



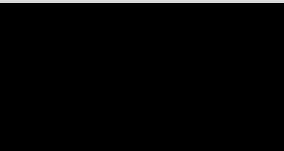
HAWTHORN MEDICAL CENTRE
RUGBY & FOOTBALL BALL STRIKE ASSESSMENT



LABOSPORT

BALL STRIKE ASSESSMENT – HAWTHORN MEDICAL CENTRE

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INTRODUCTION	A rugby pitch and a football pitch at The Armitage Sports Centre - University of Manchester are in close proximity to a proposed new medical centre development. There is a risk that balls may be kicked into the new development causing potential for injury and/or property damage. Reasonable worst-case scenarios were identified for the site, and a sophisticated trajectory model was used to predict the flight path of footballs and rugby balls, based on representative kick scenarios. Analysis of the trajectories reveals the predicted height of the balls as they pass the proposed site boundaries. This information is used to provide recommendations for the height of any required ball stop mitigation in specific locations.
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Section 1 – Site Overview

Site Overview

A rugby pitch and a football pitch at The Armitage Sports Centre - University of Manchester is in close proximity to a proposed new medical centre development, and this report will consider the ball trajectories towards the development in a southerly direction from the pitches. The illustration below provides an overview of the proposed site.



Figure 1. Overview of the site at Moseley Road

The location of the development is in close proximity to the pitch boundaries. There is a risk that balls may be kicked beyond the site boundaries into the development. There is existing fencing around the pitches (shown below), however, there is a chance that balls could surpass this existing mitigation. This report will analyse reasonable worst case ball trajectories to measure shots towards the development and propose a recommended ball containment solution.



Figure 2. Existing mitigation around pitches at The Armitage Sports Centre - University of Manchester

Section 2 –Football Trajectory Model

Football Trajectory Model Overview

A sophisticated three-dimensional trajectory model was developed to analyse the trajectory of the football ball. The model was built in the numerical programming software 'Matlab' and incorporated aerodynamic drag and lift forces, and the complexities arising from the ball's spin rate.

The model used published aerodynamic coefficients taken from wind tunnel studies on football balls at different kick velocities (Asai, T., Seo, K., Kobayashi, O. *et al.* Fundamental aerodynamics of the soccer ball. Sports Eng 10, 101–109).

The aerodynamic forces of drag (F_D) and lift (F_L) are proportional to the ball's velocity relative to the air flow, frontal area, air density and the drag coefficient respectively lift coefficient. The forces are defined as:

$$F_D = \frac{1}{2} C_D \rho V^2 A$$

$$F_L = \frac{1}{2} C_L \rho V^2 A$$

with C_D and C_L are the non-dimensional drag and lift coefficients, ρ the air density in kg/m^3 , V the air stream velocity in m/s and A the frontal area of the ball in m^2 .

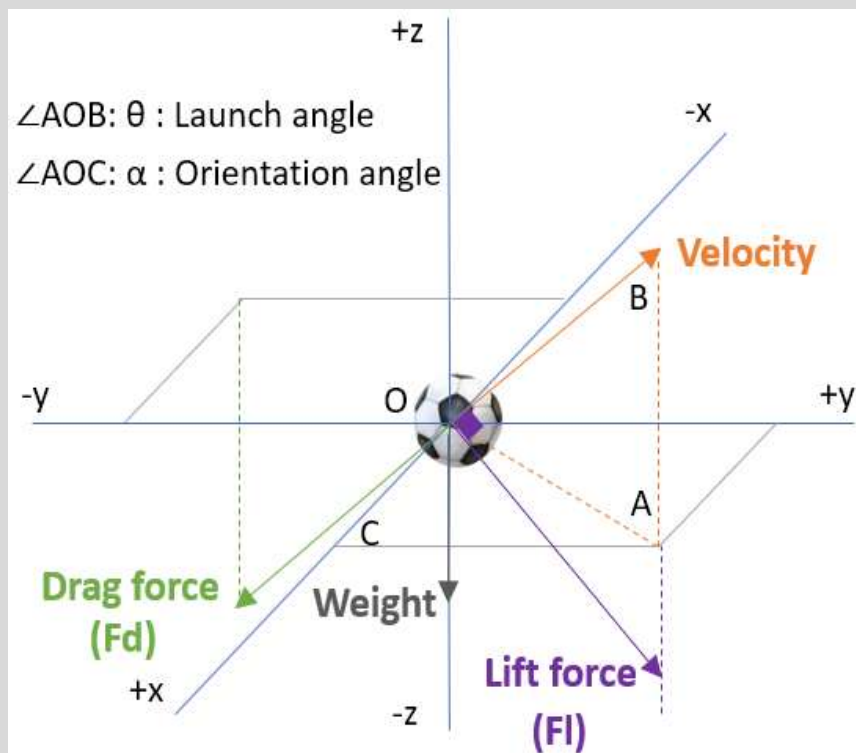


Figure 3. A free body diagram for the football ball trajectory model showing the aerodynamic drag and lift forces.

