The Impact of Formula 1 Tire Compounds

An Analysis of F1 Tire Compound Impact at the 2024 Hungarian Grand Prix

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Introduction and Race Context

Tire compound selection plays a crucial role in Formula 1 race strategy, directly affecting lap time, tire degradation, and overall race performance. However, the effectiveness of each compound can vary significantly depending on track characteristics and race conditions.

This analysis investigates which tire compound performed best at the 2024 Hungarian Grand Prix. Using lap time and stint data, we examine how tire performance changes with tire age, lap time, and compound by comparing lap times achieved by each driver on different compounds.

The results show that the medium compound consistently outperformed the soft and hard compounds at this race, while the soft compound performed poorly overall.

To understand tire performance at the Hungarian Grand Prix, we first examine how lap times evolve as tires age. We then compare each driver's fastest laps across compounds and finally discuss strategic insights for optimizing tire choice during the race.

Tire Performance Overview

How Tire Age Affects Lap Time

Tire age strongly influences lap time, as tires degrade and lose grip over more laps completed. Examining this relationship helps identify which compound maintains optimal performance and for how long.

Figure 1: Average Lap Time vs. Tire Age By Compound Line Chart

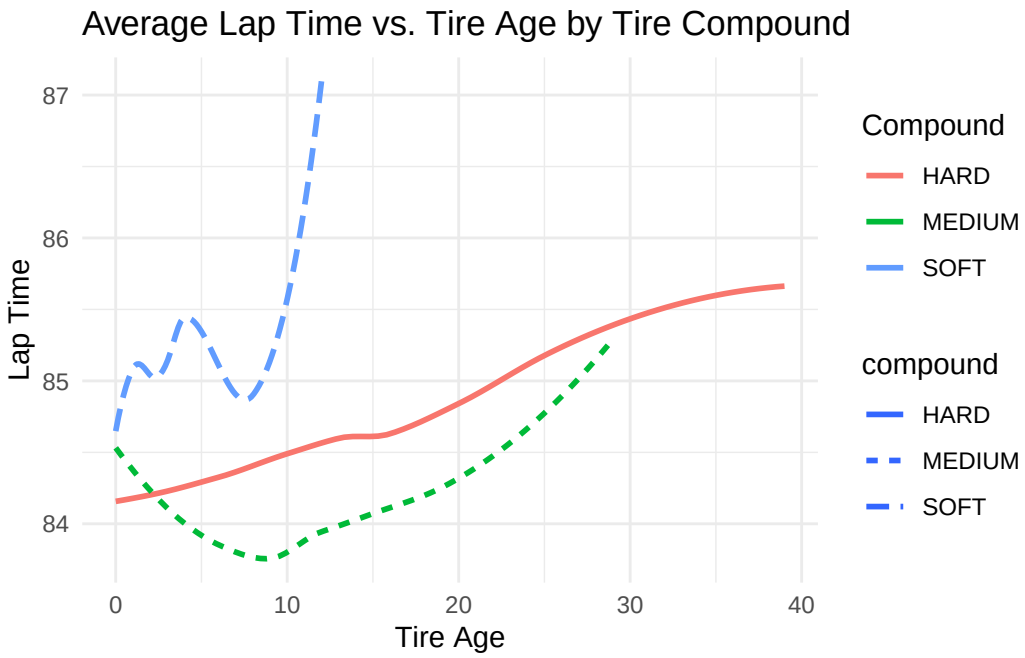

Figure 1 displays the relationship between average lap time and tire age for each tire compound (soft, medium, hard). Tire age is measured as the number of laps completed on a specific set of tires. The values were calculated by averaging lap times at each tire age across all stints using that compound. The figure illustrates distinct length patterns for each compound. Soft tires last about 10 laps, medium about 30 laps, and hard up to 40 laps. Lower points on the line represent faster lap times, while spikes and upward trends represent slower times and drop in tire performance. Softer tires are expected to be the fastest compound, however, at this race, it was the slowest on average. Medium tires performed the best overall, reaching its peak at 10 laps. Hard tires were moderate, remaining consistent between soft and medium. Overall, we learn that at the Hungarian Grand Prix, the soft compound was relatively ineffective, making it a less desirable option for race performance. In contrast, the medium compound provided the best balance of speed and durability, emerging as the optimal tire choice for this race.

