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Research Article

Building Subjective Opinions on Amateur Football Player 1 Step Kicks by Analyzing Ankle Biomechanics

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Abstract

Kicking is the fundamental skill in Football. 2 most common shots are Laces (In step) and Inside (Side foot). Key biomechanical features are Hip flexion, Knee extension, Backswing, Force on landing foot, Ball Contact and Follow through. In this experiment, a simple kick study with University football team regarding their technique upon Ball Contact is analyzed. "1-step" kicking analysis was done via video recording, importing into an application, plotting the motion of kick, and its velocities. An Inertial Measuring Unit sensor was placed on the front outer sole of the football boot to monitor the ankle rotations upon ball contact. The aim was to understand each player's technique regarding their position profile and gameplay approach. Based on existing opinions on players, could technology analysis, with camera and sensor support observation assessment? A Decision matrix was created to rank each kicker against tracked features linking to selected biomechanics. After reviewing video and sensor data, 2 players showed differences compared to initial observed rank, with greater understanding of 1 player's technique.

ABBREVIATIONS

BC: Ball contact; FT: Follow Through; BS: Backswing; AS: Ankle Stance; IMU: Inertial measuring unit sensor; VPA: Vernier Physics Pro Mobile Application; BLV: Ball launch velocity; AVR: Angular Velocity range; IKV: Initial Kick velocity; KB: Kick to ball velocity range; COR: Coefficient of Restitution

INTRODUCTION

Football has high physical demands and traits. Endurance depends on how much a player runs with varying intensities, but also how their kicking alters with fatigue [1]. Players in different positions require different physical needs. Outfield positions identified by where they play on the field; e.g. Defenders, Midfielders and Forwards (Goalkeepers the only non-outfield position) [2]. Each position has a responsibility, and within that position there are different types of roles, which can vary depending on team tactics/individual preference of gameplay approach. General skills typically associated with player position, can influence how their kicking abilities are based around.

Midfielders and Forwards generally are known to have greater accurate striking ability where Defenders are known to have power. Defenders may not prioritize on accuracy of shots, as other attributes such as short passing, has great importance. Long-range passing could be used to "enhance" their kicking competence, (depending on which defensive position they play). Midfielder's role is the most varied, ranging from position (e.g., central/wide), and role (playmaker/defensive/box-to-box) [2]. Forwards have the most influence for type of kicks that are associated with shots, making sure they have the best combination of power to accuracy. Kick methods, and skills required to continuously do this over time, means that the body must build resistance, to maintain the quality of kicks, even after fatigue settles. Same positional players with contrasting gameplay approaches can influence their kicking approach depending on what they are more required to do. If a player was always required to have greater short passing accuracy, their skills are honed to match those needs compared to a player focusing more on length of ball travelled, prioritizing power. These "responsibilities" mean they will need to work on different physical elements during training. To link how their gameplay needs effect their kicking ability, is crucial to finding which factors upon kicking biomechanics can they improve.

Objectives

1. Can opinions made on player by observation in 1 step technical kicks be supported by data findings from Sensor and Video analysis
2. Identifying gameplay influences in player approach to kicking ball at a set distance

Studies conducted on other biomechanical kinetics are good indicators for analyzing football kicks, which involve distance of landing foot, approach angles, velocity of hip abduction and knee extensions [3-5]. Crucially ankle movement help distinguish different types of technical kicking in Football. The type of shot taken is monitored to understand the corresponding ankle rotations upon BC, and its ball effects. This is because the type of shot taken, depends on the AS, at the point of ball connection.

Camera recording enables to review player movement, to know what is needed to improve technique. What a good kicker executes, does not automatically mean a poor kicker should follow the exact form, it is about understanding their own biomechanics and how consistency can lead to greater refinement in delivering good kicks. Accuracy and projection of the ball is not directly tested in this study but is referenced to grade if the kick is successful. The condition was that the ball should have passed the Goal line (6m target). Assessing kicker's technique in relation to biomechanical tracked features gets ranked chronologically.

In sport, subjective opinions always have an important influence when analyzing performance [6]. A subjective assessment is used as an evaluating tool to determine the manner of shot execution. Data itself does not display the overall performance of an athlete as some parameters cannot be monitored with technology (e.g. smart wearables). Having observations in certain scenarios produce more relevant monitoring of attributes, validating a player's performance rather than judging on monitored physical capabilities (quantifying). If a player is consistent in certain element of biomechanics, then this can be referenced as a point for comparison in reviewing a player's kicking ability.

Figure 1 explores the different motions in ankle movement. Dorsiflexion is when the feet moves up vertically only, with no horizontal movement. The angle between the lower leg and the feet's toe, decreases. Plantar flexion increases this angle, where the foot moves in downward direction, vertically [7,8]. The tarsals are the higher region of the foot (navicular, cuboid), which will elevate depending on the plantarflexion of the player, as they strike the ball. The fibularis and Longus muscles on the feet, determine how much plantar and dorsi flexion occurs [9]. Internal and External Axial Rotations of the leg is experienced around the ankle via dorsiflexion and plantar respectively [10]. Abduction is when the feet move horizontally outwards, without any vertical movement (Adduction-inwards) [7]. Inversion is foot rotating inwards, Eversion being outwards [11]. They both work around the Subtalar joint, but with different muscles (Tibialis-inversion/Peroneus-eversion) [7,11]. All interior and downward motion results in Supination, with exterior and up motion; Pronation [7-10]. Terms in ankle movements is linked to biomechanics of kicking regarding AS at BC (Figure 1).

Different type of shots will require different motions of the ankle upon BC. Variables of kicking biomechanics can exist in any form (passing, crossing, shooting), depending on the manner of approach of either the ball or the player [12]. It will require different functions of the body, in reaction time, agility, power, speed and flexibility, to work accordingly (Figure 2) Table 1.

A player approach towards the ball is influenced by the different type of kicks they intend to do. Different approaches can influence a "side stance" (inside), or "in step kick", (laces). Crucially, even with the same stance, ankle movement upon BC determines can impact shot type shot. The ankle tilts on point of contact, directs where the ball wants to be placed. Defining these can educate the player at different stages of ankle movement how they can improve approach. As the player approaches towards the ball, their speed is linked to kick power (momentum). The "hard work allowing efficient transfer of energy" could be undone if the BC execution is poor. This justifies the purpose of studying BC as a fundamental focus. There are other type of shots in football, compromised of Chip, Outside, Toe kick, Back Heel and Push Kick [18] (Figures 3 and 4) Table 2.

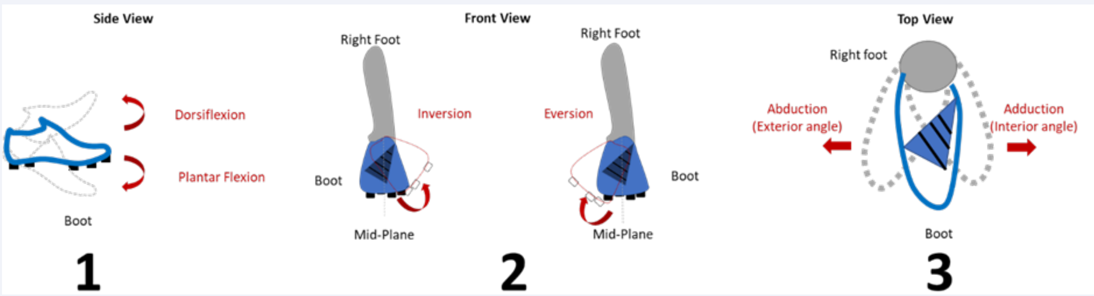

Figure 1 Diagram showing the different Biomechanical Ankle movement.

Figure 2 Biomechanics involved in kicking.

