Statistical data analysis project - Assignment 2

Dot Ball Pressure: A Statistical Analysis of Powerplay Impact in Mens T20 Internationals

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Introduction

- Cricket is a global sport with several formats.
- **T20 International (T20I)** is the shortest and fastest format—each team plays a single *innings* of up to **20 overs** (one over = 6 balls).
- In every match:
  - *Each team gets **one innings** to score as many runs as possible.*
  - *The opposing team bowls and fields, aiming to restrict runs and take wickets.*
- While T20 is famous for aggressive scoring, there is a hidden battle: the **dot ball**.
  - *A dot ball is a legal delivery where the batter scores **zero runs** (no runs off the bat and no extras).*
  - *Dot balls may seem minor, but they silently build pressure and can change the momentum of an innings.*
- Every match has three phases:
  - ***Powerplay (Overs 1–6)** – Fielding restrictions, batters attack*
  - ***Middle Overs (7–16)** – Balanced play, risk and rotation*
  - ***Death Overs (17–20)** – High pace and high risk scoring*
- This study explores dot ball distribution in Powerplay and Non-Powerplay overs.
- **Dataset:** Over **400,000+ deliveries** from men's T20I matches were analysed.

Source: @ICC on Twitter

Problem Statement

Statistical Question

Is there a significant difference in dot ball frequency between Powerplay (Overs 1–6) and Non-Powerplay (Overs 7–20) in Men's T20 Internationals?

Why This Matters

- Powerplay overs have strict fielding rules (only two fielders allowed outside the circle), increasing pressure on batters and bowlers.
- Dot balls in these overs can halt the batting side's momentum and lead to mistakes or wickets.
- For coaches and players, knowing when dot balls are most common can influence match strategy and decision-making.
- For fans, it reveals the "hidden" battles that shape T20 cricket beyond just boundary-hitting.

Source: @thetatvaindia on Twitter

Analytical Approach

- Calculate dot ball rates for both Powerplay and Non-Powerplay overs using ball-by-ball match data.
- Visualize trends in dot ball frequency by over and by innings.
- Statistically test (using chi-squared test) if any difference is significant.
- Explore categorical association by checking if teams that bowl more dot balls are more likely to win, analyzing the relationship between dot ball usage and match outcomes.

Data

Dataset: Ball-by-Ball IT20 (2005–2023) This dataset contains delivery-level records from over 1000 men's T20 International matches, including details of batters, bowlers, and ball outcomes.

- **Source:** Kaggle – Ball-by-Ball IT20 by Jamie Welsh
- **Structure:** Delivery-level data for 1000+ T20I matches, includes batsmen, bowlers, and ball outcomes.
- **Variables:** The dataset has 35 variables(columns) and 425,119 records(rows). Below are the key variables.

Variable	Type	Description
`Match ID`	Double	Unique identifier for each T20I match.
`Date`	Date	Date when the match was played.
`Innings`	Double	Innings number (1 = first, 2 = second).
`Over`	Double	Over number within the innings (1–20).
`Ball`	Double	Ball number within the over.
`Batter`	Character	Player on strike for the delivery.
`Bowler`	Character	Player delivering the ball.
`Batter Runs`	Double	Runs scored off the bat on that ball.
`Extra Runs`	Double	Runs added due to extras (wides, no-balls, etc.).
`Runs From Ball`	Double	Total runs from the ball (batter + extras).
`Ball Rebowled`	Double	1 if the delivery was re-bowled (wide/no-ball), else 0.
`Wicket`	Double	1 if a wicket fell on this delivery, else 0.
`Over Type*`	Factor	Derived: Powerplay (1–6) vs Non-Powerplay (7–20).
`Dot Ball*`	Binary	Derived: 1 if valid ball & batter_runs + extra_runs = 0, else 0.
`Valid Ball`	Double	1 if delivery was legal; used to filter for analysis.

*Derived variables created during preprocessing.