While Figure 1 shows general trends by compound, the next section explores individual driver performance to see how these trends relate to fastest laps on each tire.

Comparing Drivers' Fastest Laps by Compound

Different drivers may show different performance from the same tire compound due to driving style and stint strategy. Comparing their fastest laps highlights both individual differences and the overall effectiveness of each compound.

Table 1: Driver's Fastest Lap on each Compound

Driver	Soft	Medium	Hard
Alexander Albon	85.933	83.930	NA
Carlos Sainz	NA	82.908	81.441
Charles Leclerc	NA	82.182	82.299
Daniel Ricciardo	NA	82.640	85.717
Esteban Ocon	81.610	84.057	86.158
Fernando Alonso	85.854	83.063	83.792
George Russell	NA	80.305	82.211
Guanyu Zhou	NA	83.487	85.991
Kevin Magnussen	85.911	83.553	NA
Lance Stroll	84.400	82.338	84.176
Lando Norris	NA	82.820	81.712
Lewis Hamilton	NA	82.153	84.001
Logan Sargeant	80.561	84.090	85.070
Max Verstappen	NA	82.655	80.908
Nico Hulkenberg	NA	83.461	88.821
Oscar Piastri	NA	82.654	81.716
Pierre Gasly	NA	85.164	83.340
Sergio Perez	NA	84.197	81.096
Valtteri Bottas	NA	82.792	84.876
Yuki Tsunoda	NA	83.533	84.541

Table 1 displays the fastest lap for each driver on each compound they competed with. All drivers completed at least one stint on the medium compound, and the majority also used the hard compound. Furthermore, only 6 drivers recorded laps on the soft compound. Across nearly all drivers, the medium compound produced the fastest lap times compared to the other compounds. For drivers who used multiple compounds, their quickest lap was typically set on medium tires.The soft compound generally resulted in slower fastest lap times when compared to medium and even hard tires. This further supports the earlier findings as seen in Figure 1, that the soft compound underperformed at the 2024 Hungarian Grand Prix, despite its reputation as the fastest tire. Overall, the table strengthens the conclusion that the medium compound was the most effective tire choice for achieving peak lap performance, while the soft compound was the least competitive option in this race.

Drivers with the Fastest Lap's Compounds Over Time

Drivers use different tire compounds in a race to get the fastest lap. Softest tires are usually known to get the fastest speeds, but don't last as long as a hard tire compound. This can vary from race to race, as tracks and weather can impact lap times as well.