Table 1: Biomechanics of kicking.

Biomechanics of kicking	Description
Hip flexion Knee Extension	Gives the opportunity for forces to be produced. Knee extension and the sound of BC is evidence of energy transferred [12]. "Hip rotational torque, hip flexor strength, calves and quadriceps strength", affects force/kick speed [13]. Good balance of hip rotation = less effort required for long shots [14,15]
Backswing (BS)	BS is where force gets generated. Landing leg would have the greatest loads experienced on the quadriceps. Swing motion utilizes the lower body, Hip rotation (contracts) allows the extension of the leg to exert the force [12,13]. Hands accommodate swinging leg, helping balance. "Elastic energy" is stored during the BS, released as the kick goes through.
Force on Landing foot	Landing leg (non-kicking) is crucial to transferring the momentum. Loads applied on those muscles allow body's balance to stabilize [13,14]. Location of the landing foot is important to direct the ball. Sets up ankle contact to influence space "created" between the landing foot and ball- resulting in good posture [15] Composure can be identified, depending on rate of reaction time to settle Consistency with precise coordination, improves form [14] Safe landing of this foot can generate the required reaction force
Ball contact (BC)	Point of energy transfer. Position of the foot affects the power and accuracy of the kick [12]. Environment and conditions of ball; affect projection [16] [15] The knee can be fully extended, depending on how far the ball is. Landing feet ankle "flexed" by force transferring between the boot to ball. The rotation of ankle prior to this point determines the type of technical shot
Follow through (FT)	Further energy dissipation from the kick force comes via FT. The knee joint, consisting of the connection between Tibia, fibula, femur, and patella, extends as the kick goes from BS to FT. FT happens after the contact of the ball, from the elastic energy that was present from the BS, getting released (hip flexing) [13]. Momentum would allow the forces to be exerted [12]. Deceleration of kicking leg must be done efficiently to avoid injuries. Kinetic energy being conserved shows efficiency. Poor form of kicking will also incur problems (possible overstrain injury) Upper body works as "stabilizers" which can allow the hips to flex, whilst the calves and quadriceps execute the kick [17].

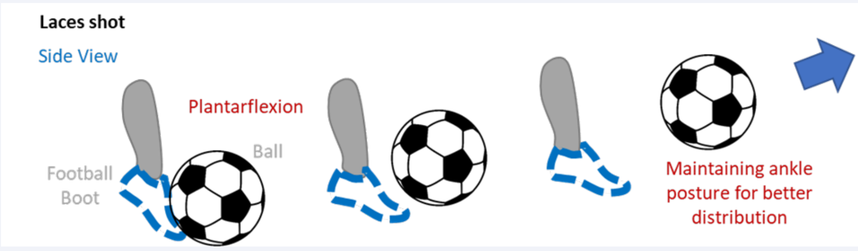

Figure 3 Laces (In step) shot.

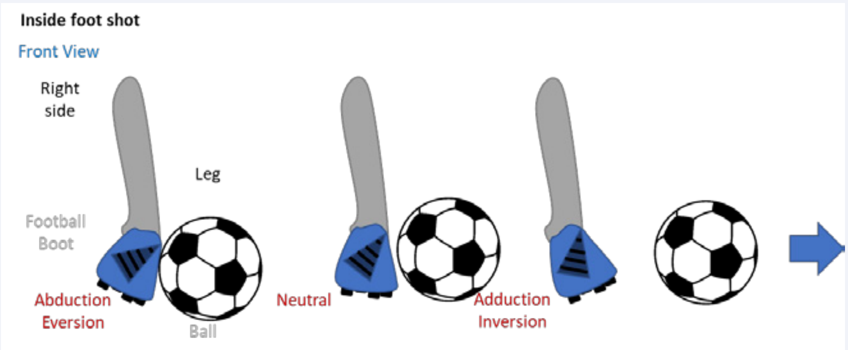

Figure 4 Inside foot (side kick) shot.

MATERIALS AND METHODS

Six University U20 Women's Football Team members participated in this study. Before attempting kicks, overseeing training sessions (2/week), consulting with two team coaches, built the "subjective" factor on the players used (Table 2 - Training notes). The experiment occurred after stretches and warm up drills were completed during a training session. The players were given freedom to their approach, and how they would attempt to make sure that they clear the target line, without constrained instructions (flexible). This was done, to understand how that player's gameplay approach type, could influence what they perceive was enough to clear a set distance, linking it to position profile. Experiment happened on a full-sized football pitch, during Winter Season, with no adverse weather conditions (no winds).

Each player was tasked to kick a "1 step" shot. This meant that there was no run up to the ball, hence influence of their physical running speed would not affect the intended analysis; just landing foot and kick. Players could generate certain amount of kick speed due to run up, which causes another element to consider when trying to analyze, so this is solely to understand their BC technique (ball stationary on ground). The landing foot was naturally in line of where the ball was placed; something all players did.

The Nano 33 IoT board was chosen due to its composition of IMU LSM6DSL (Accelerometer/Gyroscope) with microcontroller all on one board (reduce components) [19]. Producing 104 hz output data, 9600 baud-rate, connected via 2m wire to HP n019-Touch laptop to visualize data as player kicked. Integrated environment from Arduino software, automatically imported into Libre Office Calc Spread sheet. Trial tests were done prior, without control measures, to "calibrate" sensor, so they work during experiment (axis configuration to represent ankle biomechanical direction). For experiment data, code considered electronic scale conversions. Accelerometer produced results in G force, hence multiplied by 9.8 ms-2 to obtain acceleration value. Gyroscope had the sensitivity range set at ±2000 deg/s, with ±70mdps/LSB conversion (precompiled settings-Arduino LSM6DSL library).

IMU board connects onto miniature-breadboard, attached to a stretchable sleeve, placed over the kicker's boot. The thin material was Cotton fabric from tights; cut into the appropriate size (APPENDIX Figure A). This allowed flexibility for the player to use their boots when kicking for this experiment. The tights were elastic enough not to cause any wearable distress (tightness). 1 step kicks meant traction was not affected. Trial periods before main experiment, gave opportunities for modifications to improve setup. Insulation tape used over the board securing connection, allowing kicks to be done without any detachments. Foam covered electronic component with only LED light showing (protection).

Trials were done first, before suggesting "3 examined" laces and inside kicks that would be considered for analysis. The ball is hit towards a target line (goal), set from a distance (6m penalty line). After all participants finished, the post kick analysis took place into VPA (calibrates distance based on pixel) and Sensor data [19-21]. Video taken from iPhone-6 1080p/60fps with fixed distance (VPA requirement /Apple IOS compatible). Each shot sequence is cropped before controls applied (APPENDIX Figure A) (Figure 5) Table 3.

RESULTS AND DISCUSSION

Graphical analysis were made from data regarding performance parameters against the biomechanical features for both type of shots. Table 4 shows the key methods of obtaining required calculations which would help analysis.

*Laces/Inside Shot graph plots for IKV, BLV, BC height; against BS/FT (APPENDIX Figure B/C) (Table 4).

Table 2: Biomechanical associated with Laces and inside kicks.

