Spring 5-4-2024

Major Injuries Sustained in Towable Watersports

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MAJOR INJURIES SUSTAINED IN TOWABLE WATERSPORTS

By Elijah Klein

A Thesis Submitted in Partial Fulfillment

Of the Requirements for the

University Honors Program

Department of Biology

University of South Dakota

May 2024

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to examine the thesis of Elijah Klein

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ACKNOWLEDGEMENTS

I would like to thank the USD Honors Program for supporting the development of my thesis and providing a platform for me to grow as a student and researcher. The resources available through the I.D. Weeks Library and its staff have made this process straightforward and extensive. I am beyond grateful to my director Wendy Johnson for working with me through my research and her useful insights on how to portray my information. Her willingness to work with me on a subject outside my background has been excellent. I am also very thankful for my committee members Dr. Andrea Liebl and Cindy Struckman-Johnson for their support and encouragement. I appreciate all three of my committee members for taking time out of their schedules to review the thesis and be present for my defense. Without their help, this would not have been possible.

ABSTRACT

Towable watersports are activities where a participant is being pulled by a motorized watercraft while wearing or holding onto a floating device. Watersports come with many known risks such as drowning, whiplash, and fatigue; however, other injuries are often overlooked or misunderstood. With this thesis, I aimed to explore injury records pertaining to towable watersports and attempted to identify prevalent injury trends in wakeboarding, waterskiing, and water tubing. Using the National Electronic Injury Survey System (NEISS), a public database with yearly injury records, I compiled information related to the relevant sports from 2013 to 2022. Included with the data is demographic information useful for determining trends within each sport. I found prominent trends for each watersport. Wakeboarding and water tubing both featured head injuries while waterskiing had more upper leg injuries. Diagnoses for these body parts varied, but most head injuries were concussions and most upper leg injuries were strains and sprains. When isolating the injuries by diagnosis, strains and sprains led in all towable watersports, though waterskiing made up a larger portion of the data compared to wakeboarding and water tubing. Additionally, demographic trends were shown for the watersports. Waterskiing participants had the highest mean age while water tubing and wakeboarding had lower means. Similarly, water tubing had a significantly higher proportion of female participants relative to the other watersports. These trends provide more insight into the prevalent risks of towable watersports.

Key Words: Watersports, NEISS, Injury Trends, Wakeboarding, Waterskiing, Water Tubing

INTRODUCTION

I.I Towable Watersports

Throughout the history of modern sports, water activities have not always been considered official sports. In recent years, that perception has changed due to their competitive nature and physical requirements (International Waterski & Wakeboard Federation, 1998). Organizations like the World Wake Association have formed to promote the best athletes in each activity. The updated term for these water activities is watersports, and they can be classified by certain characteristics. One classification is "towable watersports" which includes any watersport that requires the participant to be pulled with a rope behind a motorized boat, personal watercraft (PWC), or by suspension cables. Examples of these include wakeboarding, waterskiing, and water tubing. Wake-surfing, a relatively new watersport, has not reached a broad market yet, but would also qualify as a towable watersport. Each sport presents unique challenges that often frustrate beginners and take experienced riders' months or years to master. One common issue for every rider is failure to maintain their balance and fall into the water. Injuries occur regardless of their training and capability, often because of such falls. The physical demands of each sport are different, and it is possible that their injuries may differ. Moreover, competitions for these sports involve complex movements or stunts which can be dangerous.

Wakeboarding is one of the three main towable watersports. A wakeboard is a floating platform capable of maneuvering and lifting the participant on the water. The rider will attach themselves to the platform using special boots called bindings (Image 1). The length of a wakeboard usually spans 119 centimeters to 140 centimeters (Jobe Sports International, 2021). Any physical strain or injury may be isolated to one side of the body since movement is

generally asymmetrical. Competitive wakeboarding involves a variety of stunts ranging from high jumps, flips, and sudden movements.

Image 1: A child preparing to be pulled on a wakeboard. The rider is attached to the board at the feet using boot bindings. A rope extends to the pulling mechanism; in this case, it is a suspension cable rather than a boat.

Image provided by R. Lach (2021)

Waterskiing is another towable watersport that involves one or two floating platforms called skis. Each ski is long and typically thin; the length of a ski can vary but usually measures between 165 and 175 centimeters long (O'Brien Watersports, 2023). Like wakeboarding, the rider is attached to skis using bindings and pulled by either a boat or suspension cable (Image 2). A modified version of skiing not covered in this thesis is barefoot waterskiing. As the name implies, barefoot skiing does not require skis, rather the person is using their feet as the platform. Competitive skiing is known for fast-paced maneuvers and timed events. Competitive water skiers must use one ski and cover long distances within a short time while navigating and avoiding a course of floating buoys.

Image 2: The participant is waterskiing behind a boat. The rider is attached to two skis using boot bindings.

Image provided by S. Forson (2018)

One primary difference between water tubing and the other sports is the rider grasps attachments on the tube rather than the rope attached to the boat (Image 3). This creates a situation where the rider does not have as much control over what occurs. Furthermore, the diverse selection of tubes available puts participants in many positions. Individuals can be seated, standing, prone, or lying on their backs during this sport. Water tubing is controversially termed a water sport because competitions are scarce. It is not excluded from this thesis due to its physical demands and injury history as indicated by Baker et al. (2010).

