 5% isometric strength increase (red dashed line) and without (black solid line). Statistically significant difference regions (p<0.05) are highlighted by a grey bar on the x-axis.

DISCUSSION: The optimised techniques of the elite male bowlers in this study with a 5% increase in isometric strength demonstrated an average increase in ball release speed of 0.8%, but no differences in ground reaction force parameters (Table 1, Figure 4). While a significant increase, this is substantially smaller than the 13.5% increase observed when the initial body configuration and front foot contact movement pattern were originally optimised (Felton et al., 2023). Though this highlights the importance of technique in maximising ball release speed, it may also highlight that ball release speed is limited in elite males by the time available to utilise increases in strength during the front foot contact phase of the fast bowling action.

Greater shoulder strength has previously been associated with faster ball release speed (Ramachandran et al., 2021), however, the cause and effect of strength on technique remains unclear. The findings of this study suggest that increased isometric flexor-extensor strength facilitates a greater delay in the timing of bowling arm circumduction (Figure 2). Greater delays

in bowling arm circumduction have previously been identified as a key technique characteristic in maximising ball release speed (Worthington et al., 2013; Felton et al., 2023). Although a greater delay in the onset of bowling arm circumduction was evident in the strengthened optimisations, no significant differences in the knee joint torque history were observed (Figure 3). Lower limb strength has also previously been linked with ball release speeds in cricket fast bowling (Kiely et al., 2021; Letter et al., 2022). No significant differences, however, were observed in the front knee or hip kinematics within this study (Figure 2). Despite this, it is unlikely that lower limb strength is not important within the front foot contact phase of fast bowling. It is more probable that the lower limb strength of the elite male fast bowlers within this study is already sufficient to withstand the torque requirements during this phase. In addition, no ground reaction force parameters were observed to be different (Table 1, Figure 4), which aligns with previous research (Callaghan et al., 2021). Future research should investigate the effect on technique of decreasing isometric strength in elite bowlers or increasing isometric strength in non-elite bowlers to further understand when isometric strength may become a limiting factor on fast bowling technique.

CONCLUSION: This study indicates that increases in isometric strength in elite male fast bowlers are associated with increased ball release speeds (although moderate in elite males compared to optimising technique), with increased shoulder strength facilitating a larger delay in the onset of bowling arm circumduction. The knowledge that increases in isometric strength lead to much smaller performance increases compared to technique interventions, and do not appear to limit technique, is likely to be useful to elite players, coaches, and sport science practitioners to ensure interventions are prescribed when appropriate. Caution is required, however, during application to consider the individual nature of human movement pattern self-organisation and the role of strength in injury prevention and other phases of fast bowling.

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