Due to the complexity of the flight dynamics, the trajectory can only be resolved by using a numerical time step approach whereby the ball conditions are calculated at small timesteps throughout the trajectory. The conditions at time step 1 are used to calculate the conditions at time step 2; the conditions at timestep 2 are used to calculate the conditions at time step 3 and henceforth. A timestep of 0.001 seconds was used to generate high-resolution trajectory data.

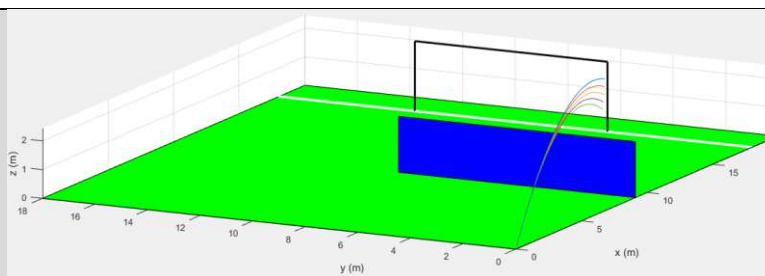


Figure 4. An example of a trajectory simulation from the Matlab model.

Trajectory models are known to exhibit high accuracy; however, it is not possible to model the full complexity of the real world and the model developed for this project is best regarded as an indicative predictive tool.

Football Kick Scenarios

In the game of football, the ball can be kicked in any direction with a wide range of velocities. Nonetheless, some trajectories are far more common than others. This risk assessment uses a proportionate approach by focusing on the common trajectories to determine the most likely scenarios where a ball may surpass the site boundary.

Labosport has significant experience and expertise in football and provides technical support to the world's national governing bodies (e.g. the FA, FFF, KNVB etc) as well as to FIFA. Labosport have drawn on their expertise to define four different in game scenarios where the ball may be kicked on a trajectory that surpasses the site boundary.

For each kick scenario, a reasonable initial speed is determined, and the trajectory is simulated for a range of different launch angles (25 degrees to 35 degrees).

Football Kick Velocities

In the game of football, the ball can be kicked with a wide range of velocities (speeds and angles). Nonetheless, previous researchers have made accurate measurements of ball speeds and spin rates using high speed video and similar technologies. The table below summarises maximal kick velocities from three different studies (taken from; Sterzing, Thorsten, and Ewald M. Hennig. "The influence of soccer shoes on kicking velocity in full-instep kicks." Exercise and Sport Sciences Reviews 36.2 (2008): 91-97).

TABLE 1. Maximum resultant ball velocity achieved with selected kicking techniques.

Study/Authors	Kicking Technique	Maximum Ball Velocity (ms ⁻¹)	SD (ms ⁻¹)	Subject Characterization
Levanon and Dapena (1998) (15)	Full-instep	28.6	2.2	Intercollegiate players, n = 6
	Side-foot	22.5	1.8	
Nunome et al. (2002) (18)	Full-instep	28.0	2.1	High school players, n = 5
	Side-foot	23.4	1.7	
Neilson and Jones (2005) (17)	Full-instep	27.1	2.2	Professional club players, n = 25
	Inner-instep	23.5	2.3	
	Outer-instep	20.9	3.1	

Figure 5. Maximum resultant ball velocity achieved with selected kicking techniques overview

We also have to consider the level of play and age when considering velocities. The table below defines the findings collated from the study into 'Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously'. (Luiz H. P. Vieira et al. (2018) Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously, Research Quarterly for Exercise and Sport, 89:2, 210-220).

Table 1. Mean $\pm$ standard deviation (95% confidence limits) for kicking performance variables according to age ($n = 366$).

