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DEVELOPMENT OF A STIMPMETER FOR CRICKET FIELDS

Francis B. Lopez* and Louis E. Chinnery

ABSTRACT

A scientific approach was used to determine specifications for a new instrument for measuring ball roll distance on cricket fields. A ball roll test performed with a stimpmeter is commonly used on golf courses to ensure that particular standards are maintained, and also for diagnostic and research purposes to improve the quality of the playing surface. A modification of stimpmeter used in the golf industry that would be suitable for use on cricket fields is described, and a predictive regression model was fitted to data relating ball roll distance on artificial turf to ball release slope, ramp length and ball mass. Data were obtained using two types of cricket balls, eight ball release slopes between 15 and 47° to the horizontal, and six ramp lengths between 1.2 and 1.7 m. In the determination of ball roll distance, the model indicated a positive linear effect of ramp length, a quadratic effect of ball release slope and an interaction between ball mass and ball release slope. Recommendations based on model parameters, field testing and video analysis of ball motion include: a ball release slope of 30° with a rail ramp length of 1.5 m and an overall instrument length of 1.75 m, measurements in forward and reverse directions at up to 24 locations per field, use of three new standard cricket balls (preferably the traditional red type) at each measurement location and a vertical ball seam orientation parallel to the direction of motion.

Keywords: Ball roll distance, turf speed, ramp slope, regression model, video analysis

Francis B. Lopez* and Louis E. Chinnery,Sports Agronomy Research Unit, Department of Biological and Chemical Sciences, The University to the West Indies, Cave Hill Campus, St. Michael, BB11000, Barbados. * Corresponding author: (francis.lopez@cavehill.uwi.edu)

INTRODUCTION

The speed and evenness (trueness) of ball movement on the cricket outfield are important features that influence the quality rating of the playing field (Adams and Gibbs, 1994). Ball roll will be affected by field conditions and ball characteristics including ball seam orientation, which needs to be considered for cricket. In order to ensure that minimum field standards for ball roll distance and trueness are met for major competitions, it is necessary to develop a system for measurement of ball roll distance on a cricket field. Such a field testing system can be useful for informing management decisions during field development and preparation, and can also serve as a research tool for refinement of grounds-keeping techniques.

Ball roll distance (BRD), sometimes referred to as turf speed, has traditionally been measured on golf courses using a stimpmeter (Nikolai, 2005; Radko, 1977). A typical golf stimpmeter consists of a grooved aluminum bar (90 cm long) with a ball-release notch 15 cm from the top end. A golf ball placed in this notch will start rolling down the grooved incline when the top end of the stimpmeter is raised to an angle of 20 degrees. The stimpmeter reading is given as the average ball roll distance of 3 balls released in forward and reverse directions (USGA, 2007). An improvement in the calculations has been suggested for sloping fields (Brede, 1991). On golf greens, turf speed is given as ball roll distance measured in feet, with readings generally varying from less than 7.5 (slow) to over 10.5 (fast) (Nikolai, 2005).

Many field factors are likely to affect ball roll distance including surface evenness, turf species, fertilizer use, rolling, grass height, turf moisture status and the presence of thatch (Nikolai, 2005). In Seashore Paspalum (*Paspalum vaginatum* Sw.), ball roll distance was largely unaffected by nitrogen fertilization, but consistently increased with lower mowing height and by rolling (Kopec et al., 2007). However increased ball roll distance achieved with a higher frequency of rolling may occur at the expense of turf quality (Hartwiger et al., 2001). In hybrid Bermuda grass (*Cynodon dactylon* Pers. x *C. transvaalensis* Burtt-Davy) increased nitrogen fertilization reduced ball roll distances (McCullough et al., 2006) probably due to increased ball roll resistance associated with increased shoot growth and wider leaves. Observed reductions in ball roll distance from morning to evening can be attributed to daily leaf growth (McCullough et al., 2005; McCullough et al., 2006). Use of plant growth regulators, particularly gibberellic acid inhibitors, increased ball roll distance while allowing reduced frequency of mowing (McCullough et al., 2005).