Data Cont.

```
# setting directory
setwd("D:/Masters/M.DS/Sem 3/Applied Analytics/Assignment 2")

# Load the dataset
cric_data <- read_csv("data/ball_by_ball_it20.csv", show_col_types = FALSE)
glimpse(cric_data)
```

```
## Rows: 425,119
## Columns: 35
## $ ...1                      <dbl> 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13…
## $ `Match ID`                <dbl> 1339605, 1339605, 1339605, 1339605, 1339605,…
## $ Date                      <date> 2023-03-26, 2023-03-26, 2023-03-26, 2023-03…
## $ Venue                     <chr> "SuperSport Park", "SuperSport Park", "Super…
## $ `Bat First`               <chr> "West Indies", "West Indies", "West Indies",…
## $ `Bat Second`              <chr> "South Africa", "South Africa", "South Afric…
## $ Innings                   <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,…
## $ Over                      <dbl> 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 3, 3, 3,…
## $ Ball                      <dbl> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6, 1, 2, 3,…
## $ Batter                    <chr> "BA King", "KR Mayers", "BA King", "J Charle…
## $ `Non Striker`             <chr> "KR Mayers", "BA King", "KR Mayers", "KR May…
## $ Bowler                    <chr> "WD Parnell", "WD Parnell", "WD Parnell", "W…
## $ `Batter Runs`             <dbl> 1, 1, 0, 0, 4, 4, 0, 0, 0, 0, 1, 0, 4, 1, 4,…
## $ `Extra Runs`              <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,…
## $ `Runs From Ball`          <dbl> 1, 1, 0, 0, 4, 4, 0, 0, 0, 0, 1, 0, 4, 1, 4,…
## $ `Ball Rebowled`           <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,…
## $ `Extra Type`              <chr> "[]", "[]", "[]", "[]", "[]", "[]", "[]", "[…
## $ Wicket                    <dbl> 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,…
## $ Method                    <chr> NA, NA, "caught", NA, NA, NA, NA, NA, NA, NA…
## $ `Player Out`              <chr> NA, NA, "BA King", NA, NA, NA, NA, NA, NA, N…
## $ `Innings Runs`            <dbl> 1, 2, 2, 2, 6, 10, 10, 10, 10, 10, 11, 11, 1…
## $ `Innings Wickets`         <dbl> 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,…
## $ `Target Score`            <dbl> 259, 259, 259, 259, 259, 259, 259, 259, 259,…
## $ `Runs to Get`             <dbl> NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, …
## $ `Balls Remaining`         <dbl> 119, 118, 117, 116, 115, 114, 113, 112, 111,…
## $ Winner                    <chr> "South Africa", "South Africa", "South Afric…
## $ `Chased Successfully`     <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,…
## $ `Total Batter Runs`       <dbl> 1, 1, 0, 0, 4, 8, 1, 1, 1, 1, 2, 8, 6, 7, 12…
## $ `Total Non Striker Runs`  <dbl> 0, 1, 1, 1, 1, 1, 8, 8, 8, 8, 8, 2, 8, 8, 7,…
## $ `Batter Balls Faced`      <dbl> 1, 1, 0, 1, 2, 3, 2, 3, 4, 5, 6, 4, 7, 8, 5,…
## $ `Non Striker Balls Faced` <dbl> 0, 1, 1, 1, 1, 1, 3, 3, 3, 3, 3, 6, 4, 4, 8,…
## $ `Player Out Runs`         <dbl> NA, NA, 1, NA, NA, NA, NA, NA, NA, NA, NA, N…
## $ `Player Out Balls Faced`  <dbl> NA, NA, 2, NA, NA, NA, NA, NA, NA, NA, NA, N…
## $ `Bowler Runs Conceded`    <dbl> 1, 1, 0, 0, 4, 4, 0, 0, 0, 0, 1, 0, 4, 1, 4,…
## $ `Valid Ball`              <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,…
```

Data Preprocessing

- ## Checked for Missing Values
  - *Found only in dismissal-related columns (`Player Out`, `Method`, `Player Out Runs`, etc.)*
  - *`Runs to Get` had NAs for 1st innings, which is expected and valid.*
- ## Filtered for Valid Deliveries
  - *Included only deliveries marked as **legal** (`valid_ball == 1`).*
  - *Created a binary variable `dot_ball` to flag deliveries where **no runs (batter + extras)** were scored.*
- ## Categorised Overs by Phase
  - *Created a new variable `over_type` to classify overs as:*
    - `"Powerplay"` (Overs 1–6)
    - `"Non-Powerplay"` (Overs 7–20)
- ## Outlier Detection & Final Cleaning
  - *Used **boxplots** to inspect `batter_runs`, `extra_runs`, and `over` for outliers.*
  - *Applied filters based on **cricket rules** to remove improbable values:*
    - `batter_runs ≤ 6`
    - `extra_runs ≤ 5`
    - `1 ≤ over ≤ 20`
- ## Fixed Inconsistent Categorical Values
  - *Standardised venue names (e.g., `"R.Premadasa Stadium"` & `"R Premadasa Stadium"`).*
- ## Converted Categorical Columns to Factors
  - *Transformed key text columns (`Venue`, `Batter`, `Bowler`, `Winner`, etc.) to **factor type** for efficient processing and grouping.*

Data Preprocessing Cont.