	U9	U11	U13	U15	U17	U20
V_{ball} (km/hr ⁻¹)	48.54 $\pm$ 8.31 ^{a, b, c, d} [42.96, 54.12]	57.87 $\pm$ 10.93 ^{e, f, g, h} [55.32, 60.42]	66.70 $\pm$ 13 ^{i, j, k} [63.81, 69.60]	76.92 $\pm$ 15.58 ^l [73.90, 79.93]	81.35 $\pm$ 16.04 ^m [77.74, 84.97]	98.74 $\pm$ 16.35 [90.55, 106.62]
V_{foot} (km/hr ⁻¹)	49.08 $\pm$ 5.16 ^{a, b, c, d} [45.62, 52.55]	53.79 $\pm$ 7.25 ^{e, f, g, h} [52.10, 55.48]	60.54 $\pm$ 8.77 ^{i, j, k} [58.58, 62.49]	65.17 $\pm$ 10.43 ^l [63.15, 67.19]	68.44 $\pm$ 11.83 ^m [65.77, 71.10]	78.24 $\pm$ 9.49 [73.66, 82.81]
V_{ball}/V_{foot} ratio (a.u.)	0.99 $\pm$ 0.13 ^{a, b, c, d} [0.90, 1.07]	1.07 $\pm$ 0.11 ^{f, g, h} [1.05, 1.10]	1.1 $\pm$ 0.11 ^{i, j, k} [1.07, 1.12]	1.18 $\pm$ 0.1 ^l [1.16, 1.20]	1.19 $\pm$ 0.1 [1.16, 1.21]	1.26 $\pm$ 0.11 [1.21, 1.31]
LSL (m)	1.09 $\pm$ 0.14 ^{a, b, c, d} [1.00, 1.18]	1.25 $\pm$ 0.14 ^{e, f, g, h} [1.21, 1.28]	1.36 $\pm$ 0.19 ^k [1.32, 1.40]	1.43 $\pm$ 0.23 ^l [1.38, 1.47]	1.44 $\pm$ 0.2 ^m [1.39, 1.48]	1.6 $\pm$ 0.14 [1.54, 1.67]
$D_{support-ball}$ (m)	0.33 $\pm$ 0.07 [0.28, 0.37]	0.3 $\pm$ 0.07 ^{e, f, g} [0.29, 0.32]	0.34 $\pm$ 0.06 [0.33, 0.35]	0.34 $\pm$ 0.09 [0.33, 0.36]	0.34 $\pm$ 0.06 [0.33, 0.36]	0.35 $\pm$ 0.04 [0.32, 0.37]
MRE (m)	1.4 $\pm$ 0.49 [1.07, 1.73]	1.65 $\pm$ 0.6 ^{f, g, h} [1.52, 1.79]	1.59 $\pm$ 0.59 ^{i, j, k} [1.46, 1.72]	1.34 $\pm$ 0.48 [1.24, 1.43]	1.29 $\pm$ 0.5 [1.18, 1.40]	1.14 $\pm$ 0.35 [0.98, 1.31]
BVE (m)	1.26 $\pm$ 0.58 [0.87, 1.65]	1.47 $\pm$ 0.73 ^{f, g, h} [1.31, 1.64]	1.30 $\pm$ 0.57 [1.17, 1.43]	1.18 $\pm$ 0.51 [1.08, 1.27]	1.17 $\pm$ 0.5 [1.06, 1.28]	1.05 $\pm$ 0.32 [0.90, 1.21]
ACUR (m)	1.93 $\pm$ 0.64 [1.50, 2.36]	2.25 $\pm$ 0.84 ^{f, g, h} [2.06, 2.45]	2.09 $\pm$ 0.72 [1.93, 2.25]	1.81 $\pm$ 0.62 [1.69, 1.93]	1.77 $\pm$ 0.5 [1.63, 1.92]	1.57 $\pm$ 0.4 [1.38, 1.76]

Note. a = U9 $\times$ U13; b = U9 $\times$ U15; c = U9 $\times$ U17; d = U9 $\times$ U20; e = U11 $\times$ U13; f = U11 $\times$ U15; g = U11 $\times$ U17; h = U11 $\times$ U20; i = U13 $\times$ U15; j = U13 $\times$ U17; k = U13 $\times$ U20; l = U15 $\times$ U20; m = U17 $\times$ U20. Confidence limits = (lower, upper bound). V_{ball} = ball velocity; V_{foot} = foot velocity; V_{ball}/V_{foot} = ball velocity-to-foot velocity ratio; LSL = last stride length; $D_{support-ball}$ = distance between support foot and ball; MRE = mean radial error; BVE = bivariate variable error; ACUR = accuracy. Significance level of post-hoc comparisons: V_{ball} = ^{a, e} $p < .01$. ^{b, c, d, f, g, h, i, j, k, l, m} $p < .001$. V_{foot} = ⁱ $p < .05$. ^{a, m} $p < .01$. ^{b, c, d, e, f, g, h, i, j, k, l} $p < .001$. V_{ball}/V_{foot} ratio = ^{a, l} $p < .05$. ^{b, c, d, f, g, h, i, j, k} $p < .001$. LSL = ^{e, l, m} $p < .01$. ^{a, b, b, d, f, g, h, k} $p < .001$. $D_{support-ball}$ = ^{e, f, g} $p < .01$. MRE = ^{i, k} $p < .05$. ^{f, h, j} $p < .01$. ^g $p < .001$. BVE = ^{g, h} $p < .05$. ^f $p < .01$. ACUR = ^{j, k} $p < .05$. ^h $p < .01$. ^{f, g} $p < .001$.

Figure 6. Mean standard deviation for kicking performance variables according to age

The pitch at The Armitage Sports Centre - University of Manchester will be a predominantly senior pitch, therefore, a maximal kick velocity of 28 m/s for senior level play with a spin rate of 40 rad/s has been selected for this ball strike assessment.

Section 3 – Trajectory Model Simulations

Trajectory simulation

The diagram below shows a global view of the five different football trajectory scenarios that will be considered for the football pitch.



Figure 7. A global overview of the site with the five different trajectory scenarios identified for the football pitch.

Shot 1 – A football clearance (28 m/s ball speed)

- 6.74 metres to the pitch boundary.
- 15.25 metres to the proposed development.

Kick launch angle (degrees)	20	25	30	35
Predicted trajectory height at pitch boundary (m)	2.02	2.68	3.40	4.18
Predicted trajectory height at development boundary (m)	3.20	4.53	5.93	7.39

Shot 2 – A penalty missing the goal high (28 m/s ball speed)

- 17.37 metres to the pitch boundary.
- 21.99 metres to the proposed development.