A cricket ball is made of leather on the outside with a cork core and a wax finish. A new ball should weigh no less than 155.9 g, nor more than 163 g, and should measure no less than 224 mm, nor more than 229 mm in circumference (Marylebone Cricket Club, 2003). The seam of a cricket ball comprises of a prominent band (approximately 2cm wide) of six lines of stitches running parallel to each other, which hold the two halves of the ball together. There are two main types of cricket balls: a red ball, which is used for most types of cricket, including professional 'Test' matches (up to 5 days duration), and a white ball, which is used for most 'One-day International' matches. In order to make meaningful comparisons between fields and reduce measurement error, it may be necessary to conduct stimpmeter tests on cricket fields using balls in a standard condition and with a particular seam orientation during tests.

This study represents a scientific approach to the development of specifications and procedures for a modified stimpmeter instrument suitable for use on cricket fields. Initial investigations were done with cricket balls on artificial turf using an aluminum rod (V-shaped in cross section) with varying ramp lengths and ball release slopes in order to construct a predictive model for ball roll distance. Such a model allowed recommendations to be made with regard to the length and slope of the ramp to be used in the modified stimpmeter. An instrument with the recommended specifications was then tested on a cricket field prepared for play. Further scrutiny of instrument performance was carried out using video analysis of ball motion.

MATERIALS AND METHODS

The Modified Stimpmeter

A 1.75m long aluminum rod (2 mm thick, V-shaped in cross section) was used as a stimpmeter with the ball rolling on rails (3.9 cm apart) formed at the upper V-surface. Each side of the rod was 3 cm wide, giving a V-shaped angle of about 81°. Two matching V-shaped metal brackets (clips: 3 mm thick, and 1.9 cm wide) were attached towards one end (called the top end) forming a small gap between each other, which served as a ball-release notch. At the opposite end (called the base) the lower side of the V-shaped rod was beveled 5 cm to the tip for maintenance of stable contact with the ground as the top end is raised and also to allow smooth rolling of the ball from the rod to the turf. To take a measurement, a cricket ball was placed in the gap formed between the two metal brackets at the top of the rod. With the base of the rod on the turf, the top end of the rod was raised slowly until the ball begins to roll down the rail ramp, and this position of the rod was maintained until the ball rolls onto the turf. The ball roll distance was then measured from the base of the rod. Variation in the angle of release of the cricket ball was achieved by using metal clips of varying thickness at the top of the rod and by varying the size of the gap between the two clips, so that the ball is positioned at different depths in the gap.

Experiment 1: Initial Instrument Testing

An investigation was done to determine whether the angle of ball release from the instrument was affected by ball type (red vs. white balls) and/or seam orientation. New standard cricket balls (three red and three white) were used in this study and three seam orientations were tested: (1) Vertical seam plane parallel to direction of rolling (vertical), (2) Vertical seam plane slanted 45° to the direction of rolling (slanted) and (3) Seam plane tilted 45° from vertical in the direction of rolling (tilted). The plane of the seam crosses both rails of the aluminum rod in the slanted orientation, while one of the rails is in the same plane as the seam in the tilted orientation. The metal clips on the aluminum rod were set at 1.5m from the base to release the ball at a slope about 34° and a meter rule held vertically during measurements allowed the calculation of the actual ball release angle when each ball began to roll. This study was done on two occasions and ball release angle was compared for the different ball types and seam orientations using ANOVA (SPSS statistical package, Release 11.0.1). Additional tests were done to determine the consistency of ball release from different points along the aluminum rod from 1.7m to 1.2m from the base at 0.1m intervals using only the vertical seam orientation (parallel to the direction of rolling). For these additional tests, a completely randomized design was used for data analysis.

Experiment 2:
Measurements on artificial turf

An initial study on artificial turf was done to determine whether ball roll distance was significantly affected by ball type (red vs. white) and seam orientation. Tests were carried out on artificial turf in the indoor cricket facility at the Cave Hill campus, The University of the West Indies, Barbados. The same red and white balls above were used for this study with a ramp length of 1.5m and an angle of ball release of 34°. Five seam orientations were used as follows:

1. Vertical seam parallel to direction of rolling (vertical)
2. Vertical seam slanted 45° to the direction of rolling (slanted)
3. Seam tilted 45° from vertical in the direction of rolling (tilted)
4. Seams slanted 45° and then tilted 45° (slanted & tilted)
5. Vertical seam perpendicular to the direction of rolling (perpendicular)

Ball roll tests were done in forward and reverse directions and pooled data for ball roll distance were compared for the different ball types and seam orientations using ANOVA (randomized block design).