Figure 2: Lap Time vs Lap Number by Compound of Top 5 Fastest Drivers

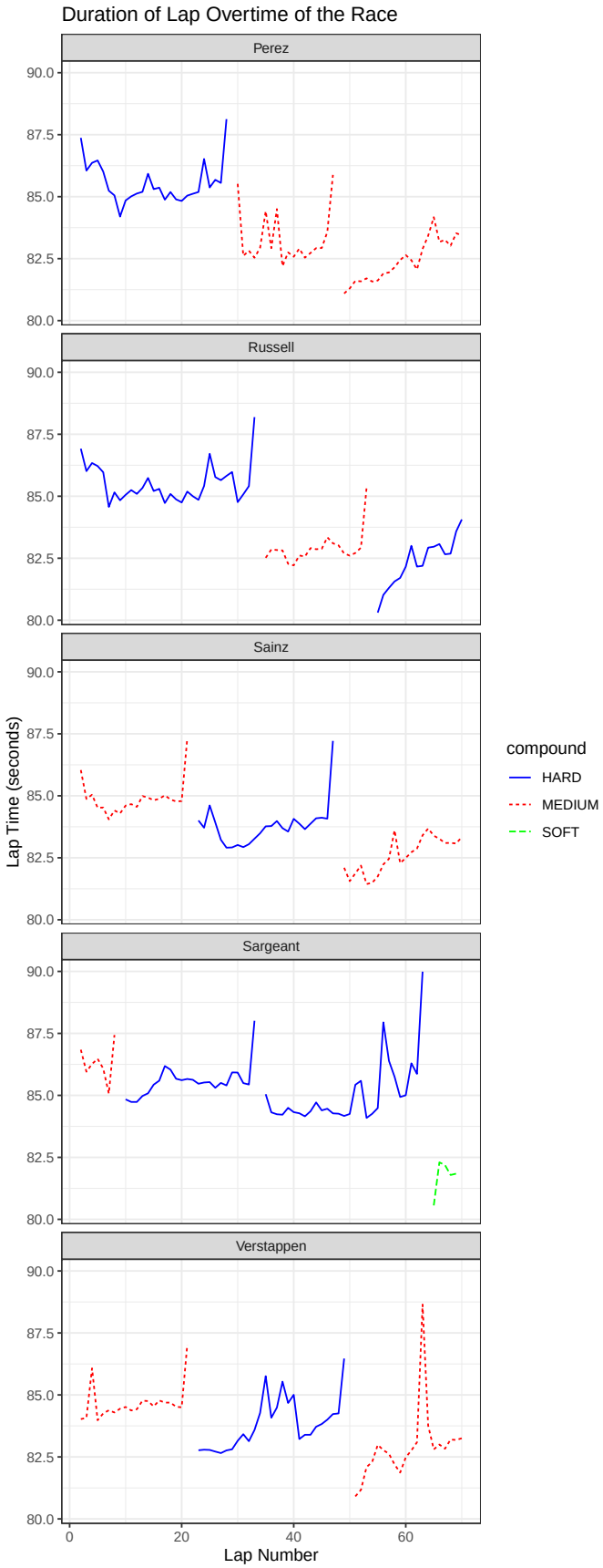

Figure 2 displays the 5 different drivers who had the 5 fastest laps in the Hungarian Grand Prix of 2024. Peaks in lines show a slower lap, while dips show a faster lap. All tire compounds were used in this sample, with soft tires being used the least overall. Among these 5 drivers, there is more variation in lap time, stints, stint number, and tire compound. The fastest lap time came from using soft tires, which happened right after Sargeant pitted for the third time in this race and switched. This is not a pattern followed by the other drivers. Overall, you can see that medium and soft achieved a faster lap, but the last third of the race was the fasted overall. An interesting thing to note about this graph is the fact that Sargeant went from having the slowest lap time, with hard compound tires, to the fastest lap time, with soft compound tires. Medium tires still showed the best performance, as supported by Figure 1, as those lines are overall lower than than the hard compound. It can also be seen that at the end of the race, when drivers are looking to get a faster lap, most drivers change to medium or soft. This was successful for Sargeant, as he achieved the fasted lap at the end of the race.

Comparing Distribution of Lap Times

Of all drivers who had the top fastest lap times recorded, there is great variation in lap number and what compound was used. Showing the distribution of lap time for each driver on each compound highlights the effectiveness of each tire and how variable each compound is.

Table 2: Summary Table for Top 5 Drivers with the Fastest Lap

Driver Last Name	Compound	Minimum	Quartile 1	Median	Quartile 3	Maximum	Mean	Standard Deviation
Perez	HARD	84.197	85.047	85.240	85.967	88.128	85.552	0.844
Perez	MEDIUM	81.096	82.129	82.742	83.195	85.878	82.806	1.040
Russell	HARD	80.305	82.991	85.028	85.472	88.191	84.450	1.726
Russell	MEDIUM	82.211	82.608	82.830	82.916	85.333	82.898	0.648
Sainz	HARD	82.908	83.269	83.769	84.004	87.215	83.793	0.843
Sainz	MEDIUM	81.441	82.552	83.644	84.784	87.324	83.699	1.351
Sargeant	HARD	84.090	84.394	85.306	85.628	89.989	85.277	1.083
Sargeant	MEDIUM	85.070	86.018	86.265	86.658	87.436	86.303	0.741
Sargeant	SOFT	80.561	81.789	81.843	82.189	82.299	81.736	0.692
Verstappen	HARD	82.655	82.970	83.585	84.264	86.468	83.811	1.015
Verstappen	MEDIUM	80.908	82.796	84.002	84.516	88.648	83.776	1.471