Kick launch angle (degrees)	20	25	30	35
Predicted trajectory height at pitch boundary (m)	3.22	4.68	6.18	7.72
Predicted trajectory height at development boundary (m)	2.85	4.50	6.11	7.64

Shot 3 – A penalty missing the goal wide (28 m/s ball speed)

- 22.24 metres to the pitch boundary.
- 28.06 metres to the proposed development.

Kick launch angle (degrees)	20	25	30	35
Predicted trajectory height at pitch boundary (m)	2.82	4.46	6.08	7.61
Predicted trajectory height at development boundary (m)	1.50	3.17	4.63	5.70

Shot 4 – A football clearance (28 m/s ball speed)

- 12.53 metres to the pitch boundary.
- 20.18 metres to the proposed development.

Kick launch angle (degrees)	20	25	30	35
Predicted trajectory height at pitch boundary (m)	3.01	4.16	5.37	6.68
Predicted trajectory height at development boundary (m)	3.06	4.65	6.24	7.81

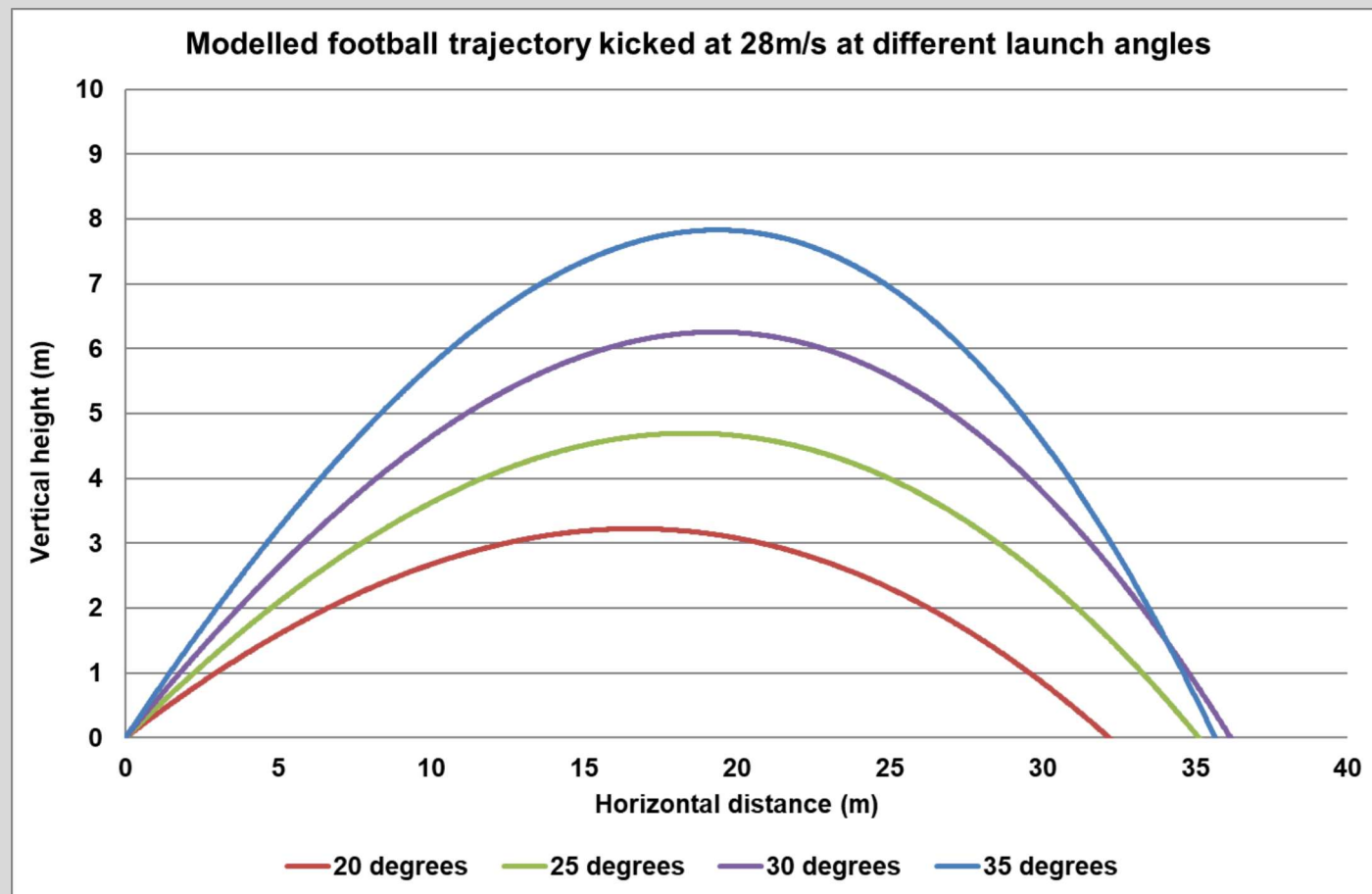


Figure 8. Modelled football trajectories at 28 m/s.

Section 4 –Rugby Trajectory Model

Rugby Trajectory Model Overview

Labosport have developed a sophisticated trajectory model to analyse the trajectory of the rugby ball. The model was built in the numerical programming software 'Matlab' and incorporated aerodynamic drag and lift forces, and the significant complexities arising from the ball's rotation and its spheroid shape.