Shot Types Analyzed	**Biomechanical associated with Laces and Inside kicks**
Laces (In step)	• Laces kick (In-step kick) contacts the ball around/top of the metatarsal, Navicular, cuboid, and phalanges region on the foot. • Players "instruct" ankle rotations (abduction/eversion), guiding the ball to a specific direction, dependant on the approach. • Contact can also happen if the ball is not on the ground, as the laces part of the boot can be angled to contact the ball at an intended point [4][18]. • Plantarflexion is generally experienced by ankle approach. • This motion gives a degree of freedom to FT efficiently, (less chances of dorsiflexion straight away) • Keeping the plantar position, the flexor digitorum brevis muscles are also required to be flexed along with Laternal Malleolus when executing shots, to give that extra rigidity to the foot positioning upon ball striking, to reduce the chance of losing shot power (isometric contraction) [17]. • Correct form/training reduce stress and increases resistance on the required muscles/bones. • The angle of decline (bottom- plantarflexion) and its rate, needs to be adequate to allow maximum possible chance of contact. • Influenced by quadrus plantae muscle which provides the angle of feet, controls laces shot direction for intended ball movement.
Inside (Side)	• Quadrus plantae muscle can allow the rotation of the ankle joint to execute a side foot shot (inside/outside). • Phalanges, just between the metatarsal joint and the Distal (toes), have key responsibility, in keeping a rigid position upon BC • Inside shots uses the inner side of the first metatarsal and medial cuneiform bones of the feet, typically in most situations for passing. • A kick that prioritises accuracy, where pace of the ball can easily be influenced by the player to determine how much effort they should exert. • Combination between Eversion/Abduction to Inversion/Adduction can experienced due to the nature of ankle movement

Table 3: Assumption on player profile.		
Player	**Training notes**	**Trial periods / Experiment Observations**
Player 1 Forward	Precise finisher High endurance	• Really good power • FT seemed high for almost all laces kicks. • Inside kicks more consistent than laces
Player 2 Defender	Short passer Powerful kicks	• Kicking was fast and powerful, but ball did not have the best launch speed • Inside shots seemed much slower • Puts a lot of effort but kicks technique was not consistent
Player 3 Midfielder	Good technique in shots and passing. Very physical in plays	• With less effort, the ball was travelling at a great speed with low BSs and FT • Best kicker based on observation • Technique seemed very honed, as every kick was consistent in how it delivered
Player 4 Forward	Fast runner Finisher Unique skill sets	• Had erratic kick actions • Kicks seemed to be faster than the ball, and gave the illusion that the outcome could be powerful. • Very inefficient, with excessive effort applied through all laces kicks. • An unorthodox kicking approach, • Unique forward position player.
Player 5 Midfielder	Smart player Precise passer Attractive play style	• Seemed very efficient. • Did not feel the need to kick with effort to pass the line
Player 6 Defender	Strong long shots Good long passer	• Laces shots seemed quite powerful. • Consistent technique throughout all kicks • Simple inside kicks

Table 4: Tracking feature calculations- used as Performance parameter with Biomechanics.	
Tracking Feature	**Method of calculation**
Backswing / Follow through	Calculated as vectors, through VPA X/Y Displacements Plots (Track point on **Ankle**). Furthest point in BS and FT were regarded as max displacements.
Initial kick velocity	Calculated as vectors, through VPA X/Y Velocity Plots (Track point on Ankle). Plots done **until** BC.
Final Kick velocity	Calculated as vectors, through VPA X/Y Velocity Plots (Track point on Ankle). Plots done **after** BC.
Ball contact height	Whilst doing VPA X/Y Displacements Plots (Track point on Ankle) height on ball is the Y axis reading on BC (x = 0m)
Ball launch velocity	Calculated as vectors, through VPA X/Y Velocity Plots (Track point on **BALL**)
Strain	VPA measures Leg length. This is then compared from the BS / FT vectors. Strain = **BS** – Leg length ; Strain = **FT** – Leg length
Kick Efficiency (Coefficient of Restitution)	Derived from Newton impact law, defined as a variable between 0 – 1, without any units (1 being most efficient – elastic collision). Football kick is how the speed of separation between the stationary ball and boot upon impact, is related to the speed of player's kick. **COR** = (Ball Launch Velocity – Final Kick velocity) / Initial Kick velocity
Angle range on contact	Videos imported into Adobe Premiere pro; capturing BC-AS. Frame drawn around, using IMU board; LED as reference, making sure ball is centered. Custom scale designed for Inside/Laces shot for analysis
Angular velocity range	IMU plots from LSM6DSL showed peak values of BS/FT around point of BC. Rotations prior show Ankle adjustment in Deg/sec, linked to ankle biomechanics rotation. VPA could only consider horizontal and vertical plots based on video frame position. The Sensor's Axis are based around the device, (3 axis analysis).

Figure 6: shows the significance of Player 4's drastic kicking methods, where FT was very high. Player 1 whilst kicking did appear to show great FT, however comparing it regards to strain, this player had the capacity to achieve those lengths. Player 2 exerted a lot of effort in both, which explains why their kick swings appeared very fast. Player 3 looked like as well, however when looking at the strain analysis, evidence of excess effort is shown. Player 5/6 kicked without applying much effort, evidently more consistent in minimal BS.

Figure 7: From the displacement graph it may appear that players 1-4 all exceeded their effort (high FT), however with the comparison to their relative leg length, only Players 2 and 3 over strained, confirming the key reason why this analysis was included, providing better context, unique to each player. An argument could be made that the taller players require more effort, to reach the bottom of the football, however, as this experiment looked at 1 step kick, the BS, FT are constrained, with the stationary ball. The relative strain measurement visualizes the excessive effort being applied by the players that is unnoticed during observation, as immediate focus would be looking at success of ball launch.

Figure 8: A custom contact angle scale is designed for both type of shots. When looking at inside shots, the angle value, is not the lateral rotation of the ankle or hip (Abduction), but can identify how much the player has had to maneuver in order to connect the ball at that angle. The point of contact reference must be the same for all kicks, hence the IMU breadboard was chosen as the ideal object due to the LED light appearing as dot. Drawing a frame around the boot shape to understand better how different players faired, highlighted each kicker's preferred

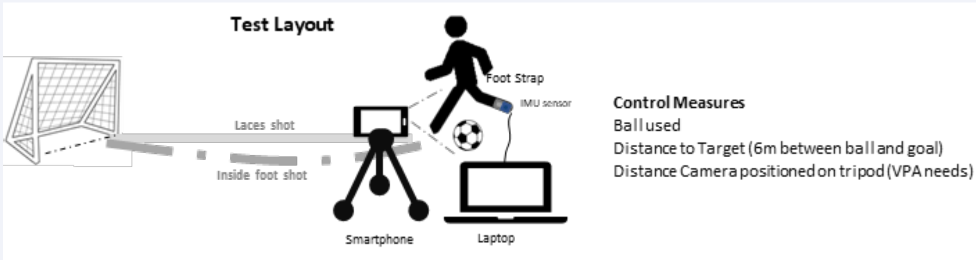

Figure 5 Experiment setup and Control measures.