Table 2 displays various numbers showing the distribution of lap times for each driver and the compounds they used. All drivers used only medium and hard tires, except for Sargeant who used all three types of tire compound. For almost all drivers, the minimum lap time for medium tires was lower then the minimum time for hard tires. The average times for both tire compounds varied from driver to driver, with no specific compound out of the two having a lower lap time. To compare the overall performance of each tire, examine Figure 1, which will show the average of each tire compound for all drivers. The fastest lap was achieved by soft tires, with the mean being the lowest recorded. However it must be taken into account that this stint with the soft tires, as seen in Figure 2, was the shortest recorded, and was the only driver who changed to soft tires, so there is no other driver data in the top 5 fastest lap to compare it to. Overall, it can be seen that medium tires are more effective for sustaining fast laps over longer periods of time in this race.

Relationship Between Tires and Optimum Age

Each tire compound has it's own strengths and weaknesses. Each tire compound wear differently and will produce fastest lap times at different stages of a stint. Soft's are often a their peak earlier in a stint while hard take longer to reach optimum speed. However, this can change from circuit to circuit.

Figure 3: Comparison of Optimized Tire Age by Compound

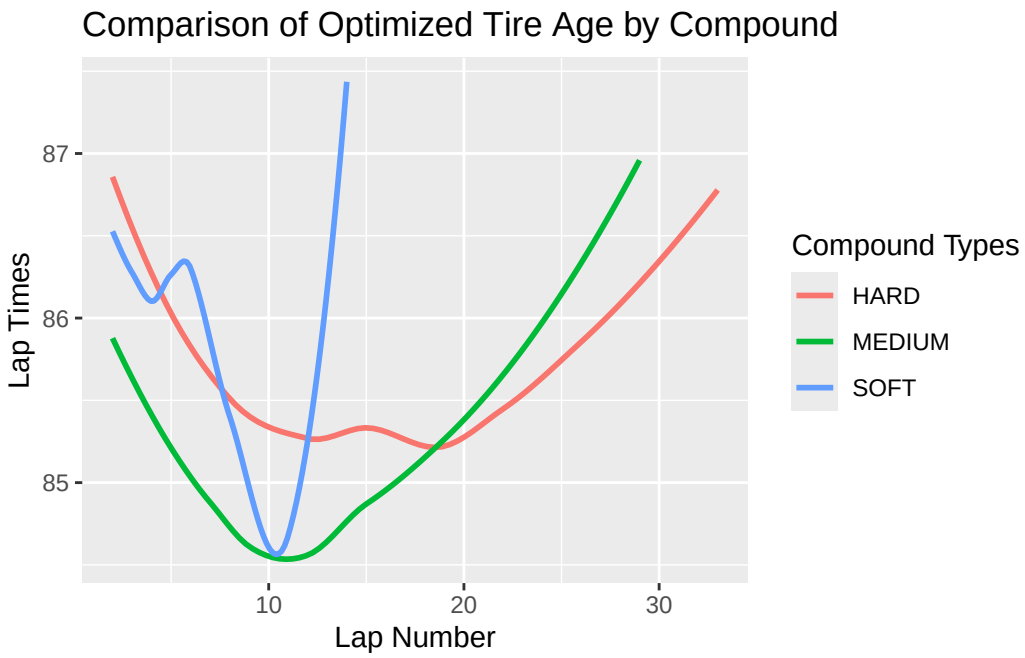

Figure 3 displays three lines representing the tire compounds hard, soft, and medium. Through this graph, it is seen that soft tires quickly reach their optimum age as it hits the fastest lap at around 10 laps in, but it decreases almost immediately after. The medium tires takes around the same time as soft's to reach their peak, but it stays consistent around 12 laps where it has similar lap times. The mediums also produce the fastest overall times out of all three compounds. It does not decrease instantly after reaching a peak, but in a slower rate that increases its usability as age increases. Finally, the hard tires don't reach a true peak but show two small peaks where they improve lap times at right before 15 laps and then a little after 15 laps. Hard tires produced the slowest overall lap times out of the three compound. They also take the longest time to reach their optimum age and take longer to start producing slower times.