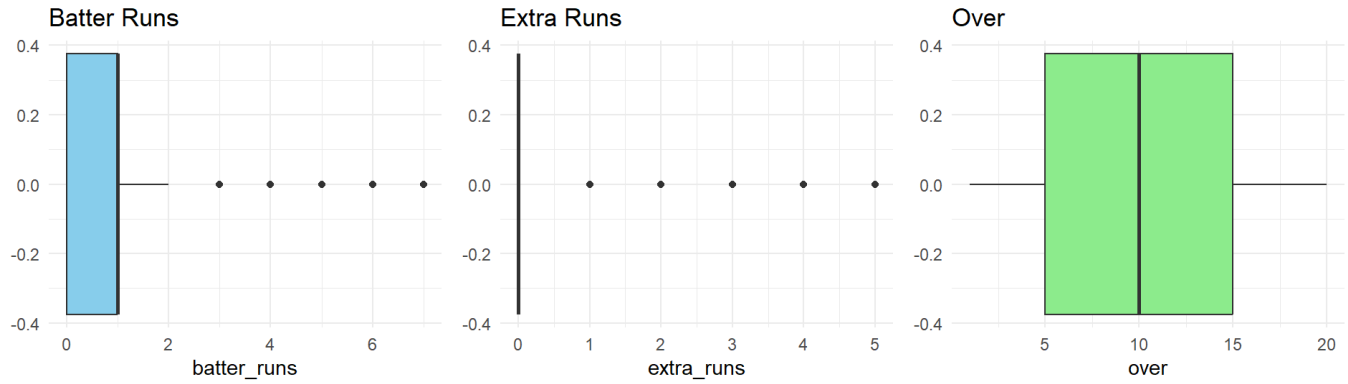
```
##                Method            Player Out       Player Out Runs
##                401460                401460                401460
## Player Out Balls Faced          Runs to Get
##                401460                224815
```

```
## [1] "Dot Ball"
```

```
##
##      0      1
## 247640 160394
```

```
##
## Non-Powerplay     Powerplay
##        275726        132308
```

Plots to show outliers




```
## [1] "Dimension of data after removing outliers"
```

```
## [1] 408032     37
```

Descriptive Statistics and Visualisation(1)

```
# Create phase for descriptive breakdown (Powerplay, Middle, Death)
dot_by_phase <- cric_data_clean %>%
  mutate(phase = case_when(
    over <= 6 ~ "Powerplay",
    over >= 17 ~ "Death Overs",
    TRUE ~ "Middle Overs"
  )) %>%
  group_by(phase) %>%
  summarise(
    total_balls = n(),
    dot_balls = sum(dot_ball),
    dot_percentage = round(100 * dot_balls / total_balls, 2),
    .groups = "drop"
  )

knitr::kable(dot_by_phase)
```

phase	total_balls	dot_balls	dot_percentage
Death Overs	66580	20764	31.19
Middle Overs	209144	74553	35.65
Powerplay	132308	65077	49.19

Descriptive statistics Cont.(2)

```
        # Summary of numeric variables
        num_summary <- summary(cric_data_clean[, c("batter_runs", "extra_runs", "over", "Target Score", "Bowler Runs Conceded", "Innings Runs",
"Runs From Ball", "valid_ball")])
        cat("\n\n")
```

```
        print(num_summary)
```

```
##   batter_runs      extra_runs           over         Target Score
##  Min.   :0.000   Min.   :0.00000   Min.   : 1.000   Min.   : 11.0
##  1st Qu.:0.000   1st Qu.:0.00000   1st Qu.: 5.000   1st Qu.:129.0
##  Median :1.000   Median :0.00000   Median :10.000   Median :154.0
##  Mean   :1.181   Mean   :0.02805   Mean   : 9.974   Mean   :153.2
##  3rd Qu.:1.000   3rd Qu.:0.00000   3rd Qu.:15.000   3rd Qu.:178.0
##  Max.   :6.000   Max.   :5.00000   Max.   :20.000   Max.   :279.0
##  Bowler Runs Conceded  Innings Runs    Runs From Ball    valid_ball
##  Min.   :0.000        Min.   :  0.00   Min.   :0.000   Min.   :1
##  1st Qu.:0.000        1st Qu.: 31.00   1st Qu.:0.000   1st Qu.:1
##  Median :1.000        Median : 64.00   Median :1.000   Median :1
##  Mean   :1.181        Mean   : 68.79   Mean   :1.209   Mean   :1
##  3rd Qu.:1.000        3rd Qu.:101.00   3rd Qu.:1.000   3rd Qu.:1
##  Max.   :6.000        Max.   :278.00   Max.   :7.000   Max.   :1
```