Experiment 3:
Further measurements on artificial turf

In this investigation, six new standard cricket balls (3 red and 3 white) of known mass were used and all measurements of ball roll distance were made on the same track on artificial turf in one direction, with the vertical ball seam orientation. The angle of release of the ball and the length of the ramp used were varied by adjustments in the positioning of the two metal clips attached to the rod. Eight ball release angles were used (47°, 42°, 37°, 34°, 31°, 26°, 21° and 15° from horizontal), and ramp length was varied from 1.7 to 1.2m at 0.1m intervals at each ball release angle. A limited number of measurements were also conducted at ramp lengths less than 1.2m. Ball roll distance was determined individually for each of the six balls at each combination of ball release angle and ramp length. The data were subjected to regression analysis using the statistical packages SPSS and Genstat (Discovery Edition 2). Predictive models were tested relating ball roll distance to ball release angle, ramp length and ball mass, looking primarily for a significant relationship involving all three independent variables.

Experiment 4:
Measurements on a cricket outfield

The modified stimpmeter described above was used to determine turf speed (ball roll distance) on a cricket field, the 3Ws Oval, on the Cave Hill Campus, Barbados. At the time of measurements (January 2006) the major turf species on the field were Bermuda grass (*Cynodon dactylon* (L.) Pers), Sour grass (*Bothriochloa pertusa* (L.) A.Camus) and Savannah grass (*Axonopus compressus* (Sw.) P.Beauv). However, there were also several weed species present including the sedges *Cyperus rotundus* L. (Purple nut sedge) and *Fimbristylis ovata* (Burm. f.) Kern. The field was divided into

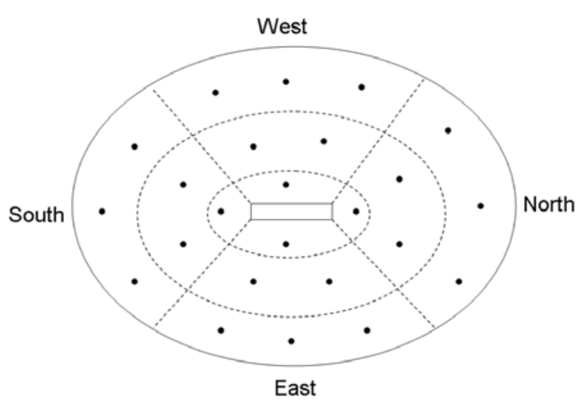

Figure 1. Diagram of the cricket field (3Ws Oval) showing the approximate location of sample points for measurement of ball roll distance (m) using the modified stimpmeter.

4 sectors (north, south, east and west) and there were six sample positions in each sector: one near the centre (next to the pitch), two mid-way towards the boundaries of the field and three on the outer ring (near the boundaries) of the field (Fig. 1).

At each sample location, ball roll distance was determined using new standard cricket balls (3 red and 3 white) with the ramp length on the modified stimpmeter set at 1.5m and the ball release angle set at 30° to horizontal. All measurements were made in forward and reverse directions, to and away from the middle of the pitch in the centre of the field. Average ball roll distances were calculated separately for the white and red balls and data were analyzed to determine whether additional replications may be beneficial to improve the accuracy of field characterization.

Experiment 5:
Video analysis

A video camera (Canon, model GL2) was used to capture the motion of cricket balls down the ramp of the modified stimpmeter described above. The camera was positioned 2 m away from the instrument with a downward view of the rolling ball. The ramp length was set at 1.5 m and the ball release slope was set at 30° to horizontal. Six new standard red cricket balls of slightly varying mass were used for this study. The speed of the cricket ball as it exits the instrument was determined by digital video analysis using the software package Pro-Trainer DV (Version 6.1, Sports Motion Inc., USA). The vertical seam orientation was used for all observations and the rotation of a small painted spot on the seam was followed as the ball rolled down the ramp of the instrument. Possible correlations between ball mass and translational and angular speed were investigated.