Therefore, based on the graph, the optimum tire age for each compound is as follows: Softs reach their optimum age at around 11 laps in and immediately decrease after that. Mediums reach their optimum age at around 12 laps in, but unlike softs they stay consistent longer and start decreasing later and slower. Finally, hard's are at their optimum around 15 laps in and also stay consistent and take the least amount of time to begin decreasing.

Compound Type and Lap Data

Each tire has a different time when it begins to stop producing desired lap times, this is when the pit-wall knows its time to switch tires. Hard compounds are known to last longer and soft compounds usually ware out quicker.

Table 3: Summary of Relationship Between Compound Type and Lap Lengths

Compound	Minimum Laps Completed	Maximum Laps Completed	Average Lap Length	Total Tires Used
SOFT	5	14	7.33	6
MEDIUM	2	31	18.38	24
HARD	17	41	29.00	30

Table 3 displays each tire compound, it's minimum laps completed, maximum laps completed, average lap lengths, and how many times it was used. Based on the graph, the soft tires has an average length of 7.33, mediums had an average of 18.38, and hard had an average of 29 laps. So the hard tires were able to last longer as compared to the soft tire. The table also shows that the soft tires have a smaller range of minimum laps completed and maximum in comparison to hard tires which were in use for 41 laps. Due to the hard tires being used the most with 30 total, it is assumed that hard tires are the most reliable in comparison to soft and even medium tires. Similarly, soft tires are the least used with only 6 total uses throughout the entire race.

Race Strategy Insights and Conclusions

Combining insights from tire age trends and driver lap times, we can conclude implications for race strategy. The data suggest which compounds offered the best balance of speed and durability, and how teams could optimize their tire choices during the race.

Medium Compound Dominance: The medium tire compound provided the best overall lap times and consistent performance across stints.

Soft Compound Underperformance: Despite expectations, soft tires did not yield the fastest laps due to rapid degradation at the Hungarian track. They led the slowest.

Hard Compound Consistency: Hard tires were slower than medium tires but provided longer stints. They are preferred in longer runs.

Race Strategy Implications: Optimal race strategy at the Hungarian Grand Prix involved prioritizing medium tires for key performance windows, while using hard tires for longevity and soft tires sparingly.

Overall, the data creates a clear narrative: medium tires were the optimal choice at this race, balancing speed and durability, while the other compounds were either too fragile (soft) or too slow (hard) for maximum performance.

Author Contribution

- **Kathryn Sujai:** GitHub page, Figure 3 and table 3 creation.
- **Ellie Wallace:** Plan document, Figure 2 and table 2 creation.
- **Elisabeth Hadzic:** Data collection, cleaning, and wrangling. Figure 1 and Table 1 creation.

All authors contributed to creation of work-in-progress presentation and final report.