Image 3: Four kids riding a water tube. Riders have the option of sitting, kneeling, or standing. They attempt to stay on the tube at high speeds.

Image provided by Elijah Klein

I.II Previous Literature on Watersports

Minimal research has been conducted on frequencies of watersport injuries and their relation to demographics. Certain case studies provide supplemental evidence for injury prevalence; however, more research is needed to understand common injuries within watersports. Related studies analyzed different features of watersport injuries but provide a framework for my thesis.

One of the earliest studies related to watersport injuries was performed by Hostetler in 2005. The study gathered results for wakeboarding and waterskiing injuries from the National Electronic Injury Surveillance System (NEISS). Data from 2001 to 2003 showed that wakeboarding participants experienced the most head injuries, whereas waterskiing participants were more prone to injuries of the lower limb (Hostetler, 2005). The study also generated scaled-estimates for the total amount of watersport injuries with emergency room visits, which showed that waterskiing injuries occurred more frequently than in wakeboarding (Hostetler, 2005). A similar study highlighted the differences between wakeboarding, water tubing, and waterskiing injuries and the rate they occurred. Baker et al. (2010) combined and examined injury data from the NEISS with the goal of highlighting primary diagnoses. By using product codes, they filtered the information to only contain watersport injuries. Moreover, he generated estimates for injury rates related to each watersport to compare changes in the years he studied. The most notable discovery from the study was that the rate of injury increased for wakeboarding, decreased for waterskiing, and did not alter significantly for water tubing from 2000 to 2007 (Baker et al., 2010). This could indicate fluctuations in injury data for watersports. His other major finding was the prominence of head and neck injuries—according to his research, it was the most

frequent injury for wakeboarding and water tubing, and the second-most frequent injury for waterskiing (Baker et al., 2010).

Research published in 2022 investigated severe wakeboarding injuries reported in France. The injuries were only used if they could be considered a trauma. Researchers also determined the participant's experience to classify them as "high level" or "amateur" depending on their hours with the activity (Bosser et al., 2022). Contrary to other studies on wakeboarding, they discovered knee injuries were the most frequent location of trauma, specifically sprains (Bosser et al., 2022). Further, their research concluded that shoulder trauma was also common and should be considered when studying wakeboard statistics (Bosser et al., 2022). Bosser et al. (2022) mention the possibility of using protective gear in the future of wakeboarding.

Another study, published in 2024, focused on different aspects of watersport injuries. The researchers targeted craniofacial injuries in all watersports which included swimming, diving, competitive watersports, and floatation toys (Mangal et al., 2024). Their study also utilized data from the NEISS but gathered information from product codes outside of towable watersports. A few of these product codes were water polo, diving boards, pool slides, and scuba diving equipment (Mangal et al., 2024). One of their main findings shows swimming activities and equipment for those activities were the largest cause of craniofacial injuries. Information regarding specific watersport injuries is limited, though they note, "Engagement in water-related activities, whether for professional sports or recreational purposes, is appealing" (Mangal et al., 2024). More participation in watersports could lead to an increase in injuries reported in databases such as the NEISS. Another critical component to this study was the demographic analysis. Particularly, they found age was significant in the injury statistics (Mangal et al., 2024).

METHODS

II.I National Electronic Injury Survey System and Excel Spreadsheets

The National Electronic Injury Surveillance System (NEISS) is an online database containing injury information from approximately 100 hospital emergency departments with simplified codes for analysis. Typically, about 500,000 injuries are reported on the database annually (United States Department of Health and Human Services, 2022). The benefit of using NEISS is the availability of information and the inclusion of consumer products within their database. Access to injury descriptions also confirmed the use of watersport equipment. Archived data was acquired through their website by downloading an Excel spreadsheet for the year of interest.

This thesis examined ten years of data spanning from 2013 to 2022. Each yearly document contained demographic information including age, sex, and race. Refined information was compiled based on the product code and written account for each injury. Product codes pertaining to towable watersports were the following: waterskiing, 1264; water tubing, 3200; and wakeboarding, 1264. Wake surfing did not have a code and entries were limited so it was excluded from this study. Wakeboarding and waterskiing entries were the same; to differentiate between the two, results were filtered using key words such as “Wakeboard”, “Wake board”, “Waterski”, or “Water ski”. Data were further refined by looking through written diagnoses to rule out unrelated entries such as the injury occurred on land, the board or skis were not being worn at the time of injury, watercraft collisions containing a listed watersport item, and errant listings such as surfing. This was performed for wakeboarding, waterskiing, and water tubing—each sport gathered 382, 403, and 383 results respectively.

A combined Excel spreadsheet containing all entries (1169) related to towable watersports was made. A supplemental category was created to list each injury by sport. The combined data file was made for simplicity in R Studio. Once the injury listings were refined, the codes for diagnoses, body part injured, sex, and race were decoded. Using the NEISS coding manual (U.S. Consumer Product Safety Commission, 2021), the corresponding term replaced two-digit codes. In listings without a code, the category "Other" was given. Occasionally, injury listings applied terms such as "Internal Organ Injury" for varying diagnoses. Those listings were addressed in the results.

II.II Data Analysis

Statistical analysis was performed in R Studio with dplyr (Henry et al., 2023) and ggplot2 (Wickham, 2016). Excel spreadsheets were imported, and categories were made into factors for producing figures. A combination of bar graphs and boxplots were made for watersport comparisons. Select injuries were only recorded in one sport. These listings are mentioned and likely require more research.