RESULTS AND DISCUSSION

Effects of ball seam orientation in Experiment 1 were not significant, however, there was a small but significant effect of ball type on the angle of release of cricket balls from the modified instrument with white balls being released at a slightly greater slope (Table 1). Although the difference in angle of release between ball types was least with the vertical seam orientation, the interaction was not significant for this data set. In more extensive tests using only the vertical seam orientation, ball release angle was not significantly ($p > 0.05$) affected by ball type (Red vs. White) or position along the modified stimpmeter (data not shown). It is likely that the effect of ball type on the angle of release from the instrument is greater for non-vertical seam orientations. These results point to

Table 1. Variation in the angle (degrees) of release of cricket balls from a modified stimpmeter for two ball types (red and white) and three ball seam orientations (vertical, slanted and tilted) with a fixed instrument setting.

Ball type	Ball seam orientation: Vertical	Slanted	Tilted	Mean
Red	33.23	33.50	33.43	33.39
White	33.75	34.35	34.40	34.17*
		SE = 0.396		
Mean	33.49	33.93	33.92	

*Significantly different from the corresponding mean for red balls ($p < 0.01$)

Table 2: Ball roll distance (m) on artificial turf for two ball types (red and white) and five ball seam orientations (vertical, slanted, tilted, slanted & tilted and perpendicular) with a stimpmeter ramp length of 1.5m and a release slope of 34°.

Ball type	Ball orientation: Vertical	Slanted	Tilted	Slanted & Tilted	Perpend -icular	Mean
Red	7.83	7.23	7.54	7.01	7.02	7.33
White	7.92	7.33	7.17	6.97	7.14	7.31
			s.e. = 0.112			
Mean	7.88 a	7.28 bc	7.35 b	6.99 d	7.08 cd	

Means with a common attached letter are not significantly ifferent from each other by the Waller-Duncan test ($p > 0.05$).

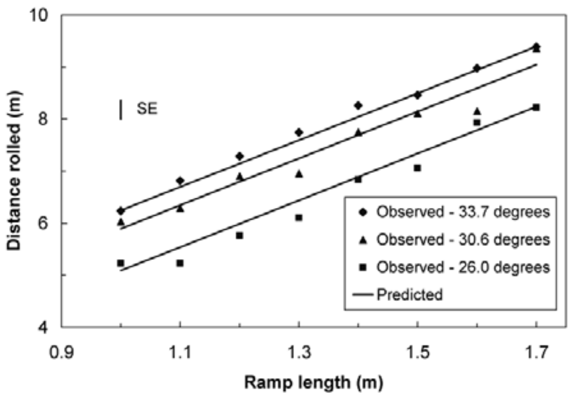

Figure 2: Observed and predicted values of ball roll distance (m) on artificial turf as affected by stimpmeter ramp length at specific ball release slopes (average ball mass = 156.9 g).

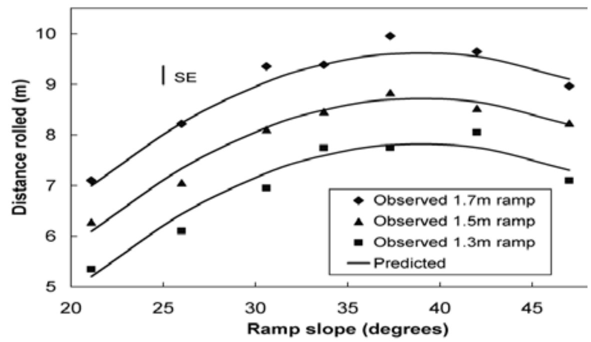

Figure 3. Observed and predicted values of ball roll distance (m) on artificial turf as affected by stimpmeter ball release slope at specific ramp lengths (average ball mass = 156.9 g).

possible differences between the ball types in the height of the seam from the rest of the ball surface. With this instrument design, the vertically orientated seam of a cricket ball does not make contact with the aluminum rod at any time during a measurement.

