Assessment of Motorcycle Safety in Wyoming: Fatal and Severe Crashes, Contributing Factors and Potential Countermeasures

**WYDOT Project Champion:** 



Jennifer Goodrich Motorcycle Safety Program Coordinator Wyoming Department of Transportation Cheyenne, WY 82009 (307) 777-4874; jennifer.goodrich@wyo.gov

## **Principal Investigator:**

Milan Zlatkovic, Ph.D., P.E., PTOE Assistant Professor University of Wyoming Laramie, WY 82071 (307) 766-2390; mzlatkov@uwyo.edu

## Submitted To:

Wyoming Department of Transportation Research Advisory Committee 5300 Bishop Blvd. Cheyenne, WY 82009

October 4, 2021.

#### **Table of Contents**

| 1.  | Problem Statement             | . 1 |  |  |
|-----|-------------------------------|-----|--|--|
| 2.  | Literature Review             | . 1 |  |  |
| 3.  | Background                    | . 3 |  |  |
| 4.  | Benefits to WYDOT             | . 5 |  |  |
| 5.  | Study Objectives and Outcomes | . 6 |  |  |
| 6.  | Study Tasks                   | . 8 |  |  |
| 7.  | Implementation                | . 9 |  |  |
| 8.  | Technology Transfer           | 11  |  |  |
| 9.  | Work Schedule                 | 12  |  |  |
| 10. | Budget and Matching Funds     | 12  |  |  |
| Ref | References                    |     |  |  |

### List of Tables

| Table 1: 12-year Motorcycle-Related Crash Frequencies in WY (2008 – 2019): |   |
|--|---|
| Severities and Helmet Use  | 4 |
| Table 2: Study Budget (January – September 2022) 1                         | 3 |

## List of Figures

| Figure 1: Map. Geo-Location of Motorcycle-Related Crashes in Wyoming (2008 –           |   |
|--|---|
| 2019). Source: Google Earth  | 1 |
| Figure 2: Photo. Biker Shield Motorcycle Barrier (Source: Safe Direction Crash Barrier |   |
| Solutions)   | ) |
| Figure 3: Photo. System Euskirchen Plus Guardrail (Source: Nicol et al.)11             | I |
| Figure 4: Illustration. Warning Signs Adapted for Motorcycles (Adapted from MUTCD)11   | I |
| Figure 5: Chart. Study Timeline and Task Schedule12                                    | 2 |

#### 1. Problem Statement

Motorcycle fatalities comprise a large percentage of total traffic fatalities in the U.S., in excess of 15 percent (*National Motorcycle Institute, 2021*). The mean fatality crash rate for motorcycles is more than six times higher than that for passenger cars, even though motorcycles account for about 0.6 percent of all Vehicle Miles Traveled (VMT) (*NHTSA, 2019*). Between 2008 and 2019, the average motorcycle-related crash frequency in Wyoming was 286 crashes/year, with the average number of fatal crashes of 17 per year, and the average number of incapacitating injury crashes of 73 per year. In 2019, there were 13 fatal motorcycle-related crashes, which was about 11 percent of the total fatal crashes. Based on the 2017 vehicle registration data, registered on-road motorcycles in Wyoming does not have a comprehensive helmet requirement law, and the helmet is only required for riders and passengers aged 17 or younger, with the exception of mopeds (*IIHS, 2021*). Of all motorcycle fatalities in Wyoming, it is estimated that 57 percent were not using a helmet (*NHTSA, 2019*).

This research will perform a comprehensive motorcycle safety assessment for Wyoming, with the focus on fatal and severe injury crashes, using at least ten years of safety data. The assessment will include crash characteristics and contributing factors, identify routes and locations where most fatal and injury motorcycle crashes occur, and identify roadway, environmental, traffic and driver characteristics common in these types of crashes. Statistical modeling will be applied to develop specific safety performance functions (SPF) for motorcycle-related crashes. Based on the locations and characteristics, potential countermeasures will be recommended with the aim to reduce the frequency and severity of motorcycle-related crashes (e.g. installing motorcycle-friendly crash barriers, warning signs and plaques for motorcyclists, improving pavement conditions, upgrading drainage and shoulders, upgrading traffic control at signalized intersections etc.). Furthermore, the study will include surveys of motorcycle safety experts within the State and beyond (e.g. rider coaches and motorcycle officers) to obtain their insights on observed issues related to motorcycle safety and potential remedies.