For the wakeboarding, waterskiing, and water tubing datasets, I calculated the number of injuries by sex using linear models. Injury values were displayed using a boxplot. The mean age and dispersion of data was visually represented and compared between watersports. A linear model was used to identify the significance of age to its respective watersport. I used this data to identify trends for each sport to understand the physical constraints of each sport by age. Linear models were also used to compare diagnoses with the body part injured. This comparison was displayed using bar graphs. Similar to the study performed by Baker et al. (2010), I examined the most frequent injuries per watersport and highlighted significant results.

In the combined dataset, I visually compared diagnoses to the body part injured based on the watersport. By comparing the linear models from the individual datasets, major differences were identified between the watersports. For ease of reference, I included a graph containing only body part injuries. The final figure in this thesis included the age and sex demographics to relate the demographical information to the major injury findings. Race was decoded, but values for races other than "Caucasian/White" were far less and could not be compared. By analyzing the injuries through linear models, I discovered the major injuries sustained in towable watersports as they relate to demographics. Figures were made for visual reference.

RESULTS

III.I Significant Injuries in Watersports

Injury prevalence based on body part varied in wakeboarding, water tubing, and waterskiing. Head injuries were significantly different than other injuries for both wakeboarding (t=2.719, p=0.0087) and water tubing (2.420, p=0.0181). In waterskiing, both ankle injuries (t=1.873, p=0.0461) and upper leg injuries (t=1.928, p=0.0304) were significantly different than other injuries. Ankle injuries were significantly different than injuries in all sports for the combined dataset (t=2.209, p=0.03158).

When using a linear model, sex had no impact on wakeboarding injuries ($F_{1,32}$=2.671, p=0.112) or water tubing ($F_{1,46}$=0.04131, p=0.8398). There was no influence based on body part or diagnosis. However, sex impacted waterskiing injuries based on body part and diagnosis values ($F_{1,34}$=8.701, p=0.00572). More males were injured in waterskiing compared to females. Similarly, age had a significant impact on waterskiing results (t=11.61, p=2e-16) but was not significant for wakeboarding (t=0.82, p=0.713) and water tubing (t=-0.62, p=0.536). More injuries occurred in waterskiing than in the other two sports. Age had an impact on this total.

III.II Combined Watersport Injury Figures

The combined dataset figures are in Appendix A. This includes Figure 1, Figure 2a, and Figure 2b.

Figure 1 isolates the age distribution for injuries in each watersport. By increasing means, water tubing had the lowest mean age at 19.8 years old, wakeboarding had an average age of 21.2 years old, and waterskiing had the highest mean age at 36.4 years old. Waterskiing had a noticeably higher age group in its injury listings compared to the other two watersports.

Figure 2a shows the frequency of injuries by body part and watersport. The most notable body part affected was the head with over 250 entries. Other major body parts were the face, lower trunk, and upper trunk with around 100 entries each. For wakeboarding and water tubing, head injuries appear to be the most common; waterskiing had more listings for the "Upper Leg" which did not include the knee. Like head injuries, wakeboarding and water tubing injury totals do not differ much in other categories. The least-common injuries by body part were the mouth, humerus, pubic region, eyeball, and toes.

Figure 2b displays the frequency of injuries by diagnosis. The main diagnosis was "Strain/Sprain" with over 300 entries. Other major diagnoses were fractures, lacerations, and contusions or abrasions between 100 and 160 entries each. The diagnosis "Other" was recorded around 150 times but entries could fall into multiple categories. The most-frequent injury for all watersports appears to be the "Strain/Sprain" diagnosis. Wakeboarding lacerations had a similar sample size to wakeboarding strains or sprains, so more breakdown is required in the individual watersport figures. The least-frequent injuries were dental injuries, hemorrhages, crushing, foreign body (impalement), and scalding. Similar to Figure 2a, smaller listings like these must be studied individually to determine occurrence risk.

III.III Individual Watersport Figures

Individual watersport figures for wakeboarding, water tubing, and water skiing are in Appendix B. Wakeboarding data is displayed in Figure 3a, Figure 4a, and Figure 4b. Water tubing data is in Figure 3b, Figure 5a, and Figure 5b. Waterskiing data is in Figure 3c, Figure 6a and Figure 6b.

Figure 3a compares the body parts injured with the diagnosis for wakeboarding. Head injuries labeled as concussions were the most common, followed by internal organ injuries in the

head and lacerations in the head and face. The least-reported injuries for wakeboarding were the humerus, elbow, and wrist in various diagnoses. Using Figure 4a and Figure 4b, the injuries were filtered by sex of the patient. In Figure 4a, the most-frequent diagnosis was “Strain/Sprain” with around 80 injuries. Male riders experienced the most injuries by diagnosis in all categories. In Figure 4b, the most frequent injury was the head with over 100 injuries. Based on body part, male riders led in all categories except for injuries to the face.

Figure 3b compares the body parts injured by diagnosis for water tubing. Concussions and internal organ injuries were the most frequent. Other common injuries were strains and sprains on the knee and neck. Using Figure 5a and Figure 5b, the injuries were filtered by sex. In Figure 5a, the most frequent diagnosis was also “Strain/Sprain” with around 80 injuries. Female riders led this category; however, the other diagnoses were evenly distributed between male and female riders excluding dislocations. In Figure 5b, head injuries were the highest at 75 injuries. Female riders also led in this category but were closer to the male injury statistics for each body part.