On artificial turf, ball type had no significant effect on ball roll distance (Experiment 2), whereas ball seam orientation was very important and there was no significant interaction between the two factors (Table 2). Ball roll distance was greatest with the vertical seam orientation and was reduced by 6.7 to 11.3 % with the other seam orientations. With the vertical seam orientation the motion of the ball is smooth and loss of energy due to friction and bumping should be lowest. The slightly greater ball release angle observed for white balls with non-vertical seam orientation in Experiment 1 apparently had no significant effects on ball roll distance.

Coefficients of a regression model for ball roll distance on artificial turf in relation to length and slope of the modified stimpmeter and ball mass (Experiment 3) are given in Table 3. This was the least complex model found that included all three independent variables with all coefficients being highly significant. There was a positive linear effect of ramp length (Fig. 2), a quadratic effect of ball release slope (Fig. 3) and a significant interaction between slope and mass in determining ball roll distance (Table 3). Using an average ball mass of 156.9 g, this equation can be differentiated with respects to slope.

Equation:

$$y = 8.706 + 4.499.\text{Length} - 0.008181.\text{slope}^2 + 0.004069.\text{slope.mass} - 0.1223.\text{mass}$$

At the turning point,

$$\frac{d.\text{y}}{d.\text{slope}} = -0.016362.\text{slope} + 0.6384261 = 0$$

Table 3: Model coefficients relating ball roll distance (m) on artificial turf to length (m) and slope (degrees) of the modified stimpmeter and ball mass (g).

	Coefficient	Std. Error	t	p
(Constant)	8.706	1.017	8.557	< 0.001
Length	4.499	0.103	43.764	< 0.001
Slope^2	-0.008181	0.000252	-32.411	< 0.001
Slope × Mass	0.004069	.000106	38.401	< 0.001
Mass	-0.1223	0.00712	-17.176	< 0.001

(Regression: $F_{4, 295} = 1065.46$, $p < 0.001$, $R^2 = 93.4$)

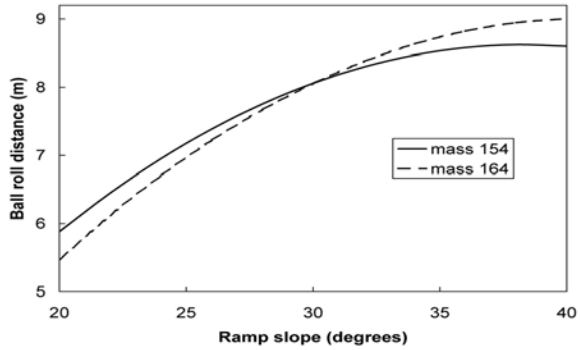

Figure 4. Predicted ball roll distance (m) on artificial turf as affected by stimpmeter ramp slope with ball mass set to 154 g (low) or 164 g (high), and ramp length set to 1.5 m.

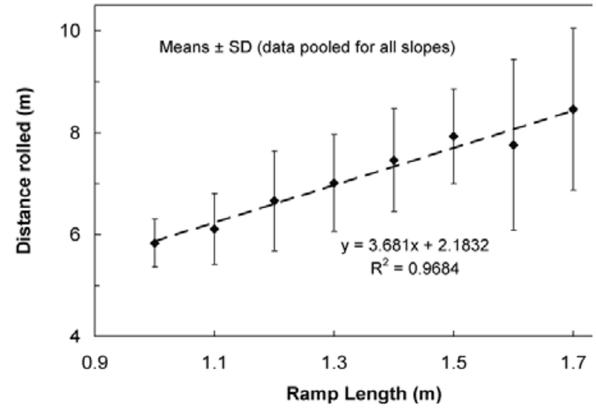

Figure 5. Ball roll distance (m ± SD) on artificial turf as affected by stimpmeter ramp length (data were pooled for various ball release slopes).

$$\text{Slope} = \frac{0.6384261}{0.016362} = 39.02$$

The model predicts that at any particular ramp length the maximum ball roll distance will occur at a ramp slope of about 39° as indicated in Fig. 3. At greater slopes it is expected that more energy will be lost as the ball bounces on contact with the turf at the base of the instrument.

