

## Comparison of player perceptions to mechanical measurements of third generation synthetic turf football surfaces

### Supplementary Material

**Table S1.** Mechanical variables for each of the RTT design configurations and for each of the five RTT assessment surfaces. See Table S4 for details of the design configurations. The thick black box highlights the current RTT test configuration output variables. The thick green box highlights the newly proposed RTT test configuration output variables.

Test Foot	Load	Variable	Surface ID				
			T1	T2	T3	T4	T5
Studded	34.6 kg	Peak Torque (Nm)	28.7 (1.7)	31.7 (1.3)	38.2 (1.7)	35.9 (1.4)	37.6 (1.7)
		Initial Stiffness (Nm/°)	3.61 (0.62)	2.84 (0.60)	3.33 (0.51)	3.84 (1.11)	4.05 (0.67)
		Secondary Stiffness (Nm/°)	0.76 (0.11)	0.85 (0.09)	1.11 (0.20)	1.06 (0.14)	1.15 (0.08)
	46 kg	Peak Torque (Nm)	35.7 (1.3)	39.9 (1.6)	47.2 (1.7)	52.7 (1.5)	47.0 (1.5)
		Initial Stiffness (Nm/°)	3.51 (0.20)	3.28 (0.23)	3.28 (0.32)	5.06 (1.86)	4.36 (0.94)
		Secondary Stiffness (Nm/°)	0.91 (0.12)	1.07 (0.07)	1.32 (0.08)	1.40 (0.11)	1.35 (0.14)
	66 kg	Peak Torque (Nm)	50.4 (1.5)	52.7 (1.7)	57.2 (1.1)	63.6 (2.1)	60.6 (2.2)
		Initial Stiffness (Nm/°)	4.54 (0.98)	3.78 (0.30)	4.79 (0.18)	4.36 (0.37)	3.99 (0.52)
		Secondary Stiffness (Nm/°)	1.14 (0.05)	1.17 (0.22)	1.47 (0.05)	1.53 (0.04)	1.67 (0.11)
Dimpled	34.6 kg	Peak Torque (Nm)	20.2 (1.7)	23.5 (1.9)	26.6 (0.6)	25.0 (1.1)	25.8 (1.2)
		Initial Stiffness (Nm/°)	3.45 (1.31)	3.46 (0.57)	2.74 (0.46)	4.72 (1.24)	5.05 (1.46)
		Secondary Stiffness (Nm/°)	1.21 (0.03)	1.30 (0.07)	1.72 (0.11)	1.49 (0.10)	1.70 (0.10)
	46 kg	Peak Torque (Nm)	29.3 (1.9)	30.7 (1.7)	35.2 (0.5)	34.3 (1.0)	34.6 (1.5)
		Initial Stiffness (Nm/°)	3.35 (1.08)	3.58 (1.36)	5.03 (0.26)	3.86 (0.87)	2.56 (0.45)
		Secondary Stiffness (Nm/°)	1.71 (0.18)	1.61 (0.18)	1.95 (0.12)	1.87 (0.07)	1.94 (0.09)
	66 kg	Peak Torque (Nm)	40.7 (2.7)	41.3 (1.2)	44.7 (1.4)	47.4 (0.8)	47.2 (2.2)
		Initial Stiffness (Nm/°)	4.77 (0.90)	4.07 (0.67)	5.28 (0.74)	5.41 (0.56)	4.76 (1.44)
		Secondary Stiffness (Nm/°)	2.09 (0.31)	2.26 (0.26)	2.15 (0.10)	2.38 (0.19)	2.52 (0.23)

**Table S2.** Mechanical variables based on the current FIFA standards algorithm [3] for each of the AAA design configurations and for each of the five AAA assessment surfaces. See Table S4 for details of the design configurations. The thick black box highlights the current AAA test configuration output variables.