Figure 3c compares the body parts injured by diagnosis for waterskiing. Upper leg strains and sprains were the most frequent injury followed by lacerations to the face. Other common injuries were ankle and knee strains and sprains. Like wakeboarding and water tubing, the results were filtered by sex. Using Figure 6a, the most frequent diagnosis was “Strain/Sprain” with around 150 injuries. Male riders led all diagnosis categories. In Figure 6b, upper leg injuries were most common, followed by lower trunk and head injuries. Male riders led every category in this analysis as well. For waterskiing, male-only injuries were more prevalent than in other watersports.

DISCUSSION

IV.I Injury Trends

By body part injured, head injuries are the most common for wakeboarding and water tubing. Multiple head diagnoses were identified in wakeboarders including concussions, lacerations, internal organ injuries, and nerve damage. Waterskiing differed with upper leg and ankle injuries occurring the most. Sex and age were both impacted waterskiing results—the increased occurrence of upper leg injuries is linked to these demographics. The corresponding diagnoses for the upper leg injuries were strains and sprains, dislocations, hematomas, contusions, and abrasions—the most abundant being strains and sprains.

The distinct experiences of each watersport may have caused differences in injury prevalence. Despite this, there were shared injury trends amongst the sports. For example, the major difference between wakeboarding and water tubing is the riders are not attached to a water tube like a wakeboard. Regardless of their functional differences, wakeboarding and water tubing show head injuries to be significant. Waterskiing did not share as many trends with the other two watersports, specifically when analyzing the body part affected. Though its riders have a similar experience to wakeboarding, there are some notable differences to explain the differing injury evaluations. The use of two platforms as opposed to one may be the cause of more strains and sprains and the higher prevalence of upper leg injuries. This is due to rider positioning that could be analyzed using a motion tracking suit. Moreover, maneuvers performed in waterskiing differentiate as riders gain experience (Jung et al., 2021). In addition to these differences, demographic information was correlated with injury differences. Sex and age impacted waterskiing results but did not impact water tubing and wakeboarding results. After examining the demographic information, it is possible sex and age impacted diagnoses as well.

This study highlighted the various trends for watersport injuries based on the type of sport and relevant demographic information. Previous literature pertaining to watersport injuries was limited and the general focus was different than this study. A study done by Baker (2010), focused on the injury diagnoses for wakeboarding, waterskiing, and water tubing while another study performed by Hostetler (2005) examined the differences in wakeboarding and waterskiing injuries. Each study produced similar results to my own. Both identified the prevalence of head injuries in wakeboarding and leg injuries in waterskiing. Only Baker et al. (2010) examined water tubing injuries and found the head and neck regions were most of the injuries. The major diagnoses for those studies were different from my research based on body part. Diagnoses varied, but the general findings in my study reflected those in the 2010 study (Baker et al., 2010).

Like other physical activities, watersports contain the risk of injury. Rather than placing restrictions on who is allowed to participate, it would be better to highlight the risks involved with wakeboarding, water skiing, and water tubing. This information would be useful for parents of kids interested in watersports or for adults who are unaware of the potential injuries they could sustain. Specifically, participants need to monitor head and leg injuries according to the data of this study. Preventative measures for these injuries is needed. Helmets, wetsuits, or padding are possible solutions to the significant injuries for towable watersports. Othe research suggests helmets are an effective method for preventing head injuries (Daneshvar et al., 2011) Helmet use could reduce the amount of head injuries seen in wakeboarding and water tubing. The significance of upper leg and ankle injuries indicates a need for protective gear for ligaments, muscles, and tendons. Equipment for other sports typically involves compressing vulnerable areas (Weakly et al., 2022). Though neoprene wetsuits are available for use in watersports, no study analyzes its injury prevention effectiveness. Only muscle activity using neoprene wetsuits

has been studied (Carpenter et al., 2015). Head injuries, particularly concussions, are also common in the watersports. Helmets are available for purchase, but it is unknown how many riders utilize them. Less common injuries such as the mouth, humerus, pubic region, and eyeball are still concerns that could be addressed using equipment. However, uncommon injuries require more research, likely in the form of case studies. Other reasons, such as broken equipment, could be the cause of less common injuries—this needs further investigation.

IV.II Limitations

My study did not focus on estimating the rates of injury, but rather investigated injury prevalence in a ten-year span. Watersport participation in the United States had increased from 13.4% to 14.4 % (Statista Research Department, 2023). An increased population of watersport participants could impact the frequencies of injuries. Furthermore, new participants may lack proper technique and could be more prone to injury.

The information provided by the NEISS database had numerous entries for all sports and the included descriptions were useful for verifying the injury sustained. Unfortunately, the sample size likely does not reflect the true injury frequency of watersport injuries. Less-severe injuries or injuries with no symptoms may not have required the rider to visit an emergency department or receive care at all. Furthermore, the cost of medical care is preventative for many populations (Taber et al., 2015). One survey found 24.1% of its respondents avoided the hospital due to cost (Taber et al., 2015). The NEISS does not list the emergency rooms it obtains its information from and may not be nationally representative. According to the United States Department of Health and Human Services (2022), the database gathers injury information from approximately 100 hospitals with at least six beds and a full-time emergency department. Compared to 6120 hospitals in the United States (American Hospital Association, 2024), this

seems to be a small sample. Interpretations of their data may be limited based on excluded details.