The model also predicts that the effects of ball mass become negligible at a slope of about 30° (calculation: 0.1223 / 0.004069) as indicated in Fig. 4. Reasons for this are unclear, however, a possible explanation is that there are two opposing effects of ball mass. As ball mass increases, a greater ball roll distance due to higher energy content may be balanced by greater frictional forces with the stimpmeter rails and turf surface.

An instrument that samples a longer section of the turf is preferable since fewer measurements will be needed to give ball roll distances that are representative of the field area being tested. However, there are problems such as wind speed and direction that can reduce the accuracy of results and this has led to the development of timed gate systems (Kolitzus, 2003; Rist et al., 1999), where the actual ball rolling speed is measured over a limited distance. The specified ball release slope on stimpmeters is 20° for golf (USGA, 2007), and 45° for soccer (FIFA, 2006). Our model suggests that there is no benefit of increasing the slope of the modified stimpmeter for cricket fields beyond 39°. In order to minimize possible variation due to small differences in the mass of cricket balls, we suggest that the cricket stimpmeter should have a ball release slope of 30°.

Our model does not suggest any benefits of using a specific ramp length in the modified instrument, however, practical considerations are also very important. An instrument with a ramp length beyond that tested in this study will not be very portable unless it was collapsible. When data were pooled for all ball release slopes the standard deviation for ball roll distance increased greatly beyond a ramp length of 1.5 m (Fig. 5). As the ball is placed closer to the top of the rod that is being raised, any overshooting of the endpoint will increasingly magnify the error due to variation in the ball height above the ground at the point of release. The data

Table 4. Ball roll distance (m) measured at different locations on a cricket field, The 3W's Oval, using a vertical ball seam orientation, a stimpmeter ramp length of 1.5 m and a release slope of 30° (data were pooled for two ball types: red and white).

Field Location	Sector				Mean
	East	South	West	North	
Near-pitch (1)	2.92	3.73	3.46	3.68	3.45 a
Mid-way (2)	3.23	3.40	3.33	3.19	3.29 b
Boundary (3)	3.10	3.38	3.08	3.13	3.12 b
	s.e. = 0.128(1), 0.091(2), 0.074 (3)				
Mean	3.08 c	3.50 a	3.29 b	3.33 b	

Means in the same row or column with a common attached letter are not significantly different from each other by LSD ($p > 0.05$).

suggest that for a rod length of 1.75 m the maximum ramp length should be 1.5 m in order to reduce measurement error.

Ball roll distance measured on a cricket field (Experiment 4) was not significantly affected by ball type and data obtained using red and white cricket balls were pooled (Table 4). These tests picked up significant differences in ball roll distance at different positions on the field (e.g. between sectors east, west, north and south (6 replications each), which were probably related to differences in grass height and species composition. An overall mean ball roll distance of just over 3 m was obtained, which could be improved with a higher level of field management. Although the overall mean of ball roll distance remained fairly stable, the standard deviation of measurements fell as the number of replications increased (Fig. 6). The standard deviation of measurements with red balls was lower than that with white balls. Fitted equations indicate that the standard deviation reaches a minimum after about 22 replications for measurements with white balls and after 26 replications for measurement with red balls. We have noticed that the white balls tend lose the original new ball shape faster than the red balls and this may be a possible explanation for the differences observed. Six replications per sector (24 measurements per field) are likely to be sufficient for characterization of a cricket field.

Digital video analysis (Experiment 5) indicated that there were seven complete ball rotations down the ramp during measurements with the modified stimpmeter

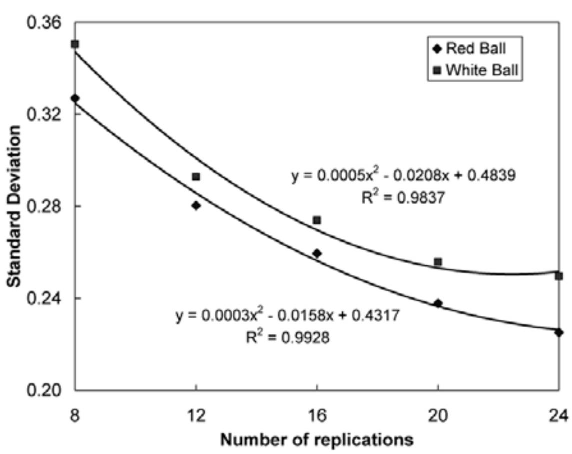

Figure 6. Standard deviation of ball roll distance (m) on a cricket field as affected by the number of replications. Replications: 8 (4 near-pitch and 4 boundary), 12 reps (add 4 midway), 16 reps (add 4 more boundary), 20 (add 4 more midway), 24 (add 4 more boundary). Measurements were made in 4 sectors (east, west, north and south).