Drop Height	Test Foot	Drops	Variable	Surface ID				
				H1	T2	T3	T4	T5
55 mm	70 mm	1	Shock Absorption (%)	72.4 (1.1)	70.1 (0.1)	71.9 (1.2)	63.2 (1.1)	75.7 (0.4)
			Vertical Deformation (mm)	10.9 (0.6)	10.4 (0.2)	11.4 (0.3)	8.5 (0.2)	12.8 (0.2)
			Energy Restitution (%)	37.1 (0.9)	39.3 (0.7)	40.9 (1.1)	39.6 (0.7)	40.8 (0.4)
		2&3	Shock Absorption (%)	71.0 (0.7)	68.9 (0.3)	69.8 (0.4)	61.6 (0.9)	74.7 (0.7)
			Vertical Deformation (mm)	10.7 (0.3)	10.2 (0.1)	11.1 (0.2)	8.1 (0.2)	12.6 (0.5)
			Energy Restitution (%)	40.0 (0.7)	42.5 (0.9)	44.3 (0.7)	42.9 (0.3)	43.7 (0.6)
	110 mm	1	Shock Absorption (%)	69.2 (0.8)	67.2 (0.5)	68.9 (1.1)	59.6 (0.9)	73.0 (0.6)
			Vertical Deformation (mm)	9.8 (0.5)	8.8 (0.2)	10.1 (0.3)	7.4 (0.2)	11.0 (0.5)
			Energy Restitution (%)	38.6 (0.7)	39.7 (0.5)	41.9 (1.1)	41.9 (0.6)	41.2 (0.3)
		2&3	Shock Absorption (%)	67.4 (0.4)	65.0 (0.5)	66.8 (0.8)	56.9 (0.4)	71.4 (0.4)
			Vertical Deformation (mm)	9.5 (0.1)	8.6 (0.1)	9.8 (0.1)	7.1 (0.1)	10.8 (0.1)
			Energy Restitution (%)	41.5 (0.6)	42.4 (0.5)	45.0 (0.8)	44.7 (0.4)	43.9 (0.5)
70 mm	70 mm	1	Shock Absorption (%)	69.7 (1.1)	67.1 (0.5)	68.1 (0.6)	60.2 (1.7)	73.7 (0.1)
			Vertical Deformation (mm)	12.2 (0.3)	11.4 (0.4)	13.0 (0.2)	9.1 (0.3)	14.2 (0.4)
			Energy Restitution (%)	39.1 (1.3)	41.6 (0.4)	42.5 (1.9)	41.1 (1.3)	42.6 (0.6)
		2&3	Shock Absorption (%)	68.6 (0.6)	64.7 (0.6)	64.4 (0.9)	57.5 (0.5)	71.9 (0.2)
			Vertical Deformation (mm)	12.2 (0.2)	11.2 (0.1)	12.3 (0.2)	8.8 (0.1)	14.0 (0.1)
			Energy Restitution (%)	41.0 (0.7)	44.8 (0.9)	46.4 (0.6)	43.8 (0.4)	45.9 (0.9)
	110 mm	1	Shock Absorption (%)	67.1 (0.6)	64.6 (0.6)	66.2 (1.1)	57.0 (0.9)	71.2 (0.3)
			Vertical Deformation (mm)	10.7 (0.5)	9.7 (0.3)	11.5 (0.3)	8.1 (0.3)	12.4 (0.2)
			Energy Restitution (%)	39.0 (0.5)	41.4 (0.4)	42.6 (1.0)	43.2 (0.7)	42.9 (0.8)
		2&3	Shock Absorption (%)	65.0 (0.5)	62.4 (0.4)	63.5 (0.6)	54.4 (0.5)	69.8 (0.4)
			Vertical Deformation (mm)	10.4 (0.2)	9.5 (0.1)	11.0 (0.1)	7.7 (0.1)	12.2 (0.1)
			Energy Restitution (%)	42.1 (1.0)	43.9 (0.6)	46.0 (0.7)	46.0 (0.4)	45.4 (0.7)

**Table S3.** Mechanical variables based on the newly proposed algorithm for each of the AAA design configurations and for each of the five AAA assessment surfaces. See Table S1 for details of the design configurations. The thick green box highlights the newly proposed AAA test configuration output variables.