#### 2. Literature Review

In the U. S. and other developed countries, motorcycles are primarily used for recreation and leisure, and are typically considered a luxury item (*Broughton and Walker, 2019*). The motorcycle share for commuting trips in the U. S. is negligible. In the developing countries, especially in Asia, motorcycling is the predominant transportation mode (*Jittrapirom et al., 2017*). Due to the lower use of resources and less required space, motorcycles can contribute to more sustainable transportation systems (*Jittrapirom et al., 2017; Rose et al., 2012*). The motorcycle can utilize up to five times

less space than a car, consumes less energy in production and operation, and emits less CO2 (*Bakker, 2018; Pfaffenbichler and Circella, 2009*). However, motorcycles are usually treated solely on the basis of their safety characteristics (*Wigan, 2002*). This is due to the fact that the motorcyclists are overrepresented in traffic fatalities. According to the NHTSA, motorcyclists are about 29 times as likely as passenger car occupants to die in a motor vehicle traffic crash (*NHTSA, 2021*). In 2019, 5,014 motorcyclists were killed in crashes in the U.S., which accounted for 14 percent of all traffic fatalities. No systematic motorcycle transportation policy exists, although steps have been taken to develop an active motorcycle safety agenda.

Motorcycle crashes result in more fatalities and serious injuries, therefore many research efforts have been focused on analyzing motorcycle crash severities and contributing factors using various methods. A 2006 study using crash data from Indiana assessed motorcyclists' injury severities in single and multi-vehicle crashes (Savolainen and Mannering, 2007). The results showed that increasing age is correlated with more severe injuries, and that collision type, roadway characteristics, alcohol, helmet use and unsafe speed were all significant factors related to injury severity. A study on single motorcycle crashes explored the effects of motorcyclists' age in combination with other factors using crash data from Florida (Islam, 2021). The results indicated intercorrelation between different factors and age (e.g. speeding, helmet use, alcohol consumption, motorcycle type, etc.). As an example, the study found that not wearing a helmet increases the likelihood of fatal injury for the age group of 50 and above, while it decreases for the middle age group (30-49). However, not wearing a helmet increases the likelihood of severe injury for the middle age group, but decreases it for the older age group. This study also showed the importance of analyzing multiple factors in combination when it comes to the injury severity outcomes of motorcycle crashes. Another study used 20 years of crash data from Pennsylvania to assess the correlations between risk factors and injury severity in motorcycle-related crashes (Li et al., 2021). The results showed that multiple factors, such as helmet use, engine size, vehicle age, motorcyclist age, pillion passenger, at-fault striking, and speeding are significantly related to motorcyclist injury severity. A study using crash data from lowa examined the factors affecting single-vehicle motorcycle crash severity outcomes (Shaheed and Gkritza, 2014). This research found a significant relationship between severe motorcycle crash injuries and factors such as speeding, run-off road, collision with fixed object, overturn or rollover, riding on high-speed and rural roads, rider's age more than 25, not using a helmet, and riding under the influence. A study using motorcycle crash data from Texas analyzed differences in factors affecting motorcycle crash injury severity (Geedipally et al., 2011). The analysis was performed on crashes in urban and rural areas. The results showed that alcohol, gender, lighting, and horizontal and vertical curves have significant impact on motorcyclists' injury severity in urban areas. In rural areas, the significant factors affecting injury severity were found to be similar as in

urban areas, with the addition of motorcyclists' age (older than 55), single-vehicle crashes, angular crashes, and divided highways. A recent research study on motorcycle safety in Wyoming applied binary and mixed binary logistic models with random parameters to assess the injury severity of single and multi-vehicle motorcycle-related crashes (*Farid and Ksaibati, 2021*). The study found that the most severe single motorcycle crashes involve collisions with animals and traffic barriers, followed by horizontal curves and older drivers. Riding under the influence and on roads with higher posted speed limits resulted in higher severity for both single and multi-vehicle crashes.

Previous research has found the most common contributing factors affecting injury severity in motorcycle related crashes, and applied different methodologies to assess the significance of these factors. This study will perform a comprehensive assessment of motorcycle related crashes in Wyoming using at least ten years of safety data, on crash, vehicle and person levels. It will add to the current body of knowledge on motorcycle-related crash injury severity by exploring different types of crashes, factors, locations, conditions, and potential countermeasures. It is expected that this study will have significant benefit for WYDOT and help with determining strategies for reducing the frequency and severity of motorcycle-related crashes in the State.