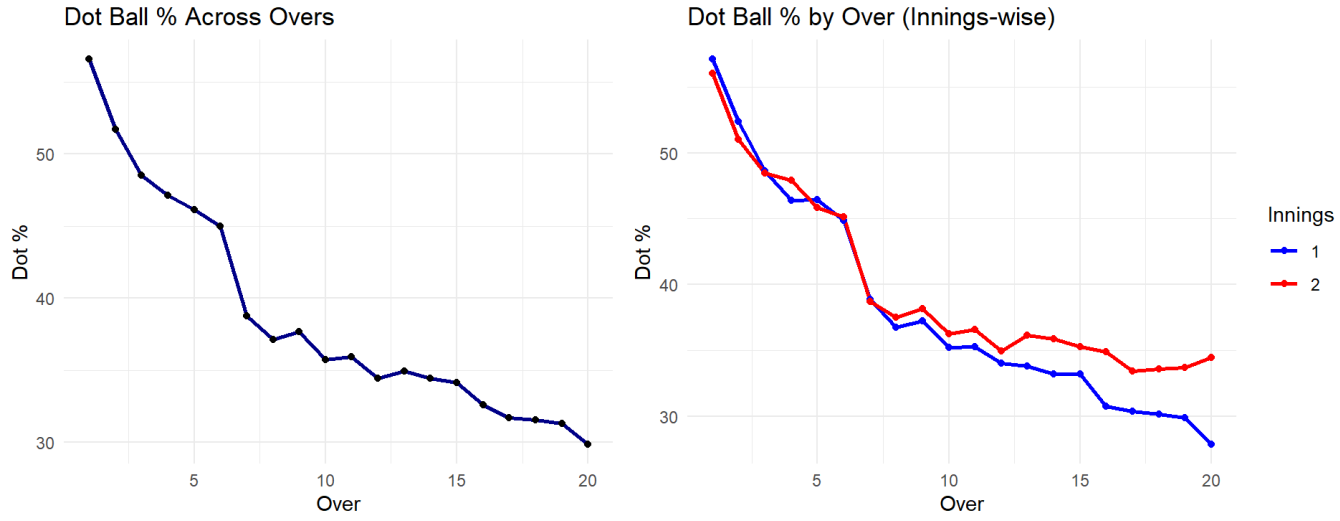
Decsriptive Statistics Cont.(3)

Dot Ball Trends by Over and Innings

```
# 1. Dot % by Over Number (Line)
dot_by_over <- cric_data_clean %>%
  group_by(over) %>% summarise(total_balls = n(), dot_balls = sum(dot_ball), dot_percentage = round(100 * dot_balls / total_balls, 2))

p1 <- ggplot(dot_by_over, aes(x = over, y = dot_percentage)) + geom_line(color = "darkblue", size = 1) + geom_point() +
  labs(title = "Dot Ball % Across Overs", x = "Over", y = "Dot %") + theme_minimal()
# 2. Dot % by Over by Innings (Line)
dot_by_over_innings <- cric_data_clean %>% group_by(Innings, over) %>% summarise(dot_percentage = mean(dot_ball) * 100)

p2 <- ggplot(dot_by_over_innings, aes(x = over, y = dot_percentage, color = factor(Innings))) +
  geom_line(size = 1) + geom_point() + labs(title = "Dot Ball % by Over (Innings-wise)", x = "Over", y = "Dot %") +
  scale_color_manual(values = c("blue", "red"), name = "Innings") + theme_minimal()
# Display side by side
p1 + p2
```



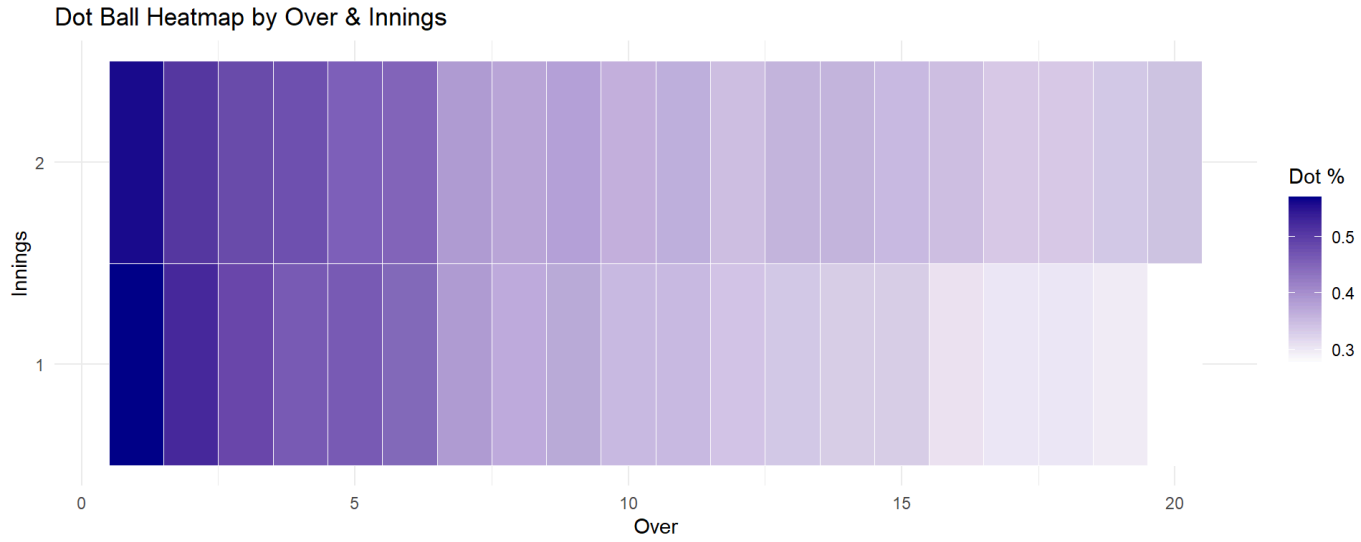
- Dot ball percentage is highest in the early overs (Powerplay), then steadily declines as the innings progresses, indicating that batters score more freely in later overs.
- Comparatively second innings shows slight higher dot ball percentages compared to the first innings, suggesting that chasing teams may face greater pressure or more disciplined bowling.