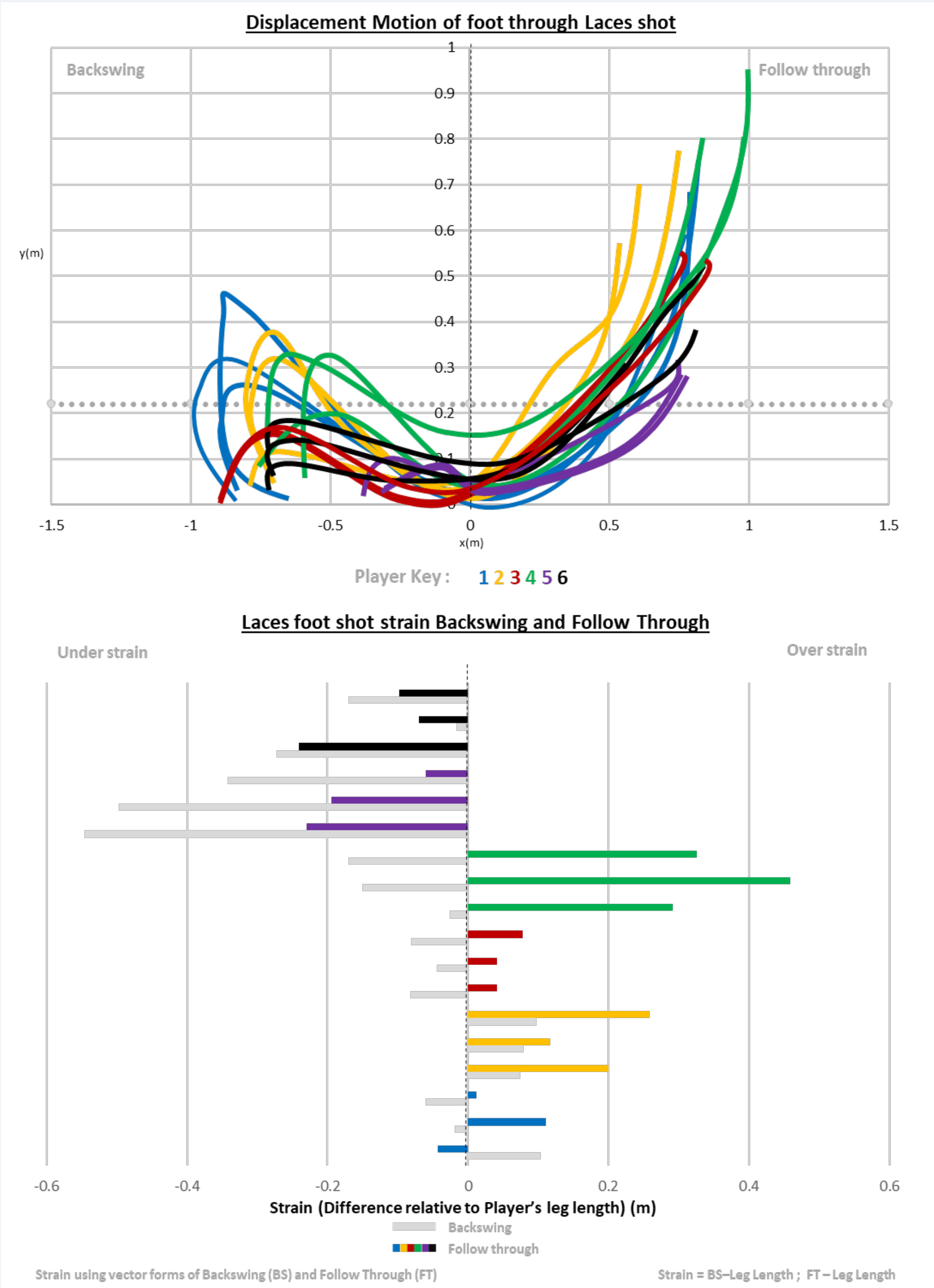

Figure 6 Displacement Motion of foot through Laces shot and strain.

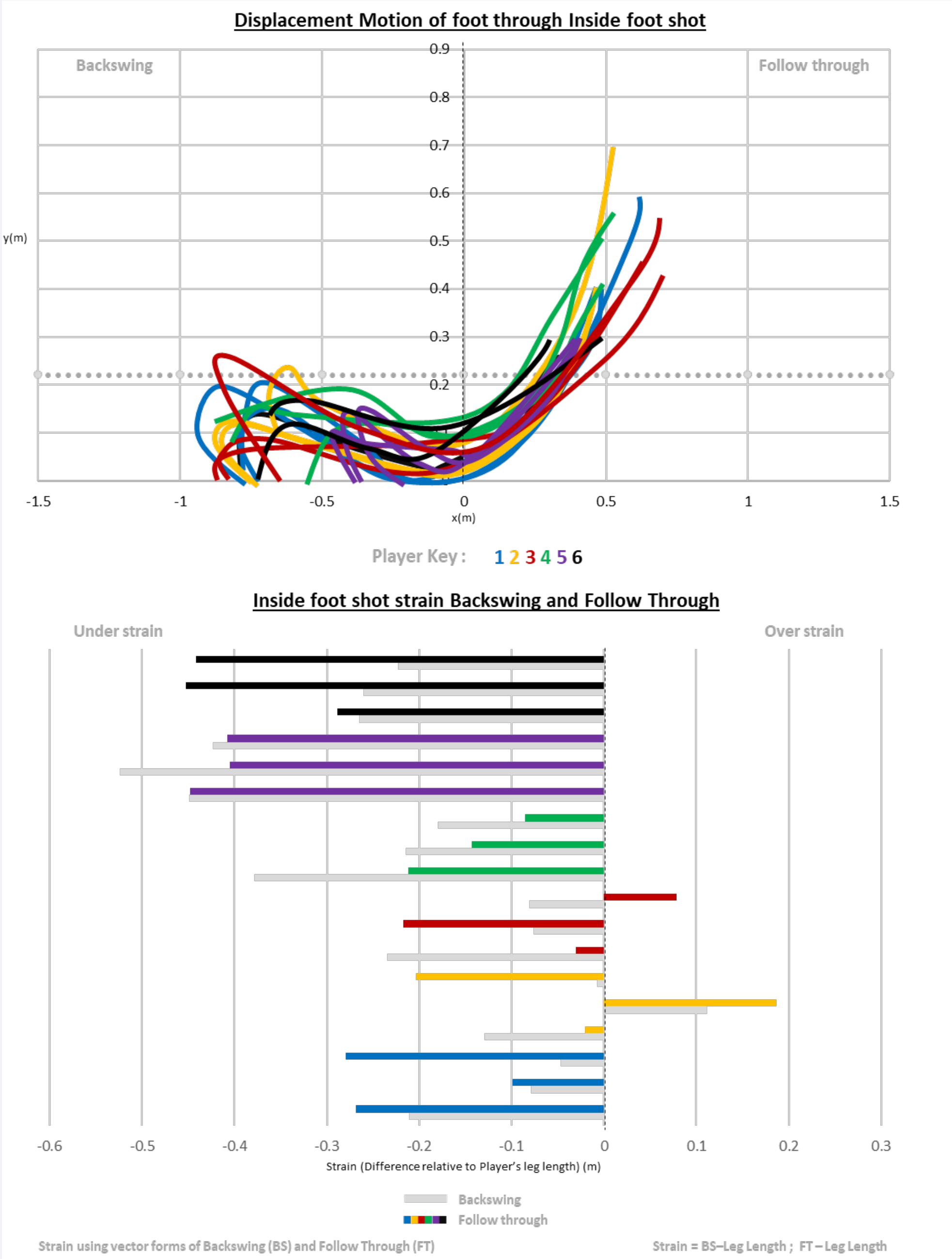

Figure 7 Displacement Motion of foot through Inside foot shot and strain.

technique. Players 3/6 allowed their "Front inner sole" to hit with a smaller angle of plantar flexion, opening the width for broader connection (Eversion). Player 1/4/5, focused their efforts in delivering more of the front sole only, hitting within 40-50 range. The Defenders (Players 2/6) naturally struck the ball in the lower region, something that could be accustomed during their gameplay, in trying to kick far, but both resulted in different ankle angles. The camera being placed in a horizontal view, meant these projections show how low players reach for their kicks. Inside shot BC point of view could have been better behind the kicker for plantar flexion projections, and higher to show how much the ankle moved away (Abduction) (Figures 6-8).

Figure 9 identifies better kickers, who achieve higher BLV with minimum IKV. COR signifies how efficient transfer of energy in their kicking was, which shows Player 3/6 being standouts in providing both kicks. Player 5 was perceived as efficient upon observation, but COR shows that was not the case, proving video analysis provides additional perspective (Figure 9).