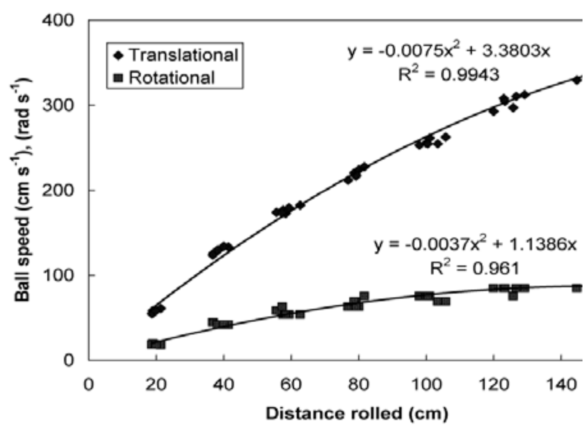

Figure 7. Translational and rotational ball speed (determined by video analysis) at each complete rotation during movement down the ramp of the modified stimpmeter set to release the ball at a 30° angle with a 1.5 m ramp length.

(Fig. 7). Translational and rotational ball speed data followed quadratic relationships (through the origin) with distance down the ramp. Fitted curves predicted that translational and rotational speeds at the end of the 1.5 m ramp were 3.38 m s^{-1} and 87 rad s^{-1}, respectively. Initial translational speeds of 1.9 m s^{-1} for the golf (Rist et al., 1999) and 3.2 m s^{-1} for the soccer stimpmeters (Kolitzus, 2003) have been reported. For the soccer stimpmeter, this observed initial ball speed using FIFA approved balls represents a reduction due to friction with air and ramp from a theoretical value of 3.46 m s^{-1} (Kolitzus, 2003). The fitted curves also predicted that with the current slope setting a ramp length of 2.25 m would be required to achieve maximum translational, and 1.54 m to achieve maximum rotational, speeds. Therefore, a ramp length beyond the current setting is likely to increase the sliding motion (and frictional energy losses) of the ball towards the end of the ramp as it approaches a maximum rotational speed.

There was a significant negative association between ball mass and angular speed at the end of the ramp (Spearman's rank coefficient = −0.812, $p < 0.05$), but no association was found between ball mass and average distance moved per rotation. Ball mass was also not associated with circumference at the seam, which conformed consistently to the standard. These findings suggest a possible explanation for the significant interaction observed between ball mass and ball release slope in the model given above. The slightly heavier balls slide more due to lower angular speed and possibly lose more energy due to friction at lower ball release slopes. All balls are likely to show increased sliding motion as ball release slope is increased, and the higher energy of the heavier balls may then result in a greater ball roll distance.

Specifications for a new instrument to measure turf speed (ball roll distance) on cricket fields can now be guided by scientific as well as practical considerations. The modified stimpmeter used in this study started with a simple "V-shaped" aluminum rod and additional features were added as required. It may be preferable to construct the new instrument with fiberglass or other non-electrical-conducting material. Improvements are also needed for the ball release mechanism to achieve a smoother movement of the ball at the point of release from the instrument. A vertical ball seam orientation parallel to the direction of rolling will also ensure a smooth movement down the ramp and on to the turf. There are advantages of using standard cricket balls for these tests since interactions between ball and turf would most closely match actual conditions, however, the use of specially manufactured 'seamless' balls with similar surface characteristics can be considered. Ball roll distance represents one component of tests for characterization of the playability and consistency of cricket fields, and other potentially useful parameters including surface hardness, traction and percentage green cover should also be considered.

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