Under rotation, the rugby ball's cross-sectional frontal area constantly changes in relation to air flow. The angle of attack between the velocity of the ball and its pitch is also subject to continuous change as the ball rotates. Angle of attack, and cross-sectional area are both important determinants of the ball's aerodynamic coefficients and were accounted for in the model.

A SolidWorks model (size of Gilbert 'Match XV') was used to determine the frontal area by projecting the body onto planes from 0° to 90° relative to the longitudinal axes in interval steps of 10°. The results were imported to Matlab's curve-fitting-tool to create a continuous function to allow the calculation of frontal area at each time step through flight.

The model used published aerodynamic coefficients taken from wind tunnel studies on rugby balls at different angle of attack to the airflow (Seo et al. 2004, plus Djamovski et al. 2012).

The aerodynamic forces of drag (F_D) and lift (F_L) are proportional to the balls velocity relative to the air flow, frontal area, air density and the drag coefficient respectively lift coefficient. The forces are defined as:

$$F_D = \frac{1}{2} C_D \rho V^2 A$$

$$F_L = \frac{1}{2} C_L \rho V^2 A$$

with C_D and C_L are the non-dimensional drag and lift coefficients, ρ the air density in kg/m^3 , V the air stream velocity in m/s and A the frontal area of the ball in m^2 .

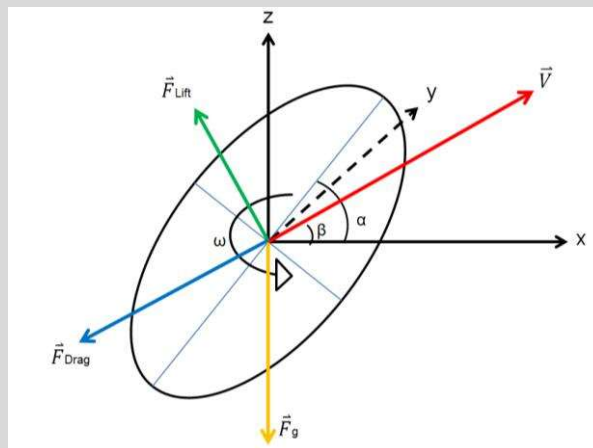


Figure 9. A free body diagram for the rugby ball trajectory model showing the aerodynamic drag and lift forces.

Due to the complexity of the flight dynamics, the trajectory can only be resolved by using a numerical time step approach whereby the ball conditions are calculated at small timesteps throughout the trajectory. The conditions at time step 1 are used to calculate the conditions at time step 2; the conditions at timestep 2 are used to calculate the conditions at time step 3 and henceforth. A timestep of 0.001 seconds was used to generate high-resolution trajectory data.

Rugby Trajectory Model Validation

The model was validated by comparing the computational output to an actual measured rugby ball trajectory. In his PhD thesis, Holmes (2008) created a kicking machine to investigate the flight distance and time of flight for different rugby balls in an indoor aircraft hangar (to avoid the influence of wind). Holmes also accurately measured the launch conditions from his kicking machine using high speed video.

The launch conditions measured by Holmes were used as inputs to the trajectory model and the predicted flight distance and time of flight were calculated. The model calculations were found to be very close to the measured trajectory and the model was deemed to be accurately validated.

	Holmes (2008) measured flight data	Trajectory model calculated flight data
Distance (m)	56.8	58.3
Time of flight (s)	3.70	3.74

Table 1. Validation of the trajectory model by comparison to measured flight data

Rugby Kick Scenarios (relevant to this site)

This report will consider various different reasonable worst case trajectory scenarios for the pitch. In the game of Rugby Union, the ball can be kicked in various directions and with a range of velocities. Nonetheless, some trajectories are far more common than others. This trajectory assessment uses a proportionate approach by focusing on the common trajectories to determine the most likely scenarios where a ball may surpass the site boundary.

Labosport has significant experience and expertise in rugby and provides technical support to Rugby Football League, World Rugby, and the RFU. Labosport have drawn on their expertise to define trajectory scenarios where the ball may be kicked on a trajectory that surpasses the site boundary.

Conversion/penalty kicks

Numerous researchers have measured the ball launch dynamics in rugby conversion/penalty kicks using high speed video techniques or Doppler radar speed guns. Table 2 shows a summary of ball launch conditions as reported in six different peer reviewed scientific journal publications. Of these studies, the work of Holmes *et al* (2006) is the most comprehensive for professional players, and the work of Sinclair *et al* (2014) is the most comprehensive for amateur players.

	Participants	2D/3D Data	Ball velocity (m/s)	Launch angle (°)	End-over-end spin (°/s)
Ball (2010) *	7 professionals	2D	25.2 ± 4.0	36 ± 3	
Bezodis <i>et al.</i> (2007)	5 amateurs	3D	24.5 ± 1.0	35	
Holmes <i>et al.</i> (2006)	14 professionals	2D	26.4 ± 3.0	30 ± 4	1440 ± 252
Linthorne & Stokes (2014)	1 amateur	2D	26.2 ± 1.7	31 ± 5	
Sinclair <i>et al.</i> (2014)	20 amateurs	3D	26.6 ± 1.6	34 ± 2	
Zhang <i>et al.</i> (2012)	7 amateurs	3D	17.8 ± 2.5		

* The studied participants were Rugby League players

Figure 10. A summary of ball launch conditions as reported in six peer reviewed scientific journal publications.