Code Appendix

```
source("Data/DataFiles.R")
# Lap Time vs. Tire Age Visualization
# Author: Elisabeth Hadzic

# 1: Load needed packages
library(tidyverse)
library(ggplot2)

# 2:Create the line plot
laps_stints_data %>%
  group_by(driver_number, stint_number) %>% # group by driver and stint
  arrange(lap_number) %>%
  mutate(
    stint_lap = row_number() - 1, # resets the stint lap number to 1 for each new stint
  ) %>%
  ggplot(aes(x=stint_lap, y=lap_duration, color = compound, linetype = compound)) + # map the a
  geom_smooth(se = FALSE) + # smooths the line
  theme_minimal() +
  labs( # Adds labels to the plot
    title = "Average Lap Time vs. Tire Age by Tire Compound",
    x = "Tire Age",
    y = "Lap Time",
    color = "Compound"
  )
# Driver's fastest lap per compound table
# Author: Elisabeth Hadzic

# 1: Load needed packages
library(tidyverse)
library(kableExtra)
library(knitr)

# 2: Filter for medium tires and find fastest laps
compound_fastest <- laps_stints_data %>%
  filter(compound %in% c("SOFT", "MEDIUM", "HARD")) %>%  # filter 3 compounds
```

```r
  mutate(compound = factor(compound, levels = c("SOFT", "MEDIUM", "HARD"))) %>% # to stay in or
  mutate(driver = paste(first_name, last_name)) %>% # Combines driver name into one
  group_by(driver, compound) %>% # group by driver and compound
  summarise(
    fastest_lap = min(lap_duration, na.rm = TRUE), # take min lap time for fastest
  ) %>%
  pivot_wider(
    names_from = compound,
    values_from = fastest_lap
  )

# 3: Create the table with kableExtra
compound_fastest %>%
  kable(
    caption = "Driver's Fastest Lap on each Compound", # add title
    col.names = c("Driver", "Soft", "Medium", "Hard"), # apply column names
    align = c("l", "c", "c", "c"),
    booktabs = TRUE,
  ) %>%
  kableExtra::kable_classic(
    font_size = 15,
    lightable_options = "striped" # style type
  )
# Load Needed Packages
library(ggplot2)
library(dplyr)
library(tidyverse)
library(httr)
library(jsonlite)

# Import the Stint data
response <- GET('https://api.openf1.org/v1/stints?meeting_key=1241') # meeting key 1241 = Hunga
stint_data <- fromJSON(content(response, 'text'))

# Import the Lap data
response1 <- GET('https://api.openf1.org/v1/laps?meeting_key=1241')
laps_data <- fromJSON(content(response1, 'text'))

# Import Driver Data
response3 <- GET('https://api.openf1.org/v1/drivers?meeting_key=1241&session_key=9566')
drivers_data <- fromJSON(content(response3, 'text'))


# Clean the Stint Data
stint_data_clean <- stint_data %>%
  filter(
    session_key == 9566 # filter for the race session only
```

```
  ) %>%
  select( # Select needed columns
    stint_number,
    driver_number,
    lap_start,
    lap_end,
    compound,
    tyre_age_at_start
  ) %>%
  mutate(
    stint_length = (lap_end + 1) - lap_start # create a stint_length column
  )

# Clean the Laps Data
laps_data_clean <- laps_data %>%
  filter(
    session_key == 9566, # filter for the race session only
    lap_number != 1, # remove lap 1 due to incomplete data
    is_pit_out_lap == FALSE # remove outlaps to prevent outliers
  ) %>%
  select( # Select needed columns
    driver_number,
    lap_number,
    lap_duration
  )

# Clean the Driver Data
driver_data_clean <- drivers_data %>%
  select( # Select needed columns
    driver_number,
    team_name,
    first_name,
    last_name
  )

# Join the data
laps_stints_data_clean <- laps_data_clean %>%
  left_join(stint_data_clean, by = "driver_number", relationship = "many-to-many") %>%
  left_join(driver_data_clean, by = "driver_number") %>% # join on driver number
  filter(lap_number >= lap_start & lap_number <= lap_end) # assign lap time to correct stint

# Edit data to make specific to fastest drivers
fastest_lap <- laps_stints_data_clean %>%
  filter(last_name %in% c("Russell", "Sargeant", "Verstappen", "Perez", "Sainz"))

# Create the data visualization
fastest_lap %>%
```

```
  ggplot( #select data
    mapping = aes( #assign variables
      x = lap_number,
      y = lap_duration,
      color = compound,
      linetype = compound,
      group = stint_number
    )
  ) +
  geom_path() + #create line plot
  labs( #add labels