To understand IMU plots, the peaks showed the point of BC, as this moment is when BS would become FT, hence change in linear acceleration/angular velocity direction (APPENDIX Figure D). Analyzing Figure 10 (Sample laces shot); Gyroscope graphs plot "peak value", is assigned after a certain number of seconds, to "emulate" how the shots would have looked, had all players

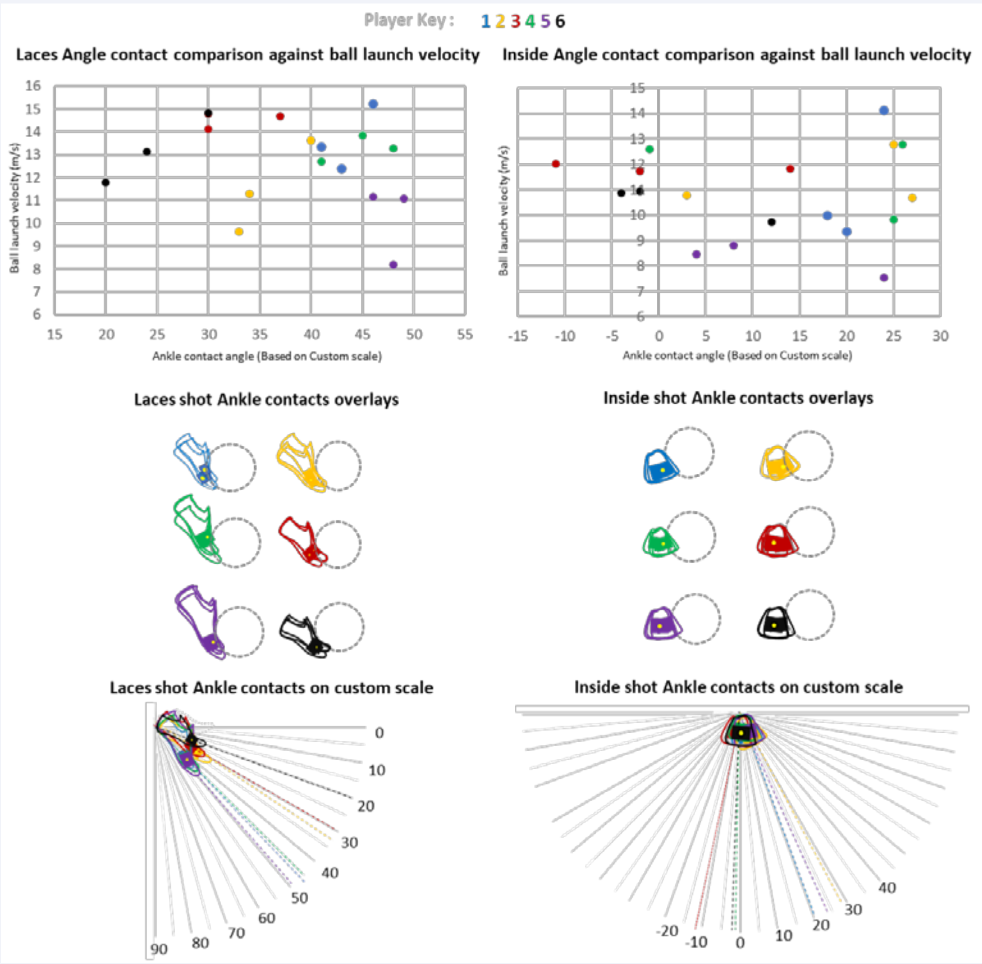

Figure 8 Ankle position upon BC for laces/inside shots with Custom scale.

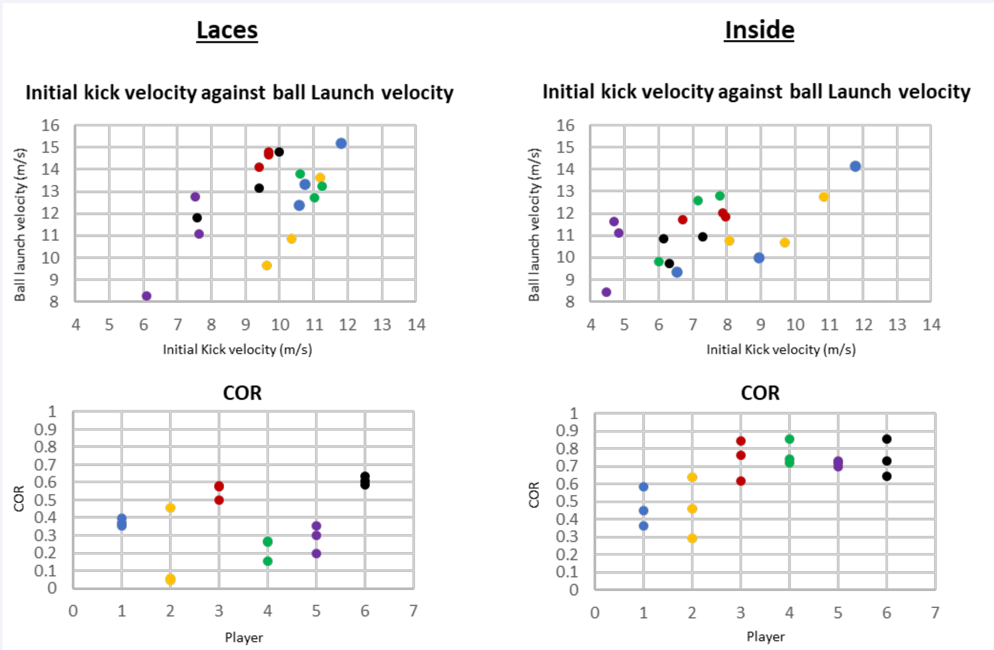

Figure 9 IKV against BLV and COR of each player.

started their kick at the same time, allowing direct comparison in how each player kicked. Players 1-3 maintained minimal rotation, as they went through their kick. Players 5 and 6, stressed more inwards, where inversion was more likely to have occurred at the start of the BS. Player 5 had low BS, but greater angular velocity around the ankle to connect the ball. The drastic motion of player 4 was also evident, as the kicks could be described as “snap shots”. Players 4/6 experienced greater number of smaller peaks, which showed how as the kick was going through, their ankle rotations altered prior to BC, which could mean their starting position was not ideal, but knew what to do in order to get required connection.

Player 5 took big plantar flexion angles as the kick phase started and did not kick with great speed or BS distance; hence this shows the technique emphasizing the AS they are familiarized with. Player 2 showed one of the highest BS for Inside shot, and it shows that the ankle maintained their position of Dorsiflexion upon kick, with low BC point. During the BS phase, the Lateral rotation showed how some players “opened out” their foot, as the Z axis going down showed abduction (Players 1/3/6). Player 5 stressed more inwards, where adduction was more likely to have occurred at the start of the BS. This could suggest more stresses felt around the first metatarsal - phalange joint. Player 2/4 show that as the kick went through, they shot “inside-out”, meaning they applied effort on an inner angle upon contact before FT brought their ankle back out.

Prior to peak values, which show the shot taken, the potential ankle changes are shown as difference between the angular velocity before the kick phase starts, displaying AS at the start of the kick phase and how it maneuvered, under player control. Every player has a different AS at start, but rate of ankle rotation, provides a “forced motions”; identifying what ankle biomechanics direction they want to apply. This behavior is studied to understand what the player thinks is correct for execution. Figure 11/12 displaying graphical analysis of the rate in angle changes of ankle position; before the kick started. The “adjustment” is monitored to understand how ankle changes could have differed to the final BC stance. Each shot has its own unique plot line markers on top (box, circle, line, diamond), corresponding to each axis movement, to identify the same shot upon the 3 axis graphs. The bottom marker starts at IKV, and top marker, resultant BLV (Figure 10).