#### 3. Background

Various factors affect the frequency and severity of motorcycle crashes. Roadway geometry, road, weather, environmental and traffic conditions, setting (urban or rural), the number of vehicles involved, relation to a junction, helmet use, driver condition and action (e.g. riding under the influence or speeding), are some of the most common factors attributed to motorcycle crashes. Motorcycle riders and passengers are overrepresented in traffic fatalities. It is generally accepted that motorcycle crashes result in higher severity due to the exposure of the riders and the lack of construction and restrain elements, which exist in other vehicle types. Even though efforts are being made to improve motorcycle safety, a more proactive and collaborative approach is needed to address this issue.

In Wyoming, motorcycle-related fatal and severe crashes are significantly represented in the crash statistics. A pilot study using 12 years of crash data (2008 – 2019) from the WYDOT Critical Analysis Reporting Environment (CARE) system revealed a total of 3,429 motorcycle-related crashes during the 12-year period, with 202 fatal and 875 incapacitating injury crashes. About 60 percent of total crashes were single-vehicle, where most of them were recorded in rural areas. Majority of motorcycle-related crashes (about 27 percent of all crashes) occurred during the month of August. Furthermore, helmet was not used in 69 percent of fatal motorcycle-related crashes. Table 1 shows some of the descriptive statistics obtained in the pilot study. Figure 1 shows locations of motorcycle-related crashes in Wyoming for the 12-year period, obtained from the database and plotted in Google Earth.

|                        | Helmet<br>Used | Helmet<br>Not Used | N/A | Unknown | Sum   |
|------------------------|----------------|--------------------|-----|---------|-------|
| Fatal (K)              | 59             | 139                | 2   | 2       | 202   |
| Incapacitating (A)     | 332            | 498                | 3   | 42      | 875   |
| Non-incapacitating (B) | 497            | 787                | 6   | 66      | 1,356 |
| Possible (C)           | 186            | 276                | 5   | 41      | 508   |
| No injury (O)          | 96             | 66                 | 0   | 24      | 186   |
| Unknown                | 71             | 171                | 3   | 57      | 302   |
| Total                  | 1,241          | 1,937              | 19  | 232     | 3,429 |

# Table 1: 12-year Motorcycle-Related Crash Frequencies in WY (2008 – 2019):Severities and Helmet Use



Figure 1: Map. Geo-Location of Motorcycle-Related Crashes in Wyoming (2008 – 2019). Source: Google Earth

Some notable clusters of motorcycle-related crashes in Wyoming are in the Grand Teton, Devil's Tower and Bighorn National Forest areas, as well as in larger cities (Cheyenne, Casper, Gillette, Sheridan, Laramie, Riverton, Cody, Rock Springs). Furthermore, rural routes with a notable number of motorcycle-related crashes include Rt. 85, Rt. 601, Rt. 37, Rt. 10, Rt. 36, I-80, Rt. 150, Rt. 607 and Rt. 34, all of them with more than 40 recorded crashes during the 12-year period.

A further analysis of motorcycle-related crashes in Wyoming in the pilot study revealed the following statistics:

- Close to 60 percent of fatalities and incapacitating injuries occurred in motorcycle riders and passengers who were not wearing a helmet
- 21 percent of single rural motorcycle crashes involved run-off-road
- 69 percent of multi-vehicle urban crashes with motorcycle involvement were intersection/interchange/driveway related
- 19 percent of all motorcycle crashes occurred during reduced visibility conditions
- Of all motorcycle-related crashes, 18.4 percent involved speeding, 10.7 percent involved alcohol, and 6.4 percent involved animal collision

Motorcycle safety in Wyoming requires further in-depth analysis in order to uncover contributing factors, roadway, environmental, traffic and driver conditions leading to motorcycle crashes, with a focus on fatal and severe injury crashes. Furthermore, better understanding the factors and conditions leading to motorcycle crashes will help the engineers and decision makers implement potential countermeasures to reduce the frequency and severity of these crashes.