Drop Height	Test Foot	Drops	Variable	Surface ID				
				H1	T2	T3	T4	T5
55 mm	70 mm	1	Shock Absorption (%)	72.4 (1.1)	70.1 (0.1)	71.9 (1.2)	63.2 (1.1)	75.7 (0.4)
			Vertical Deformation (mm)	14.6 (0.7)	13.5 (0.4)	16.1 (0.7)	12.1 (0.5)	16.7 (0.5)
			Energy Restitution (%)	37.5 (0.9)	38.8 (0.6)	41.1 (1.3)	34.6 (0.7)	43.1 (0.3)
		2&3	Shock Absorption (%)	71.0 (0.7)	68.9 (0.3)	69.8 (0.4)	61.6 (0.9)	74.7 (0.7)
			Vertical Deformation (mm)	14.1 (0.1)	13.2 (0.2)	15.3 (0.1)	11.6 (0.1)	16.4 (0.1)
			Energy Restitution (%)	39.7 (0.5)	41.1 (0.6)	43.3 (0.4)	36.6 (0.1)	45.4 (0.5)
	110 mm	1	Shock Absorption (%)	69.2 (0.8)	67.2 (0.5)	68.9 (1.1)	59.6 (0.9)	73.0 (0.6)
			Vertical Deformation (mm)	13.0 (0.8)	12.1 (0.6)	13.9 (0.5)	11.1 (0.6)	14.2 (0.6)
			Energy Restitution (%)	37.3 (1.1)	37.4 (0.4)	40.6 (1.1)	34.1 (0.5)	41.9 (0.3)
		2&3	Shock Absorption (%)	67.4 (0.4)	65.0 (0.5)	66.8 (0.8)	56.9 (0.4)	71.4 (0.4)
			Vertical Deformation (mm)	12.5 (0.3)	11.7 (0.5)	13.2 (0.2)	10.3 (0.5)	14.0 (0.1)
			Energy Restitution (%)	39.4 (0.4)	39.2 (0.2)	42.9 (0.5)	35.5 (0.2)	44.0 (0.4)
70 mm	70 mm	1	Shock Absorption (%)	69.7 (1.1)	67.1 (0.5)	68.1 (0.6)	60.2 (1.7)	73.7 (0.1)
			Vertical Deformation (mm)	15.5 (0.8)	14.0 (1.0)	18.0 (0.4)	12.5 (0.8)	17.8 (0.4)
			Energy Restitution (%)	38.1 (0.9)	39.6 (0.4)	40.8 (1.5)	34.2 (0.7)	43.7 (0.6)
		2&3	Shock Absorption (%)	68.6 (0.6)	64.7 (0.6)	64.4 (0.9)	57.5 (0.5)	71.9 (0.2)
			Vertical Deformation (mm)	15.3 (0.3)	14.1 (0.3)	16.7 (0.2)	12.1 (0.1)	17.7 (0.2)
			Energy Restitution (%)	39.6 (0.4)	41.8 (0.7)	43.3 (0.2)	35.6 (0.1)	46.2 (0.8)
	110 mm	1	Shock Absorption (%)	67.1 (0.6)	64.6 (0.6)	66.2 (1.1)	57.0 (0.9)	71.2 (0.3)
			Vertical Deformation (mm)	14.2 (0.6)	13.1 (0.4)	15.5 (0.7)	11.7 (0.7)	15.9 (0.6)
			Energy Restitution (%)	36.1 (0.3)	37.5 (0.4)	39.7 (1.2)	33.6 (0.3)	42.6 (0.7)
		2&3	Shock Absorption (%)	65.0 (0.5)	62.4 (0.4)	63.5 (0.6)	54.4 (0.5)	69.8 (0.4)
			Vertical Deformation (mm)	13.5 (0.2)	12.6 (0.1)	14.5 (0.3)	11.0 (0.4)	15.5 (0.1)
			Energy Restitution (%)	38.6 (0.8)	39.4 (0.4)	42.2 (0.4)	35.3 (0.1)	44.6 (0.5)

**Table S4.** Details of the different design configurations tested and for each, the corresponding mechanical variables measured / calculated, sensory attributes tested, and surface paired comparisons used.

Design configurations	Mechanical variables	Sensory attributes	Surface paired comparisons
<b>RTT</b>			
Load (34.6, 46.0, 66.0kg) Test foot (studded and dimpled) <b>(Total = 6 configurations)</b>	Peak torque Initial stiffness Secondary stiffness	<i>Movement speed</i> <i>Slip</i>	T1-T2, T1-T3, T1-T4, T1-T5, T2-T3, T2-T4, T2-T5, T3-T4, T3-T5, T4-T5 (Total = 10 pairs)
<b>AAA</b>			
Drop height (55 and 70 mm) Test foot diameter (70 and 110 mm) Drops (1st, average 2 <sup>nd</sup> & 3 <sup>rd</sup> ) Algorithms (current [3] and new) <b>(Total = 16 configurations)</b>	Shock Absorption Vertical Deformation Energy Restitution	<i>Leg Shock</i> <i>Give</i>	H1-H2, H1-H3, H1-H4, H1-H5, H2-H3, H2-H4, H2-H5, H3-H4, H3-H5, H4-H5 (Total = 10 pairs)

**Table S5.** Assessment criteria values for each of the RTT design configurations and output variables. See Table 3 for details of the individual assessment criteria. The thick black box highlights the current RTT test configuration output variables. The thick green box highlights the newly proposed RTT test configuration output variables.

Sensory Attribute	Mechanical Variable	Assessment Criterion (Table 5)	Device Configuration					
			Studded			Dimpled		
			34.6 kg	46 kg	66 kg	34.6 kg	46 kg	66 kg
Movement Speed	Peak Torque	1	0.90	0.60	0.70	0.90	0.90	0.90
		2	60%	60%	10%	0%	10%	20%
		3	22.6%	13.5%	20.9%	21.1%	22.6%	35.4%
	Initial Stiffness	1	0.50	0.10	0.50	0.40	-0.10	0.50
		2	0%	0%	0%	0%	0%	0%
		3	58.0%	39.7%	127.6%	43.6%	33.6%	82.4%
	Secondary Stiffness	1	1.0	0.70	0.90	0.90	0.80	0.40
		2	0%	60%	40%	50%	0%	0%
		3	32.1%	21.2%	20.2%	16.2%	37.8%	58.3%
Slip	Peak Torque	1	-0.60	-0.90	-1.0	-0.60	-0.60	-0.90
		2	40%	50%	10%	0%	10%	20%
		3	22.6%	13.5%	20.9%	21.1%	22.6%	35.4%
	Initial Stiffness	1	-0.60	-0.60	-0.80	-0.60	-0.40	-0.80
		2	0%	0%	0%	0%	0%	0%
		3	58.0%	39.7%	127.6%	43.6%	33.6%	82.4%
	Secondary Stiffness	1	-0.70	-1.00	-0.90	-0.60	-0.50	-0.60
		2	0%	40%	30%	30%	0%	0%
		3	32.1%	21.2%	20.2%	16.2%	37.8%	58.3%