(Figure 11) From the ankle rotations Player 3’s consistency be all axes have shown a similar region of changes, with very similar KB difference. Based on this set of results, Player 3 has a strong claim to be best kicker. With rate of changes, Player 1 showed the most variance, but still managed to connect the ball in a similar region. This player who had powerful swings, still managed to adjust the ankle in time to match consistent hits.

Player 5 (circle) *vs.* Player 6 (box); started with similar ankle rotations to get Eversion/Plantar flexion. Player 6 managed to get a slightly higher BLV, with more BS but less plantar flexion AS at BC (-26), allowing more of the first metatarsal connection being angled to distribute greater surface area onto the ball.

All players at the initial phase rotated for a plantar flexed stance, however when closely looking at the smaller peaks, Player 4 experienced dorsiflexion and plantar flexion inconsistently, which could indicate why upon viewing kick, the technique seemed unique. All of Player 4’s shots show that they were “forcing” inner ankle movement (supination), which adds stress onto the first metatarsal.

Player 2’s weakest kick (line) suggests that the AS was almost executing a “toe kick” with very low contact (0.04m), highlighting potential risk of injury to the phalanges and distal bone. Player 3 showed similar AVR to Player 2, but had very different shot outcomes. Major difference was contact angle being 10 degrees greater plantar at point of contact for Player 2, at similar BC height. The muscle mass could have affected this, had that been taken into consideration analyzing could have shown difference. However, Player 2 displayed they could generate sufficient speed with their other kicks. Including a larger BS, justifying importance in BC.

Comparing Player 6, two shots with almost identical Adduction (box vs. line), emphasizing the stiff posture, shows that the differences are marginal, in Eversion and Plantar flexion experienced. Kicking at the same height on ball, contact angle within approx. 4-degree difference, resulted in similar kick to ball speed change (2m/s). This shows that the technique is consistent for Player 6, as they exerted lower BS for the weaker shot (approx. 16cm), but with very similar FT. Player 3/6 is an example, of how consistency in their rotation, didn’t hinder their natural ability to strike the ball well, producing good KB, emphasizing their technique is honed (Figure 11).

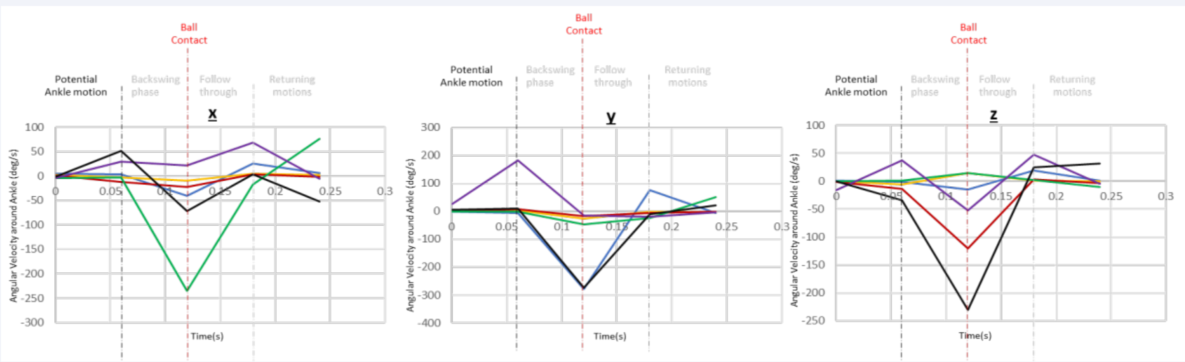

Figure 10 IMU Gyroscope plot- Sample Laces shot graph analysis.

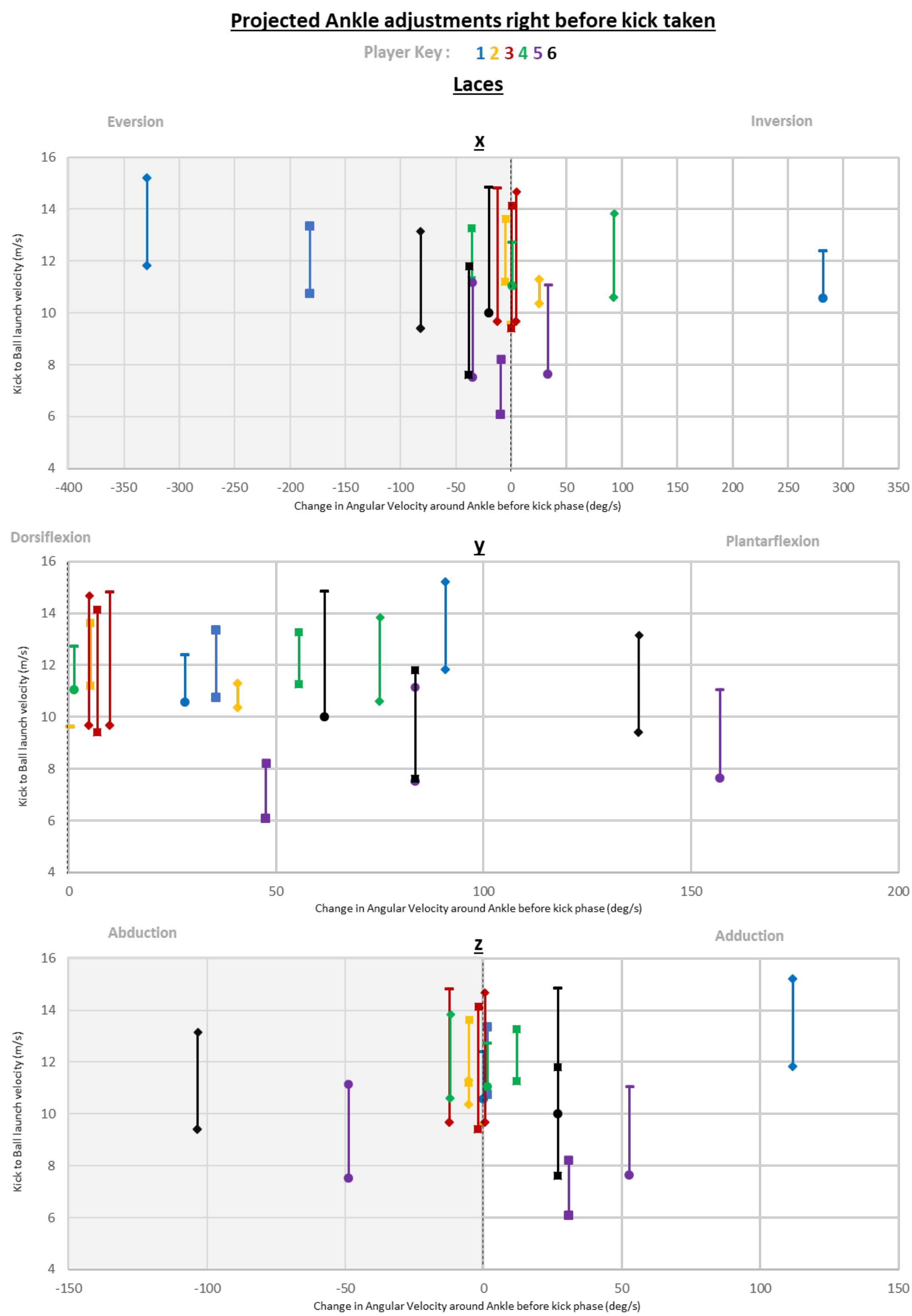

Figure 11 Laces shot change in AVR experienced by ankle with KB velocity.