#### 4. Benefits to WYDOT

Safety data reveal that motorcycle-related crashes are significantly represented in Wyoming crash statistics, especially fatal and severe crashes. However, a comprehensive analysis is needed to fully understand the factors behind these crashes, especially considering local Wyoming conditions (challenging roadway geometry, weather conditions such as high winds, pavement conditions, roadside, traffic control, signage etc.). This research will provide more insight into the characteristics of fatal and severe motorcycle crashes, and recommend potential location-specific countermeasures to reduce their frequency and severity.

Through the review of literature and practice, this research will identify measures and remedies to better understand motorcycle safety, and practical methods, infrastructure improvements, traffic control and education measures to reduce the frequency and severity of motorcycle crashes. Statistical models and data analysis will be used to determine the significance of crash characteristics and contributing factors, so the improvement focus can be directed toward those that are more common. Surveys of

motorcycle safety experts will provide further insight into the practical problems and issues that motorcycle riders face on a daily basis, and provide materials to be included in the education of motorcycle riders. All these finding will be summarized and will help WYDOT implementing effective countermeasures to improve motorcycle safety in the State.

The study will also conduct a benefit-cost analysis to rank the critical locations and improvement measures to be implemented at those locations. This will help WYDOT better manage their resources in long-term improvements of motorcycle safety.

Overall, this research is expected to benefit WYDOT through the reduction of motorcycle fatalities and severe injuries, and help create an environment welcoming to motorcycle enthusiasts. Riding a motorcycle is a great way to explore this State, but this needs to be in a safe and efficient manner.

#### 5. Study Objectives and Outcomes

The goal of this study is to assess the characteristics of motorcycle safety in Wyoming, with the focus on fatal and severe injury crashes, and provide a set of recommendations with a potential to reduce the frequency and severity of motorcycle-related crashes.

The main research objectives of this study are as follows:

- Summarize motorcycle crash characteristics for Wyoming.
- Develop statistical models for motorcycle safety assessment, using at least 10 years of crash data. The measure of success will be the calibration of the models.
- Determine the major contributing factors for severe and fatal motorcycle crashes.
- Develop recommendations for countermeasures. The success of these recommendations will be assessed using data from other states with implemented measures.

The study will first perform a detailed assessment of motorcycle crash characteristics using at least 10 years of safety data on crash, vehicle and person levels. The assessment will show crash characteristics such as crash types, severities, locations, contributing factors, roadway, traffic, environmental and driver conditions, as well as other elements of importance. These descriptive statistics will show the current state of motorcycle safety and needs for improvements.

The collected crash data will be used to develop statistical safety models for motorcycle crashes. The data will be organized by selected variables (crash characteristics, traffic, environmental conditions and roadway characteristics) and imported into statistical software. First, statistically significant variables for injury and fatal motorcycle crashes will be determined. Then, statistical models will be developed to create locally applicable SPFs for these types of crashes, to the fullest extent possible. In addition to modeling frequencies and rates for motorcycle crashes, the SPFs will be able to predict

safety performance for future changes in traffic patterns, as well as the implemented countermeasures and other updates. The measure of success will be the calibration of these models, to ensure realistic representations of safety characteristics.

Through both data analysis and statistical modeling, the study will determine the major contributing factors for motorcycle crashes, with a focus on severe injury and fatal crashes. The contributing factors will show the direction for needed improvements in the motorcycle safety area for the two states.

Finally, the study will recommend potential countermeasures for the reduction of severe and fatal motorcycle crashes and assess their effectiveness, using the previously developed statistical models. Some of the effectiveness of the countermeasures will be determined using available Crash Modification Factors (CMFs) and experiences from other states.

The study is expected to have five main outcomes. The first outcome will be a synthesis of existing literature and practice on motorcycle safety. The reviews will help identify the major problems and gaps that exist in the motorcycle safety research. Furthermore, the reviews will produce recommendations for analysis methods, potential countermeasures and existing CMFs.

The second outcome will be a set of motorcycle safety data and descriptive statistics for Wyoming. The data will be redacted, organized, analyzed and presented to show the current state of motorcycle safety, crash characteristics and contributing factors, which will be used in further research.

The third outcome will be a set of statistical models describing the interdependency among motorcycle crash characteristics, traffic and environmental conditions, and roadway characteristics, to the fullest extent possible. These models will be used to develop specific SPFs for motorcycle crashes in Wyoming, and assess the effectiveness of potential countermeasures.