A reasonable worst-case scenario has been identified as a player attempting to score a conversion/penalty is 15 metres from the try line, and directly in front of the goal posts. This scenario is a plausible game event and represents the maximum ball trajectory risk. The relevant ball velocity for this site is 26 m/s and a launch angle of 34°.

Junior conversion/penalty kicks

No peer-reviewed published data is available on youth rugby and ball kick velocities; however, by comparing the difference between youth and adult soccer ball velocities, a reasonable approximation of how ball speed reduces with age can be made. The table below defines the findings collated from the study into 'Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously'. (Luiz H. P. Vieira et al. (2018) Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously, Research Quarterly for Exercise and Sport, 89:2, 210-220).

Table 1. Mean $\pm$ standard deviation (95% confidence limits) for kicking performance variables according to age ($n = 366$).

	U9	U11	U13	U15	U17	U20
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V_{foot} (km/hr ⁻¹)	49.08 $\pm$ 5.16 ^{a, b, c, d} [45.62, 52.55]	53.79 $\pm$ 7.25 ^{e, f, g, h} [52.10, 55.48]	60.54 $\pm$ 8.77 ^{i, j, k} [58.58, 62.49]	65.17 $\pm$ 10.43 ^l [63.15, 67.19]	68.44 $\pm$ 11.83 ^m [65.77, 71.10]	78.24 $\pm$ 9.49 [73.66, 82.81]
V_{ball}/V_{foot} ratio (a.u.)	0.99 $\pm$ 0.13 ^{a, b, c, d} [0.90, 1.07]	1.07 $\pm$ 0.11 ^{e, f, g, h} [1.05, 1.10]	1.1 $\pm$ 0.11 ^{i, j, k} [1.07, 1.12]	1.18 $\pm$ 0.1 ^l [1.16, 1.20]	1.19 $\pm$ 0.1 [1.16, 1.21]	1.26 $\pm$ 0.11 [1.21, 1.31]
LSL (m)	1.09 $\pm$ 0.14 ^{a, b, c, d} [1.00, 1.18]	1.25 $\pm$ 0.14 ^{e, f, g, h} [1.21, 1.28]	1.36 $\pm$ 0.19 ^k [1.32, 1.40]	1.43 $\pm$ 0.23 ^l [1.38, 1.47]	1.44 $\pm$ 0.2 ^m [1.39, 1.48]	1.6 $\pm$ 0.14 [1.54, 1.67]
$D_{support-ball}$ (m)	0.33 $\pm$ 0.07 [0.28, 0.37]	0.3 $\pm$ 0.07 ^{e, f, g} [0.29, 0.32]	0.34 $\pm$ 0.06 [0.33, 0.35]	0.34 $\pm$ 0.09 [0.33, 0.36]	0.34 $\pm$ 0.06 [0.33, 0.36]	0.35 $\pm$ 0.04 [0.32, 0.37]
MRE (m)	1.4 $\pm$ 0.49 [1.07, 1.73]	1.65 $\pm$ 0.6 ^{f, g, h} [1.52, 1.79]	1.59 $\pm$ 0.59 ^{i, j, k} [1.46, 1.72]	1.34 $\pm$ 0.48 [1.24, 1.43]	1.29 $\pm$ 0.5 [1.18, 1.40]	1.14 $\pm$ 0.35 [0.98, 1.31]
BVE (m)	1.26 $\pm$ 0.58 [0.87, 1.65]	1.47 $\pm$ 0.73 ^{f, g, h} [1.31, 1.64]	1.30 $\pm$ 0.57 [1.17, 1.43]	1.18 $\pm$ 0.51 [1.08, 1.27]	1.17 $\pm$ 0.5 [1.06, 1.28]	1.05 $\pm$ 0.32 [0.90, 1.21]
ACUR (m)	1.93 $\pm$ 0.64 [1.50, 2.36]	2.25 $\pm$ 0.84 ^{f, g, h} [2.06, 2.45]	2.09 $\pm$ 0.72 [1.93, 2.25]	1.81 $\pm$ 0.62 [1.69, 1.93]	1.77 $\pm$ 0.5 [1.63, 1.92]	1.57 $\pm$ 0.4 [1.38, 1.76]