**Table S6.** Assessment criteria values for each of the AAA design configurations and output variables. See Table 3 for details of the individual assessment criteria. The thick black box highlights the current AAA test configuration output variables. The thick green box highlights the newly proposed AAA test configuration output variables.

Sensory Attribute	Algorithm	Mechanical Variable	Assess. Criterion (Table 5)	Drop Height 55 mm				Drop Height 70 mm			
				Test Foot 70 mm		Test Foot 110 mm		Test Foot 70 mm		Test Foot 110 mm	
				Drop 1	Drop 23	Drop 1	Drop 23	Drop 1	Drop 23	Drop 1	Drop 23
Leg Shock	Current	Shock Absorption	1	-0.70	-0.70	-0.70	-0.70	-0.70	-0.40	-0.70	-0.70
			2	60%	50%	60%	60%	50 %	50 %	60 %	50%
			3	6.5%	5.7%	6.2%	4.4%	6.2%	5.3%	5.1%	4.3%
		Vertical Deformation	1	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90
			2	50 %	50 %	60%	60 %	50 %	50 %	60 %	50 %
			3	7.5%	6.2%	9.6%	7.7%	7.0%	5.0%	7.6%	6.5%
		Energy Restitution	1	-0.60	-0.60	0.10	-0.30	-0.60	-0.70	0.20	0.10
			2	30 %	30 %	20%	30%	10%	40%	30%	40%
			3	20.6%	17.5%	21.0%	13.0%	30.8%	17.2%	16.8%	17.7%
	New	Shock Absorption	1	-0.70	-0.70	-0.70	-0.70	-0.70	-0.40	-0.70	-0.70
			2	60%	50%	60%	60%	50%	50%	60%	50%
			3	6.5%	5.7%	6.2%	4.4%	6.2%	5.3%	5.1%	4.3%
		Vertical Deformation	1	-0.90	-0.90	-0.90	-0.90	-1.0	-0.90	-0.90	-0.90
			2	50%	50%	50%	50%	60%	60%	50%	50%
			3	13.0%	9.3%	9.9%	11.8%	12.4%	8.6%	14.6%	11.8%
		Energy Restitution	1	-0.80	-0.80	-0.80	-0.90	-0.80	-0.80	-0.80	-0.80
			2	50%	60%	50%	50%	40%	50%	50%	50%
			3	8.8%	6.8%	9.0%	6.8%	9.7%	6.5%	6.7%	7.1%
Give	Current	Shock Absorption	1	0.70	0.70	0.70	0.70	0.70	0.40	0.70	0.70
			2	60%	60%	60%	60%	60%	60%	60%	60%
			3	6.5%	5.7%	6.2%	4.4%	6.2%	5.3%	5.1%	4.3%
		Vertical Deformation	1	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
			2	60%	60%	60%	60%	60%	60%	70%	70%
			3	7.5%	6.2%	9.6%	7.7%	7.0%	5.0%	7.6%	6.5%
		Energy Restitution	1	0.60	0.60	-0.10	0.30	0.60	0.70	-0.20	-0.10
			2	30%	30%	40%	50%	10%	40%	40%	50%
			3	20.6%	17.5%	21.0%	13.0%	30.8%	17.2%	16.8%	17.7%
	New	Shock Absorption	1	0.70	0.70	0.70	0.70	0.70	0.40	0.70	0.70
			2	60%	60%	60%	60%	60%	60%	60%	60%
			3	6.5%	5.7%	6.2%	4.4%	6.2%	5.3%	5.1%	4.3%
		Vertical Deformation	1	0.90	0.90	0.90	0.90	1.0	0.90	0.90	0.90
			2	70%	70%	50%	60%	70%	70%	60%	60%
			3	13.0%	9.3%	9.9%	11.8%	12.4%	8.6%	14.6%	11.8%
		Energy Restitution	1	0.80	0.80	0.80	0.90	0.80	0.80	0.80	0.80
			2	70%	70%	70%	70%	60%	60%	70%	70%
			3	8.8%	6.8%	9.0%	6.8%	9.7%	6.5%	6.7%	7.1%