    title = "Duration of Lap Overtime of the Race",
    x = "Lap Number",
    y = "Lap Time (seconds)"
  ) +
  facet_wrap(vars(last_name), ncol = 1) + #create one vertical panel per driver
  scale_color_manual(values = c("HARD" = "blue", "MEDIUM" = "red", "SOFT" = "green")) + #set co
  theme_bw()
# Load Needed Packages
library(kableExtra)
library(knitr)
library(tidyverse)
library(dplyr)

# Create the new Data Frame for the Table
fastest_lapstat <- fastest_lap %>%
  select( #eliminate unessecary columns
         -driver_number,
         -lap_number,
         -stint_number,
         -lap_start,
         -lap_end,
         -tyre_age_at_start,
         -stint_length,
         -team_name,
         -first_name) %>%
  group_by(last_name, compound) %>% #group name and compound variables together
  summarise( #calculate the values for the data
    Min = min(lap_duration, na.rm = TRUE),
    Q1 = quantile(lap_duration, probs = 0.25, na.rm = TRUE),
    Median = median(lap_duration, na.rm = TRUE),
    Q3 = quantile(lap_duration, probs = 0.75, na.rm = TRUE),
    Max = max(lap_duration, na.rm = TRUE),
    Mean = mean(lap_duration, na.rm = TRUE),
    Standard_Deviation = sd(lap_duration, na.rm = TRUE),
    .groups = "drop"
  )
```

```r
# Create new data set for the table
fastest_lap_table <- fastest_lapstat

# Rename column names to be more proper
names(fastest_lap_table) <- c(
  "Driver Last Name",
  "Compound",
  "Minimum",
  "Quartile 1",
  "Median",
  "Quartile 3",
  "Maximum",
  "Mean",
  "Standard Deviation"
)
# Create the table
fastest_lap_table%>%
  kable(
    caption = "Summary Table for Top 5 Drivers with the Fastest Lap", #add captions
    align = c("l", rep("c", 10)),
    digits = 3 #round to 3 decimals
  ) %>%
  kable_classic(
    font_size = 8, #edit font size
    lightable_options = "striped" #make table easier to read and striped
    )
# Optimum Tire Age Visualization
# Author: Kathy Sujai
library(ggplot2)
library(tidyverse)

stint1_data <- laps_stints_data %>% #create new dataframe with only stint 1 data
  filter(stint_number == 1)

ggplot( #create a graph that shows optimum tire age
  stint1_data,
  mapping = aes(
    x = lap_number,
    y = lap_duration,
    color = compound
  )
) +
  geom_smooth(se = FALSE) + #line of best fit
  labs(
    title = "Comparison of Optimized Tire Age by Compound",
    x = "Lap Number",
    y = "Lap Times",
```

```
    color = "Compound Types"
  )

# Compound vs Lap Length
# Author: Kathy Sujai
# Load Needed Packages
library(kableExtra)
library(knitr)
library(tidyverse)


stint_softs <- stint_data_clean %>% #create a new data-frame for soft tire compounds
  filter(compound == "SOFT") %>% #filters out only data for soft tires
  summarise( #finds the min lap length, max lap length, and average tire age, and total used
    compound = "SOFT",
    Min = min(stint_length, na.rm = TRUE),
    Max = max(stint_length, na.rm = TRUE),
    Mean = mean(stint_length, na.rm = TRUE),
    count = n()
  )

stint_mediums <- stint_data_clean %>% #create a new data-frame for medium tire compounds
  filter(compound == "MEDIUM") %>% #filters out only data for medium tires
  summarise(
    compound = "MEDIUM",
    Min = min(stint_length, na.rm = TRUE),
    Max = max(stint_length, na.rm = TRUE),
    Mean = mean(stint_length, na.rm = TRUE),
    count = n()
  )

stint_hards <- stint_data_clean %>% #create a new data-frame for hard tire compounds
  filter(compound == "HARD") %>% #filters out only data for hard tires
  summarise(
    compound = "HARD",
    Min = min(stint_length, na.rm = TRUE),
    Max = max(stint_length, na.rm = TRUE),
    Mean = mean(stint_length, na.rm = TRUE),
    count = n()
  )

stint_comparison <- bind_rows( #creates a new dataframe with all three tire compound
  stint_softs, stint_mediums, stint_hards
)

stint_comparison %>% #creates a clean table using Kable of the compound types
  kable(
```

```
  caption = "Summary of Relationship Between Compound Type and Lap Lengths",
  col.names = c("Compound", "Minimum Laps Completed", "Maximum Laps Completed", "Average Lap
  align = c("l", "c", "c", "c"),
  digits = 2
) %>%
kable_classic(
  font_size = 8,
  lightable_options = "striped"
)
```