Note. a = U9 $\times$ U13; b = U9 $\times$ U15; c = U9 $\times$ U17; d = U9 $\times$ U20; e = U11 $\times$ U13; f = U11 $\times$ U15; g = U11 $\times$ U17; h = U11 $\times$ U20; i = U13 $\times$ U15; j = U13 $\times$ U17; k = U13 $\times$ U20; l = U15 $\times$ U20; m = U17 $\times$ U20. Confidence limits = (lower, upper bound). V_{ball} = ball velocity; V_{foot} = foot velocity; V_{ball}/V_{foot} = ball velocity-to-foot velocity ratio; LSL = last stride length; $D_{support-ball}$ = distance between support foot and ball; MRE = mean radial error; BVE = bivariate variable error; ACUR = accuracy. Significance level of post-hoc comparisons: V_{ball} = ^{a, e} $p < .01$, ^{b, c, d, f, g, h, i, j, k, l, m} $p < .001$. V_{foot} = ⁱ $p < .05$, ^{a, m} $p < .01$, ^{b, c, d, e, f, g, h, j, k, l} $p < .001$. V_{ball}/V_{foot} ratio = ^{a, l} $p < .05$, ^{b, c, d, f, g, h, i, j, k} $p < .001$. LSL = ^{e, l, m} $p < .01$, ^{a, b, b, d, f, g, h, k} $p < .001$. $D_{support-ball}$ = ^{e, f, g} $p < .01$. MRE = ^{i, k} $p < .05$, ^{f, h, j} $p < .01$, ^g $p < .001$. BVE = ^{g, h} $p < .05$, ^f $p < .01$. ACUR = ^{j, k} $p < .05$, ^h $p < .01$, ^{f, g} $p < .001$.

Figure 11 - Mean standard deviation for kicking performance variables according to age

Kicking the ball into touch

Within the game of rugby union, a ball may surpass a boundary when a player 'kicks the ball into touch' to achieve an attacking line out after a penalty. In this scenario, the ball is launched via a punt kick out of the hands.

A reasonable worst-case scenario has been identified as a player attempting to punt kick the ball into touch at a location of 10 metres inside the touch line, and at an angle of 45 degrees towards the opponent's goal. This scenario is a plausible game event and represents the maximum ball trajectory risk to the site boundary which can occur at any point on the boundary.

Pavely, Stuart et al (2010) analysed maximal punt kicks out of the hands from 10 professional rugby players. The mean measured distance of the kicks was 42 metres, and the mean launch angle was 18 degrees. This study determined a punt kick velocity of 28 m/s.

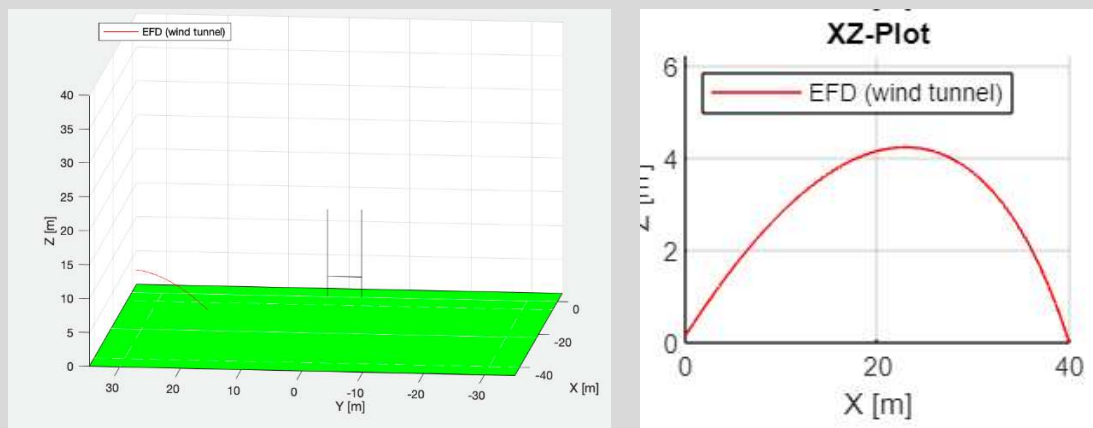


Figure 12 – Trajectory visualisation of a punt into the corner

Section 5 – Trajectory Model Simulations

Trajectory simulation

The diagrams below shows a global view of the two different rugby ball trajectory scenarios that will be considered for the rugby pitch.



Figure 13. A global overview of the site with the two different trajectory scenarios identified for the rugby pitch

Shot 1 – Rugby kick into touch – 22.06 metres to the edge of the proposed car park location

The distance to the pitch boundary is **15.6 metres**. The trajectory model predicts that the rugby ball will have height **3.75m** as it reaches the pitch boundary. However, if the ball surpasses the existing mitigation it is predicted to have a height of **4.23m** as it reaches the boundary of the proposed car park. Note this trajectory can take place anywhere along the touchline and the worst-case scenario will be chosen for mitigation.

Shot 2 – Rugby kick into touch – 17.66 metres to the edge of the proposed car park location

The distance to the pitch boundary is **12.07 metres**. The trajectory model predicts that the rugby ball will have height **3.22m** as it reaches the pitch boundary. However, if the ball surpasses the existing mitigation it is predicted to have a height of **3.98m** as it reaches the boundary of the proposed car park. Note this trajectory can take place anywhere along the touchline and the worst-case scenario will be chosen for mitigation.

Section 6 – Discussions and Conclusions

Discussions and Conclusions

This report has been prepared to assess the potential risk of balls surpassing the boundaries of the football and rugby pitches at The Armitage Sports Centre - University of Manchester and to advise on the mitigation recommended to provide a suitable level of protection to the proposed development at Moseley Road, Manchester.