Decsriptive Statistics Cont.(4)

Heatmap of Dot Ball Percentage by Over and Innings

```
dot_heat <- cric_data_clean %>%
  group_by(Innings, over) %>%
  summarise(dot_rate = mean(dot_ball))

ggplot(dot_heat, aes(x = over, y = factor(Innings), fill = dot_rate)) +
  geom_tile(color = "white") +
  scale_fill_gradient(low = "white", high = "darkblue", name = "Dot %") +
  labs(title = "Dot Ball Heatmap by Over & Innings", x = "Over", y = "Innings") +
  theme_minimal()
```



- The darkest cells in the left columns show that dot balls are much more frequent in the early overs of each innings, suggesting that batters find it hardest to score at the start—especially during the Powerplay phase.

Decsriptive Statistics Cont.(5)

To further investigate the effect of dot ball pressure, a specific match was selected in which a batter was dismissed following a streak of three or more consecutive dot balls. This case serves as a representative illustration—highlighting how sustained dot ball pressure may contribute to wickets. It is intended as a narrative example, not as statistical proof or a generalization across all matches.

```
# Identify matches where a batter was dismissed after 3+ dot balls
dot_dismissal_matches <- cric_data_clean %>% arrange(match_id, Innings, over, Ball) %>% group_by(match_id, Innings, Batter) %>%
  mutate( dot_streak = with(rle(dot_ball), rep(lengths * values, lengths)), dismissed = !is.na(Method)) %>%
  filter(dismissed, dot_streak >= 3) %>% ungroup() %>% count(match_id, sort = TRUE)
options(width = 20, heigth=10)
print(head(dot_dismissal_matches))
```

```
## # A tibble: 6 × 2
##   match_id     n
##      <dbl> <int>
## 1  1283049     8
## 2  1215164     7
## 3  1273143     7
## 4  1298161     7
## 5  1298168     7
## 6  1310175     7
```

```
# one match_id from above
one_match <- cric_data_clean %>% filter(match_id == 1283049) %>% arrange(Innings, over, Ball) %>%
  select(Innings, over, Ball, Batter, dot_ball, Method, batter_runs, extra_runs)
knitr::kable(head(one_match, 5))
```

Innings	over	Ball	Batter	dot_ball	Method	batter_runs	extra_runs
1	1	1	AR Patwa	0	NA	1	0
1	1	2	II Selemani	0	NA	1	0
1	1	3	AR Patwa	0	NA	0	1
1	1	4	II Selemani	0	NA	4	0
1	1	5	II Selemani	1	NA	0	0