(Figure 12) The ranges between Eversion/Inversion were similar between players, as were Plantar/Dorsiflexion. This suggests their ease of approach for this type of shot, and how laces are more difficult to shoot. Player 5 approached with the least effort, still experienced more rotations but made sure they matched similar BC, which proves they are used to delivering 1 step kicks. This hints at their playing style during training observation, known as someone that played "with flair", they believed in their ability to achieve set distance with the least amount of effort. Their role in the team, and their gameplay,

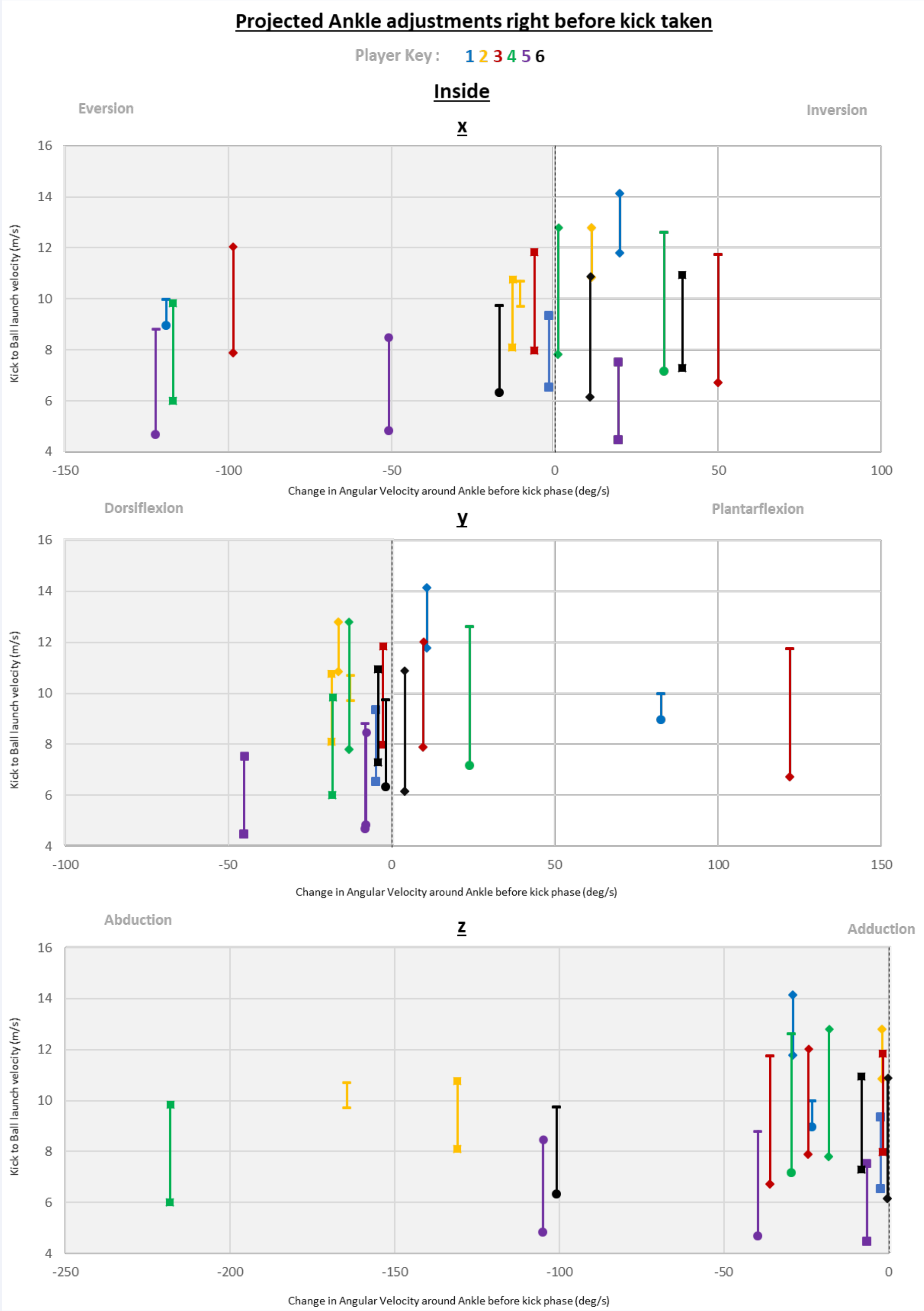

Figure 12 Inside shot change in AVR experienced by ankle with KB velocity.

effectively gave a "football personality" associated with this. This should be considered as it links to how a player profile is built for the team, and how their biomechanics reflect this. Player 3, who was considered the best kicker, had a varied range in inside kick analysis, with BC and AS, but still manages good BLV, suggesting this player's best attribute would be their power.

Player 6 is the most consistent comparing to all axes, their range was the lowest. Player 4 experienced more rotations, which would emphasize that even when BS is not exceeding the limits, the rate of change shows that they are applying excessive effort on forcing that rotation of the ankle to connect the ball. Even with BC inconsistency, the actual KB was good. This shows how analysis made by video and sensor, could lead to understanding unique player ability, something that subjective opinions may not highlight.

All players initially forced Abduction, emphasizing rotation laterally before they struck the ball. Player 2 showed their significant difference in this ankle rotation compared to their others. Player 1 maintained angle range of BC and rate of Abduction changes. Like Laces shots, this player adjusts quickly to match consistent BCs, however their BLV are not the best. Player 1/2 have bigger potential, because they know what their leg must do, to deliver consistent kicks (Figure 12).

The Decision matrix is designed to consider all tracked features (attribute weighing in column bracket). For this set, the scoring worked in reverse principles because the ranking was based on best being "1"; (lowest total is regarded as the best kicker). Laces shots are harder to execute than inside, hence all their tracked features have a higher weighing. The validity of the actual values is based on VPA and IMU data, however this gives more context to how close subjective opinions match these data. Low standard deviation was used for anything IMU related, due to 3 axes being involved. For standalone analysis, average calculations were made, before ranking chronologically (Table 5).

REVIEW

VPA upon 2nd analysis redo, stopped tracking. This meant plot points for VP had to be made manually. This reduced the chance of systematic errors, but because human errors being more prone, this step was done 3 times, and checked if the values were close (<0.04m/ ±0.2ms^{-1}). Player 4 was the only player who was left footed, hence the camera was turned around for analyzing; VPA IMU values had to be inverted where necessary (negative - positive) any horizontal axis (Inversion/Eversion-Abduction/ Adduction) is flipped to match the right footed players. VPA data would not have affected these results as the ball size was manually adjusted based on pixels for every cropped video.

To understand the acceleration of a kick, the mass of leg should be known. The weight of the players was not calculated. This is different for each player, and even though, a leg's relative weight is approx. 6% body weight (male/female differs) the ball launch speeds get judged as performance, rather than kick speed [22]. Hence kicking efficiency is computed with COR for this experiment.

IMU sensor had to have adjusted values, as tolerance at standstill showed; Accelerometer 0.15 m/s2 ±0.03; Gyroscope -1.03 deg/s ±0.09, which were not too drastic. The Z axis on the accelerometer was reading approx. 9.8m/s2 (gravitational force). There were 11/72 accelerator readings had error, (monitored values too low- unreliability concern). The gyroscope was more consistent in showing more realistic values. Anomalies occurred more in trial tests and could have been more visible in experiment with greater sample.

If Decision matrix had considered higher scoring for sensor readings, the perception may have allowed Player 3 to be the best kicker, without COR consideration. The Gyroscope AVR showed consistency for Player 3's laces kick, conveying the qualities of a player that knows how to alter their AS and transfer their energy properly upon BC. From analyzed elements, Player 1/2/3 knew what their body's capability were. IMU sensor showed that there is more reliance in linking shot types to Gyroscope readings when attached to boot because the rotation was monitored for BC purposes. Placement of sensors in other parts of the leg, could show another source of physical data. However, when trying got distinguish the type of shot taken, there is always a need to know the AS upon BC.