Diagnoses were displayed on figures; however, no distinct diagnosis was significant. This is likely due to the diagnoses coming from different doctors and hospitals. Moreover, diagnoses were not always listed. For listings without a diagnosis, I used the term “Other”. These values may have contributed to different categories, but the physician responsible for the report would need to confirm the result. These values may have changed the final injury trends of this study. Moreover, NEISS had categories for “Other Diagnoses” and “Other Items”, but this information was excluded from the study. These variables were not utilized in every entry, thus containing a lot of unknown information. Consistent results could not be obtained due to the gaps in data.

It is possible the discrepancy between male and female injuries may have impacted this study. Confirming the role of sex as it pertains to the injuries may be errant based on the sample size. It is possible the number of female participants may be lower, but this information is not readily accessible. Sex was included because of known differences in male versus female sports injuries (Casey et al., 2018). For example, female athletes are more likely to sustain concussions and ACL tears compared to male athletes who sustain more hip and upper extremity injuries (Zech et al., 2022).

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Appendix A

Combined Dataset Figures

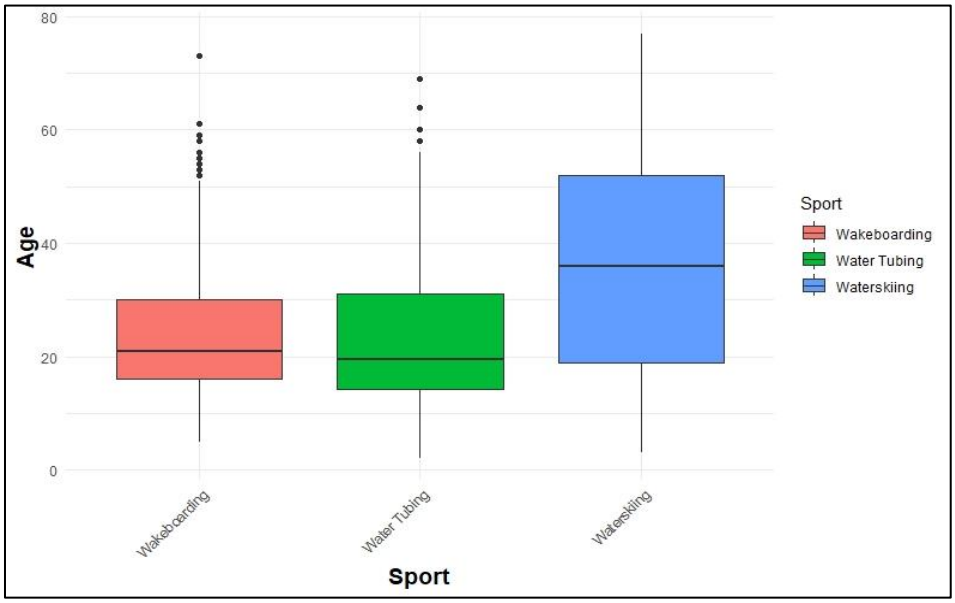

Figure 1: *Wakeboarding, Waterskiing, and Water Tubing Age Distribution from 2013 to 2022 on the NEISS Database. Age values outside of the normal distribution are displayed using dots. Mean age is marked in each box. Age affected waterskiing injuries with more injuries occurring in the sport.*

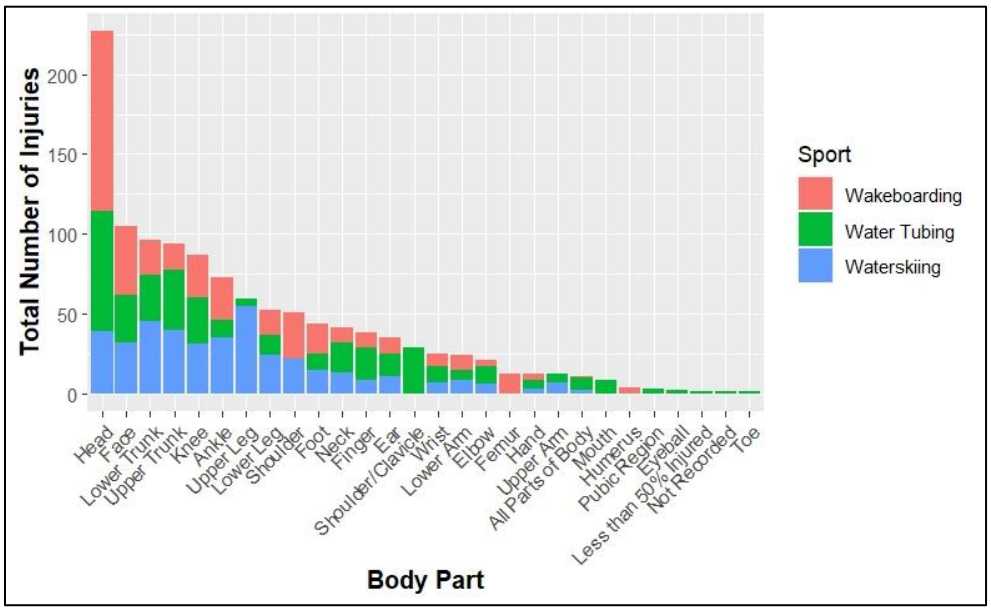

Figure 2a: *Wakeboarding, Waterskiing, and Water Tubing Injuries by body part from 2013 to 2022 on the NEISS database. Each horizontal gridline represents 25 injuries. Head injuries outnumber all other injuries in the combined dataset.*