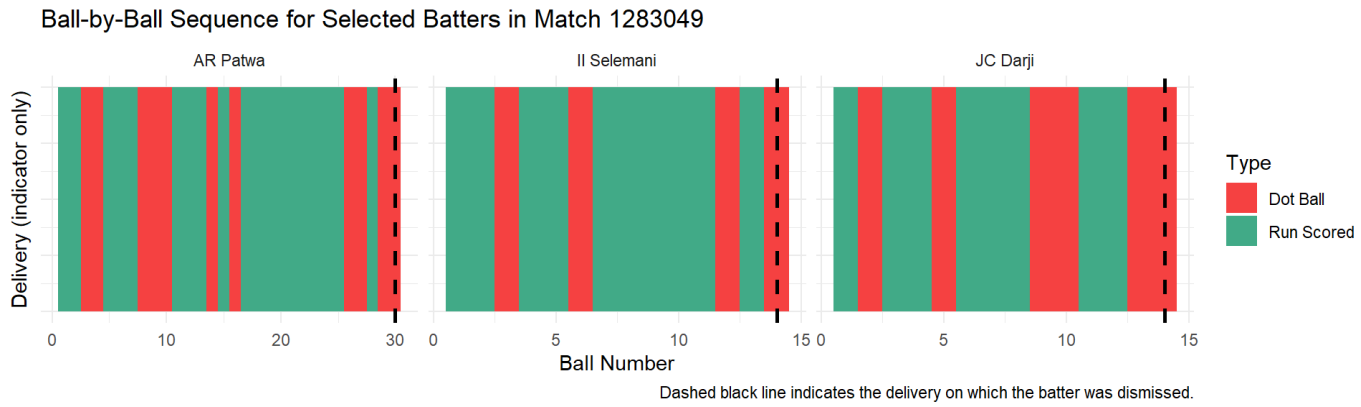
Decsriptive Statistics Cont.(6)

```
        match_id_selected <- 1283049

        selected_batters <- cric_data_clean %>% filter(match_id == match_id_selected, !is.na(Method)) %>%
          pull(Batter) %>% unique() %>% head(3)

        batter_plot_data <- cric_data_clean %>%
          filter(match_id == match_id_selected, Batter %in% selected_batters) %>% group_by(Batter) %>%
          mutate( ball_number = row_number(), dot_flag = ifelse(dot_ball == 1, "Dot Ball", "Run Scored"),
            dismissed = ifelse(!is.na(Method), TRUE, FALSE)) %>% ungroup()

        ggplot(batter_plot_data, aes(x = ball_number, y = 1, fill = dot_flag)) +
          geom_col(width = 1, show.legend = TRUE) +
          scale_fill_manual(values = c("Dot Ball" = "#F94144", "Run Scored" = "#43AA8B")) +
          geom_vline( data = batter_plot_data %>% filter(dismissed), aes(xintercept = ball_number), linetype = "dashed", color = "black",
linewidth = 1) +
          facet_wrap(~ Batter, scales = "free_x") +
          labs( title = paste("Ball-by-Ball Sequence for Selected Batters in Match", match_id_selected),
                x = "Ball Number", y = "Delivery (indicator only)", fill = "Type", caption = "Dashed black line indicates the delivery on which
the batter was dismissed.") +
          theme_minimal() +
          theme(axis.text.y = element_blank(), axis.ticks.y = element_blank())
```



Hypothesis Testing

Test whether the **proportion of dot balls** differs between **Powerplay** and **Non-Powerplay** overs.

Null Hypothesis (H_0)

- H_0:The proportion of dot balls is the same in Powerplay and Non-Powerplay overs.

$$p_1 = p_2$$

Alternate Hypothesis (H_A)

- H_A:The proportions are different.

$$p_1 \neq p_2$$

Assumptions:

- Independent observations(each ball is a separate event)
- Sufficient sample size for proportions (normal approximation valid)
- The test assumes binary outcomes (dot vs non-dot), which matches dot_ball flag.

```
# Summarise dot balls by over type
dot_table <- cric_data_clean %>%
  group_by(over_type) %>%
  summarise(
    dot_balls = sum(dot_ball),
    total_balls = n()
  )

knitr::kable(dot_table)
```

over_type	dot_balls	total_balls
Non-Powerplay	95317	275724
Powerplay	65077	132308

Hypothesis Testing Cont.

```
# Chi-square test for proportion difference with confidence interval

chi_result <- prop.test(
  x = dot_table$dot_balls,
  n = dot_table$total_balls,
  alternative = "two.sided",
  correct = FALSE  # Turn off Yates correction for large sample
)
chi_result
```