Monitoring has shown in Player 4's case; who performs unorthodox kicking methods, yet still produce good BLV, their technique was hard to deduce during observation but sensor and video analysis showed how every player has exclusive methods. This can help visualize human centered design solutions for player specific data. Kinematic analysis of how the knee bends with BS, and extends in FT, could have developed more insights into this unique player's technique, and whether it can be a positive performance indicator.

Player 3's claim to be the best kicker relies on their consistent form, and how even if the player has taken a lot of FT strain, their level of consistency shown and execution meant that this player is able to do this, without hindering performance. Player 6 is a defender who was known to be a good shooter; Player 2 (other defender) was known to be more powerful. Analysis between them supports the claim that, even for the same position player, attribute traits are different, but similar approach. When comparing their respective velocity graphs which illustrate how well the acceleration/deceleration phases are, it is easy to see how the more powerful kickers achieved a greater BLV due to good BC.

Overseeing training, Player 3/5 had promising prospect of delivering good shots. During observation, Player 3 did look like the best kicker. Revaluating collective data for this experiment, multiple reviews of video and understanding the different factors of tracked features relating to biomechanics, Player 6 is graded as the best kicker. This is relative to the decision matrix scoring principles set. Post analysis data feedback was given to players, regarding their motion, discussing what they do well, and how their kicking could be improved. Players that can remind themselves of what they have done well, giving them "reference points" in relation to biomechanics to recall, as they perform kicks. With the aid of video and sensor analytic data; improvement in consistency and maintaining quality of good kicks is possible (Table 6).

FUTURE

Only BC was monitored as this was a refined element to truly differentiate laces and inside foot shots. Other biomechanical features do not directly involve the type of shot taken, however more experiments can help classify body part behavior in relation to quality of football kicks using video tracking and sensor placement [18]. Future study into how other body parts work simultaneously to affect the type of contact can build more tracked features to be calculated. This is something that could benefit Players 1/2 who can learn if other body mechanics are affecting their consistency, as their ankle biomechanics know what to do to assign the desired kick.

Table 5: Decision Matrix ranking of Player tracked attributes*.

Player	Player 1	Player 2	Player 3	Player 4	Player 5	Player 6
Initial Rank	4	6	1	5	3	2
La. KB (10)	3	6	1	5	4	2
La. BCC (8)	5	4	1	6	3	2
La. ST (6)	4	5	3	6	1	2
La. EFF (6)	3	6	2	5	4	1
La. AVR (4)	6	2	1	3	4	5
La. AR (2)	2	4	5	3	1	6
In. KB (9)	5	6	2	1	4	3
In. BCC (7)	5	2	4	6	1	3
In. ST (5)	4	6	5	3	1	2
In. EFF (5)	5	6	3	1	4	2
In. AVR (3)	3	2	5	6	4	1
In. AR (1)	1	5	4	6	3	2
DS	275	313	167	277	195	159
Final Rank	4	6	2	5	3	1

*PL = Player; La. = Laces shot; In. = Inside Shot; IR = Initial ranking based on observations; EFF = Efficiency of BS/FT; AR = Angle range on contact; AVR = Angular velocity range; KB = Kick to ball velocity range; BCC = BC consistency; DS = Decision matrix score (low ranks highest).

Table 6: Post Analysis Discussion.

Player	Post Analysis Discussion
Player 1 Forward	Good kicker, with better potential if Player improves their FT. They know what they must do, to kick well, hence working with efficiency could help increase quality of kicks. Laces kicks do not need to require too much effort and Inside kicks could be better.
Player 2 Defender	Improving "BC" needed, as the kicks were fast relative to ball. Showed signs of consistent ankle rotation rates, suggesting they know what makes a good kick, just needs to consider applying less effort to maintain better ball connection. Do not need to get underneath the ball for every kick.
Player 3 Midfielder	Technique honed for laces, has "raw power". Building a consistent technique for inside kicks and efficiency could make this player better relative to position and role.
Player 4 Forward	Capabilities seemed unique but managed to get good ball velocity. Could improve a lot on efficiency, but unique approach should stay due to promising results. Discussed if kicks cause any overuse injuries, and insights were built in how to not overstretch on FT.
Player 5 Midfielder	Due to nature of gameplay and role; kicks did not require effort. Natural ability in striking well but would want more of the Managed to have better BLV with low BS. Would be interesting to see performance regarding long passes.
Player 6 Defender	According to data, was a better kicker than initially visualized? Inside foot shots, does not always need trajectory, as Defenders still need to be able to kick along the ground.

Understanding sensor could have benefitted with a Test rig; where the kick speed is "assigned" in a controlled environment (increasing reliability). Function in type of sensor can depend on location, which could increase tracked biomechanics features [3,23,24]. How frequently can good kicks be achieved, could provide "fatigue factor", relying on load calculation from additional sensors used. Sensor on hip could analyze if balance results in less effort, for same distance ball travelled. Stadiometer and electronic scale can further enhance player information, then form more relevant data to compute against subjective opinions. Kick power could be captured regarding how far it travels (benefits defenders/midfielders) [25].

Ball used were Size 5, pumped to a satisfactory standard, however the precise pressure of the ball was not measured (aerodynamic effects with pressure links to the stitch designs on footballs) [16]. Boot design can also affect ball deformation upon BC [26]. Indoor tests can reduce concerns of air resistance. Phone camera not being able to view the whole length from ball to target, means the actual ball velocity at target line was not calculated, which could have varied through distance (acceleration dependent). BLV was monitored, how quick it reached passed the camera screen, which the application still computed (Ball tracking). Upgrading to sports cameras and additional placement with processing on PC software; are all future alternatives and control measures [27].

With multiple targets, and varying distance, the kicker rank could have altered, as perception of players could change. Not having a run up could be a factor in them not giving their "best possible kick", so various approach methods will need to be planned. The positions were relative to the 3 outfield options. To delve deeper into understanding football personalities associated with specific player position, future tests will need participants to specifically state their dominant position, such as "Left back defender", or "center back defender"., further enhancing how gameplay and roles of positional players can have different physical attribute demands, towards technical kicking. Players can also state what their desired roles are, to educate them their requirements. Other shot types which require same part of inner foot, such as Curled shots has importance for wide players, regardless of position [28]. Studying hybrid shot between laces/inside, where more connection of first metatarsal and navicular bone with plantarflexed stance, can relate to how the kick affects around the surface of the boot.

CONCLUSION

Full post analysis was shown to educate players, relative to their position and to understand their motivation of approach to gameplay. Hence the impact of this experiment, was greater to participated players, learning their data, (physical capability as performance parameter). Evidently players who can generate greater ball speed with minimum effort (BS) viewed themselves as good shooters. Players who were known not for their power, but finesse-built insights into how biomechanical data exhibited their approach. Defenders who were known to kick powerfully, generated more projectile. Computing efficiency played a big role in Player 6 became higher ranked with weighted Decision matrix scoring.

Subjective opinions during observation were influenced by Researcher's sports background, and coaches' insight. More methods to apply multiple views on players could benefit widening player profile. Different position player have different perception regarding kicking for a set distance. Results supports that data monitoring does show similar perspective on actual player data, but also highlighted other factors that were not found in observation. Findings were relayed back to Team coaches, broadening participated player profiles. More testing is needed with different sensors and linking it to position traits, which can further build Amateur Football position personalities; helping coaches/team selectors identify the type of player they want. Ankle biomechanics data analysis proved very important when reflecting player kicking techniques and approach to gameplay, where unique performances can be compared fairly. There is importance of video and sensor data analysis regarding biomechanics for amateur level sport.

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