The fourth outcome will be a set of location-specific countermeasures aimed at reducing the frequency and/or severity of motorcycle-related crashes. The effectiveness of these countermeasures will be assessed through the previously developed SPFs, estimated CMFs using the available data, and the CMFs obtained from the literature and practice, as applicable.

The final outcome of the study will be a set of journal publications, reports and presentations describing the research and its results.

#### 6. Study Tasks

It is estimated that the performance period of this study will be 9 months, split into six tasks. The anticipated start date is in January of 2022, and the end in September of 2022. The tasks necessary to implement the study successfully are detailed as follows:

# Task 1: Review of Literature and Practice (Jan – Feb 2022, and updated throughout the study)

The research team will review the existing research studies, guidelines and best practices from different agencies related to the motorcycle safety assessment. The literature review will also provide recommendations for the selection of data, analysis methodologies, results interpretation, and potential countermeasures and their effectiveness. The research team will review all relevant safety studies in Wyoming to identify locally specific conditions which have an impact on motorcycle safety. Current state and local laws will be reviewed to better understand the governing principles of motorcycle licensing, enforcement and contributions to safety. All findings from the literature will be summarized in a formal report.

#### Task 2: Data Collection (Jan – May 2022)

First, the research team will identify all potential sources of safety data to be used in the study. This will include, but not be limited to, WYDOTs Critical Analysis Reporting Environment (CARE) system, Fatality Analysis Reporting System (FARS), National Motorcycle Institute Fatality Reporting System, Crash Investigation Sampling System, police reports and similar. The team will also collaborate with WYDOT to identify and obtain any additional local safety data to be used in the analysis. Next, the research team will create comprehensive databases containing at least a decade of data related to motorcycle crashes, with a focus on injury and fatal crashes in Wyoming. Additional data, such as traffic conditions, environmental conditions and roadway geometry will be collected to the maximum extent possible for each crash identified in the previous databases. This will provide additional important variables for safety modeling and statistical analysis.

#### Task 3: Data Analysis and Statistical Modeling (Feb – Jul 2022)

The data collected in the previous task will first be analyzed to obtain descriptive statistics for injury and fatal motorcycle crashes. This analysis will determine the major crash characteristics and contributing factors, identify routes and locations where most fatal and injury motorcycle crashes occur, and identify roadway, environmental, traffic and driver/passenger characteristics common in these types of crashes. Then, the data will be organized by selected variables (crash characteristics, location, traffic, environmental conditions, roadway characteristics and driver characteristic) and analyzed using statistical methods. In recent years, the research team has been successfully using RStudio software for safety analysis, which is recommended for data

analysis and statistical modeling. First, statistically significant variables for injury and fatal motorcycle crashes will be determined. Then, statistical models will be developed to create locally applicable SPFs for these types of crashes, to the best extent possible considering the available data. In addition to modeling frequencies and rates for motorcycle crashes, the SPFs will be able to predict safety performance for future changes in traffic patterns, as well as the implemented countermeasures and other updates. A detailed description of the data analysis and safety models development will be provided in a formal report.

### Task 4: Expert Surveys (Apr – Jun 2022)

The team will reach out to the experts such as motorcycle riding coaches and officers in Wyoming and beyond to obtain their insights on observed issues related to motorcycle safety and potential remedies. Surveys and conversations with the experts will help develop the guidelines for improvements, as well as advice for safe riding within the State. This can also lead to the creation of educational materials to be used to educate riders, as well as other participants.

#### Task 5: Recommendations for Improvement (Jul – Sep 2022).

Data analysis and statistical modeling from the previous task will provide information on potentially dangerous locations and combinations of contributing factors that can lead to severe motorcycle crashes. Through literature review and by querying the Crash Modification Factor (CMF) Clearinghouse, as well as through conversation with experts, the research team will identify potential countermeasures for each location (e.g. installing motorcycle-friendly crash barriers, warning signs and plaques for motorcyclists, improving pavement conditions, upgrading drainage and shoulders, upgrading traffic control at signalized intersections etc.) to the maximum extent possible. The effectiveness of the proposed measures will be assessed through the statistical models developed in the previous task.

#### Task 6: Reporting (throughout the study, Final Report Sep 2022)

The research team will provide constant updates to WYDOT throughout the study. Progress reports will be sent in predetermined intervals. A draft final report will be submitted toward the end of the study in September of 2022. The team will allow the WYDOT personnel and other stakeholders to comment on the findings, and those comments and recommendations will be included in the final report.