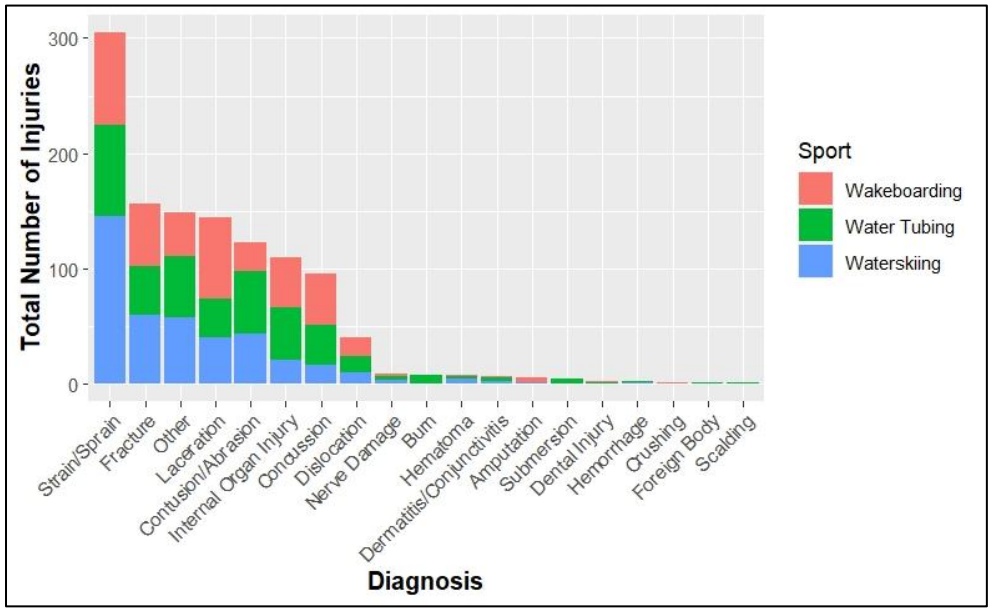

Figure 2b: *Wakeboarding, Waterskiing, and Water Tubing Injuries by diagnosis from 2013 to 2022 on the NEISS database. Each horizontal gridline represents 50 injuries. Strains and sprains lead all diagnoses in the combined dataset.*