The exact frequency of events resulting in a football ball or rugby ball being kicked into the adjacent area is unknown and impossible to predict with certainty (player skills, type of game and many other factors can influence this) hence a proportionate approach needs to be taken to provide safety to these users. In reality, there may be a “freak” kick that will result in a further than expected trajectory, but a balanced risk mitigation strategy needs to be implemented that is proportionate. Indeed, there are risks associated with many everyday activities, but plans need to be developed to reduce risk following good practical health and safety principles including a combination of likelihood and severity.

In consideration of the risks posed by the simulated rugby and football trajectories in relation to the context of the location, there is a need for ball stop mitigation to prevent balls leaving the pitch boundaries and impacting on the new development. It is acknowledged that there is existing mitigation around the football and rugby pitches, however, the height of the existing mitigation is unknown so it may already be sufficient or may need to be extended. The following mitigation solutions are proposed:

- **Extending existing mitigation around pitches**

This report has considered the height that rugby balls and footballs are predicted to be at when they reach the existing mitigation. Based on this, this report recommends that the mitigation around the pitches would need to be at heights as shown below. If the existing mitigation is already at these heights, then no further action need be taken. However, if the existing mitigation is lower than the heights shown below, it is recommended that the existing mitigation be extended to these heights.



Figure 14. Ball containment recommendations around pitches, based on simulated trajectories

- **Installing new mitigation around new development**

Alternatively, if the existing mitigation around the rugby and football pitches are not at the recommended heights and there is no scope to extend them higher, then this report recommends that mitigation be erected around the boundary of the proposed development, as shown below.

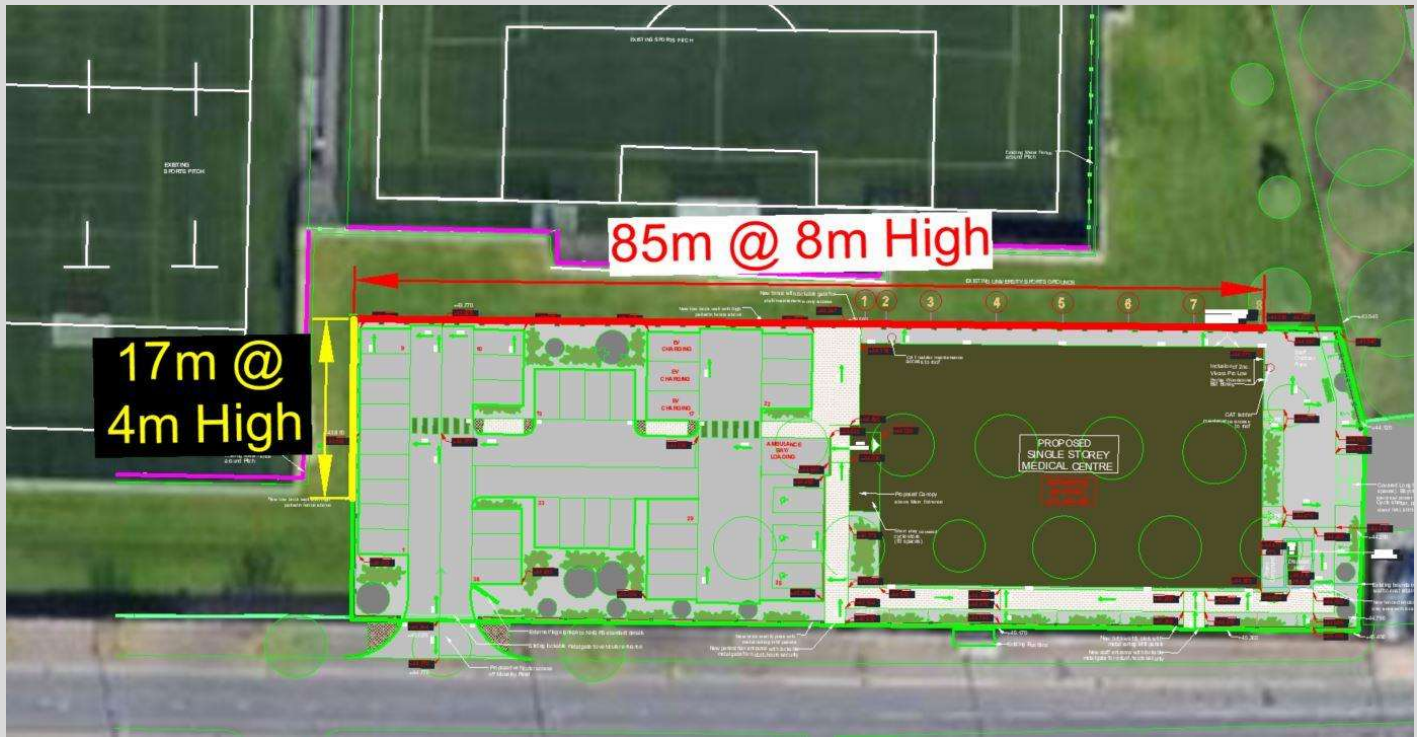


Figure 15. Ball containment recommendations around proposed development, based on simulated trajectories

It is important to note that these recommendations may not stop all balls from landing beyond the proposed mitigation location, but it is predicted from the assessment of ball trajectory it will significantly reduce their frequency.

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