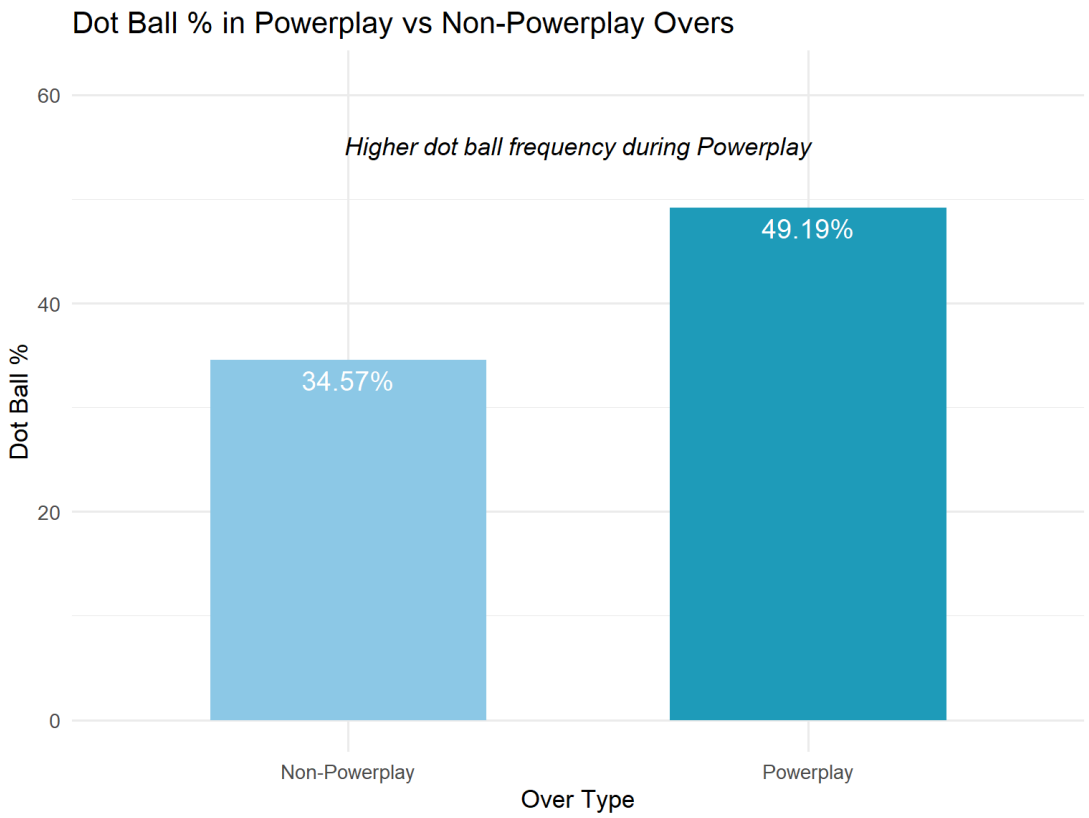
```
##
##  2-sample test for
##  equality of
##  proportions
##  without
##  continuity
##  correction
##
## data:  dot_table$dot_balls out of dot_table$total_balls
## X-squared =
## 8006.1, df = 1,
## p-value < 2.2e-16
## alternative hypothesis: two.sided
## 95 percent confidence interval:
##  -0.1493889 -0.1429366
## sample estimates:
##    prop 1    prop 2
## 0.3456971 0.4918599
```

- Since the p-value is **extremely small** (far less than 0.05) and the confidence interval does not include 0, reject the null hypothesis.
- There is a **statistically significant difference** in dot ball frequency between Powerplay and Non-Powerplay overs.

Hypothesis Testing Cont.

```
dot_table <- dot_table %>%
  mutate(dot_percentage = round(100 * dot_balls / total_balls, 2))

ggplot(dot_table, aes(x = over_type, y = dot_percentage, fill = over_type)) +
  geom_col(width = 0.6, show.legend = FALSE) +
  geom_text(aes(label = paste0(dot_percentage, "%")), vjust = 1.5, color = "white", size = 5) +
  scale_fill_manual(values = c("Powerplay" = "#219ebc", "Non-Powerplay" = "#8ecae6")) +
  labs(
    title = "Dot Ball % in Powerplay vs Non-Powerplay Overs",
    x = "Over Type",
    y = "Dot Ball %"
  ) +
  annotate("text",
           x = 1.5,
           y = max(dot_table$dot_percentage) + 6,
           label = "Higher dot ball frequency during Powerplay",
           size = 4.5,
           color = "black",
           fontface = "italic") +
  ylim(0, max(dot_table$dot_percentage) + 12) +
  theme_minimal(base_size = 13)
```



Categorical association

Is there an association between dot ball usage and match outcome (win/loss) in T20 Internationals?

Method:

- A **Chi-Square Test of Independence** was used to test the relationship between:
  - *Dot Ball Usage Category (High vs Low) - calculated based on above or below median dot ball rate.*
  - *Match Outcome (Win vs Loss) - using the Chased Successfully column (1 = Won, 0 = Lost).*

```
match_outcome <- cric_data_clean %>%
  filter(Innings == 2) %>%
  group_by(match_id) %>%
  summarise(
    dot_rate = mean(dot_ball),
    result = unique(ifelse(`Chased Successfully` == 1, "Won", "Lost")))
match_outcome <- match_outcome %>%
  mutate(dot_usage_category = ifelse(dot_rate >= median(dot_rate), "High", "Low"))

table_dot_win <- table(match_outcome$dot_usage_category, match_outcome$result)
chisq.test(table_dot_win)
```

```
##
##  Pearson's
##  Chi-squared test
##  with Yates'
##  continuity
##  correction
##
## data:  table_dot_win
## X-squared =
## 75.941, df = 1,
## p-value < 2.2e-16
```