Appendix B

Individual Watersport Figures

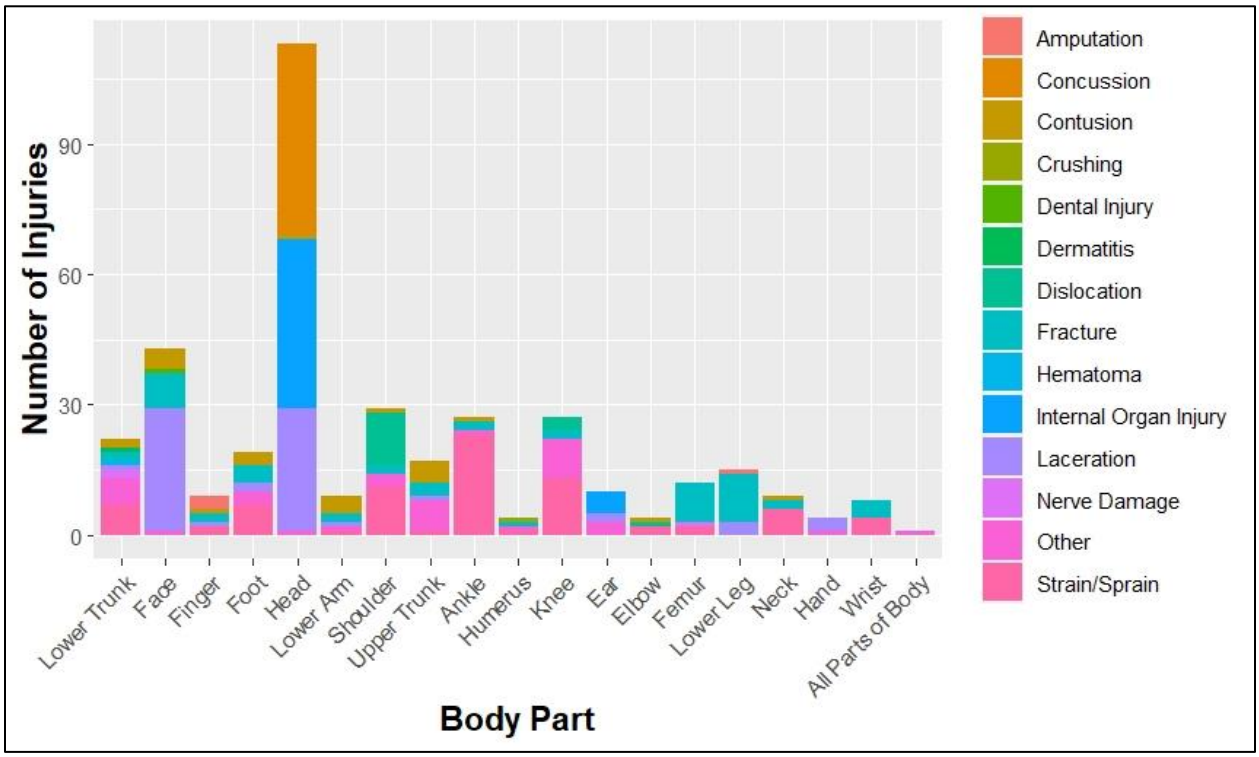

Figure 3a: *Wakeboarding diagnoses by body part from 2013 to 2022 in the NEISS database. Each horizontal gridline represents 15 injuries. Head injuries were significantly different than other injuries in wakeboarding.*

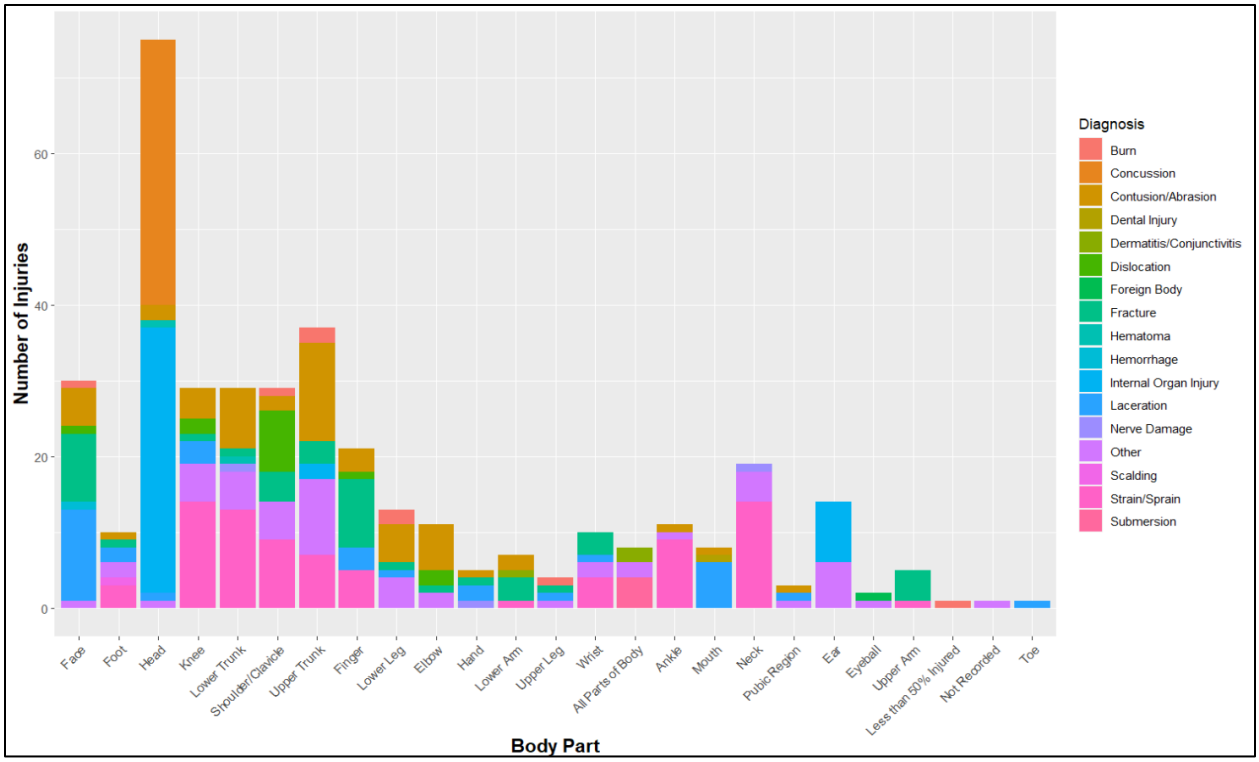

Figure 3b: *Water tubing diagnosis by body part from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 10 injuries. Head injuries were significantly different than other injuries in water tubing.*