#### 7. Implementation

This study will develop models for assessing motorcycle safety in Wyoming, identify locations in rural and urban areas which are prone to motorcycle crashes (especially fatal and severe injury crashes), and provide a set of potential countermeasures to be implemented at those location with the aim to reduce the frequency and severity of

motorcycle-related crashes. Furthermore, the study will provide materials which can be used to educate motorcycle riders on safe riding practices specific to Wyoming conditions.

The study is expected to provide practical guidelines for the implementation of traffic control, signage and infrastructure measures with the potential to reduce motorcycle crashes at specific locations. For example, sealant used to fill cracks in the pavement, especially if applied longitudinally in horizontal curves, when combined with the motorcycle turning dynamics, can cause a loss of traction and a dangerous situation for the motorcyclist, leading to a potential crash. If this is the case at certain locations, this research will recommend potential remedies and practices to reduce the impacts of sealants.

Run-off-road is found as one of the prevalent crash characteristics in single rural motorcycle crashes in Wyoming. This research will focus on the locations where this is the case, and recommend improvements, such as signage or motorcycle-friendly crash barriers, an example of which is shown in Fig. 2 and Fig. 3.



Figure 2: Photo. Biker Shield Motorcycle Barrier (Source: Safe Direction Crash Barrier Solutions)



Figure 3: Photo. System Euskirchen Plus Guardrail (Source: Nicol et al.)

Warning signs aimed at motorcycle riders can be successful in preventing potentially dangerous riding and maneuvers at certain locations, such as sharp curves, gravel on the roadway, grooving and similar. Warning signs from the Manual on Uniform Traffic Control Devices (MUTCD) (*FHWA*, 2012) can be adapted for motorcyclists and used at these locations. This research will propose the use of some additional signage at the locations which are found to be dangerous. An example of the signage is shown in Fig. 4.



# Figure 4: Illustration. Warning Signs Adapted for Motorcycles (Adapted from MUTCD)

This study will provide recommendations for implementation of various countermeasures for identified locations, accompanied by the analysis of their effectiveness.

#### 8. Technology Transfer

The findings, methodologies and recommendations will be shared with WYDOT throughout the research. Furthermore, the research team will reach out to the transportation community to discuss and present the methodologies and results of the

study, where the practitioners and researchers will be the target audience. This will be done through personal communication, web sites, social media, conferences and journal publications. The research team will seek input from other interested parties to improve upon the study design and methodology. The findings of this study will be included in current and future university courses in transportation engineering.

#### 9. Work Schedule

It is expected that the duration of the study will be 9 months, with the anticipated start in January of 2022, and end in September of 2022. The work in split in six tasks. The anticipated work schedule for each task is given in Fig. 5. The solid fill shows the main work on the task, while the hatched fill shows additional work associated with the task.



Figure 5: Chart. Study Timeline and Task Schedule

### **10. Budget and Matching Funds**

The total cost of this study to WYDOT will be **\$50,510**. The breakdown of costs is given in Table 2. This study also has **matching funds of \$45,838** from the Mountain Plains Consortium (MPC) already **in place**. The MPC study began in May of 2021 (Project No. MPC-655).

| CATEGORY                     | WYDOT<br>Cost | Notes   | MPC<br>funds |
|------------------------------|---------------|---|--------------|
| Faculty Salaries (Zlatkovic) | \$14,291      | 1.5 months summer                             | \$9,505      |
| Grad Student Salaries        | \$14,288      | PhD student spring and summer                 | \$14,288     |
| Fringe Benefits              | \$6,417       | 42.1 percent faculty, 2.8 percent students    | \$4,402      |
| Total Salaries and Benefits  | \$34,996      |   | \$28,195     |
|                              |               |   |              |
| Domestic Travel              | \$2,000       | Meetings and conferences                      |              |
| Other Direct Costs           | \$5,096       | PhD student tuition/fees and health insurance | \$5,096      |
| Total Other Direct Costs     | \$7,096       |   | \$5,096      |
|                              |               |   |              |
| F&A (Indirect) Costs         | \$8,418       |   | \$12,547     |
| TOTAL COSTS                  | \$50,510      |   | \$45,838     |

#### Table 2: Study Budget (January – September 2022)

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