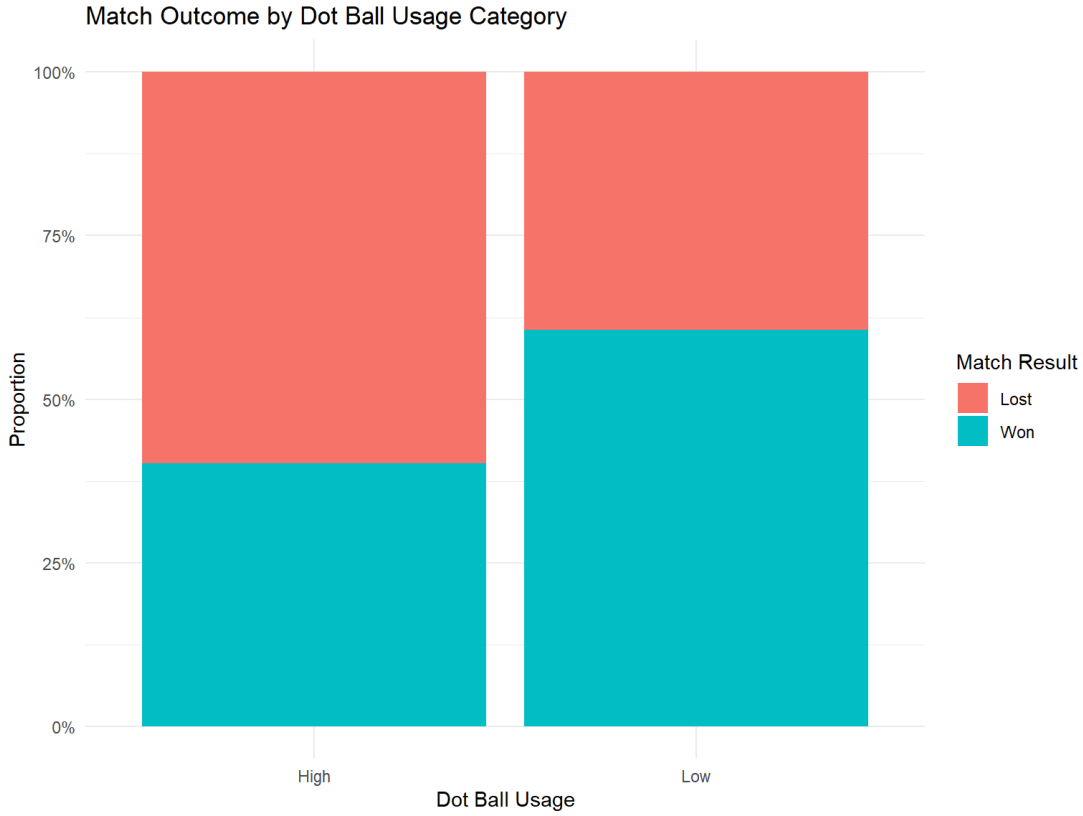
- The p-value < 0.001 indicates a strong association between dot ball usage and match outcome.

Categorical association Cont.

```
df_plot <- as.data.frame(table_dot_win)
colnames(df_plot) <- c("DotUsage", "MatchResult", "Count")

df_prop <- df_plot %>%
  group_by(DotUsage) %>%
  mutate(Proportion = Count / sum(Count))

ggplot(df_prop, aes(x = DotUsage, y = Proportion, fill = MatchResult)) +
  geom_bar(stat = "identity", position = "fill") +
  labs(
    title = "Match Outcome by Dot Ball Usage Category",
    x = "Dot Ball Usage",
    y = "Proportion",
    fill = "Match Result"
  ) +
  scale_y_continuous(labels = scales::percent) +
  theme_minimal()
```



- Teams with **lower dot ball usage** had a **higher winning proportion**.
- Teams with higher dot ball usage were more likely to lose.

Discussion

Key Findings:

- Dot balls occur more frequently during Powerplay overs (1–6) than in later overs.
- The difference in dot ball frequency between Powerplay and Non-Powerplay is statistically significant (Chi-squared test, $p < 0.001$).
- A Chi-squared test of association showed that teams with fewer dot balls were more likely to win.

Strengths:

- Used a large dataset of 400,000+ deliveries for strong insights.
- Applied both statistical testing and categorical analysis.

Limitations:

- Did not consider match context like batting first or second.
- Dot ball usage was categorized into 'High' and 'Low' using a median split, which may oversimplify underlying variation.

Dot balls are significantly more common in the Powerplay phase of T20 cricket, and higher dot ball frequency makes batting team to lose which shows the pressure dot ball can build on a team.

Source: @IndiaToday

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