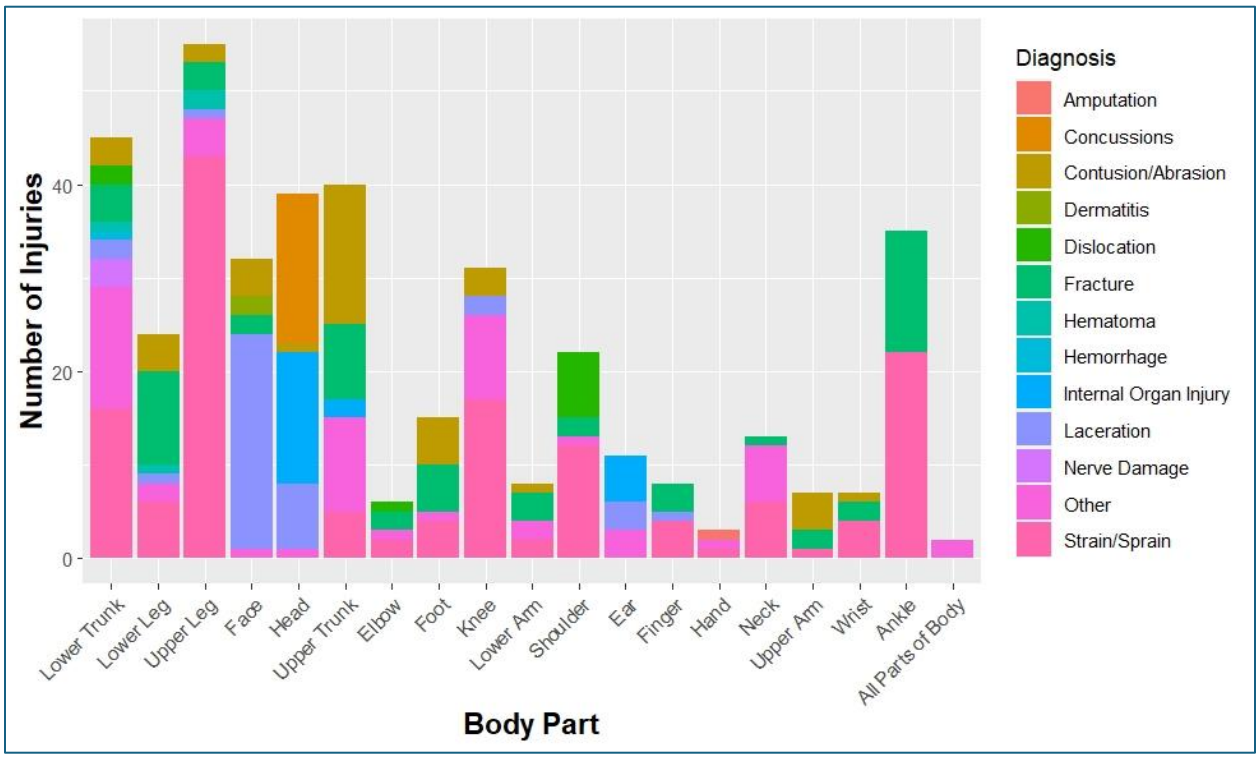

Figure 3c: *Waterskiing diagnosis by body part from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 10 injuries. Upper leg and ankle injuries were significantly different than other injuries in water skiing.*

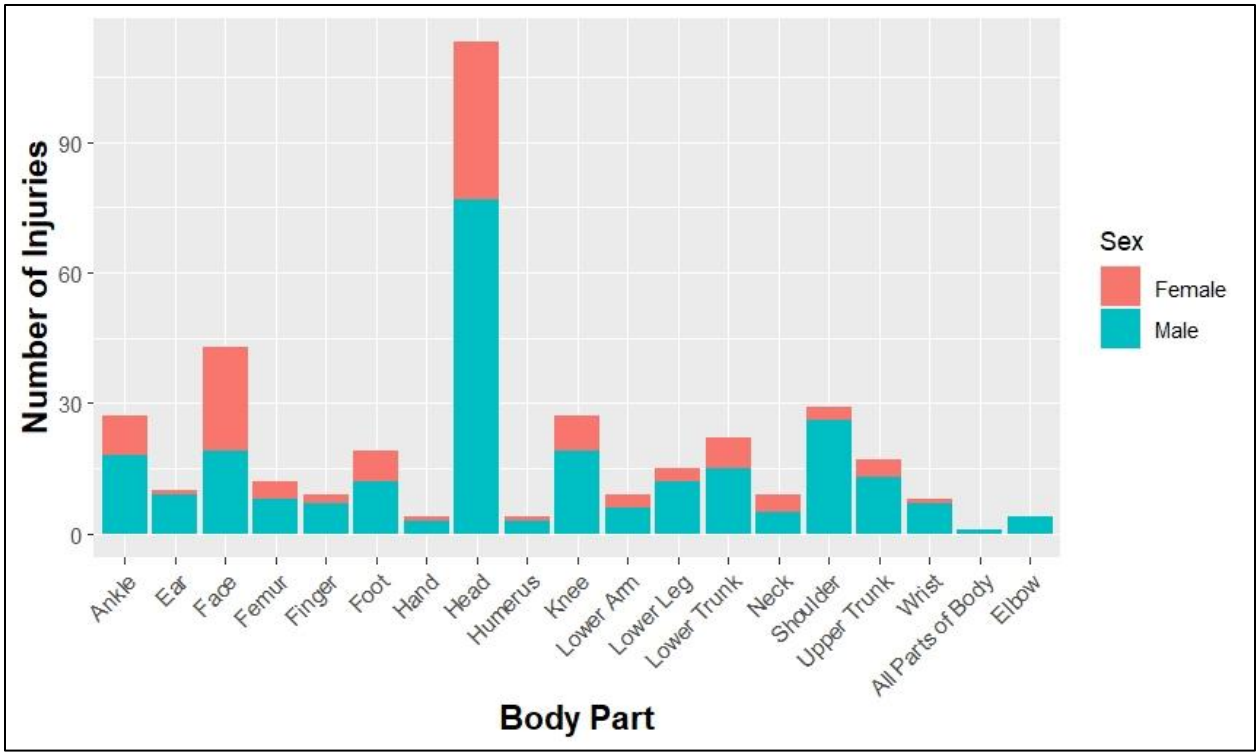

Figure 4a: *Wakeboarding injury diagnoses from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 15 injuries. Sex had no impact on injuries by body part in wakeboarding.*

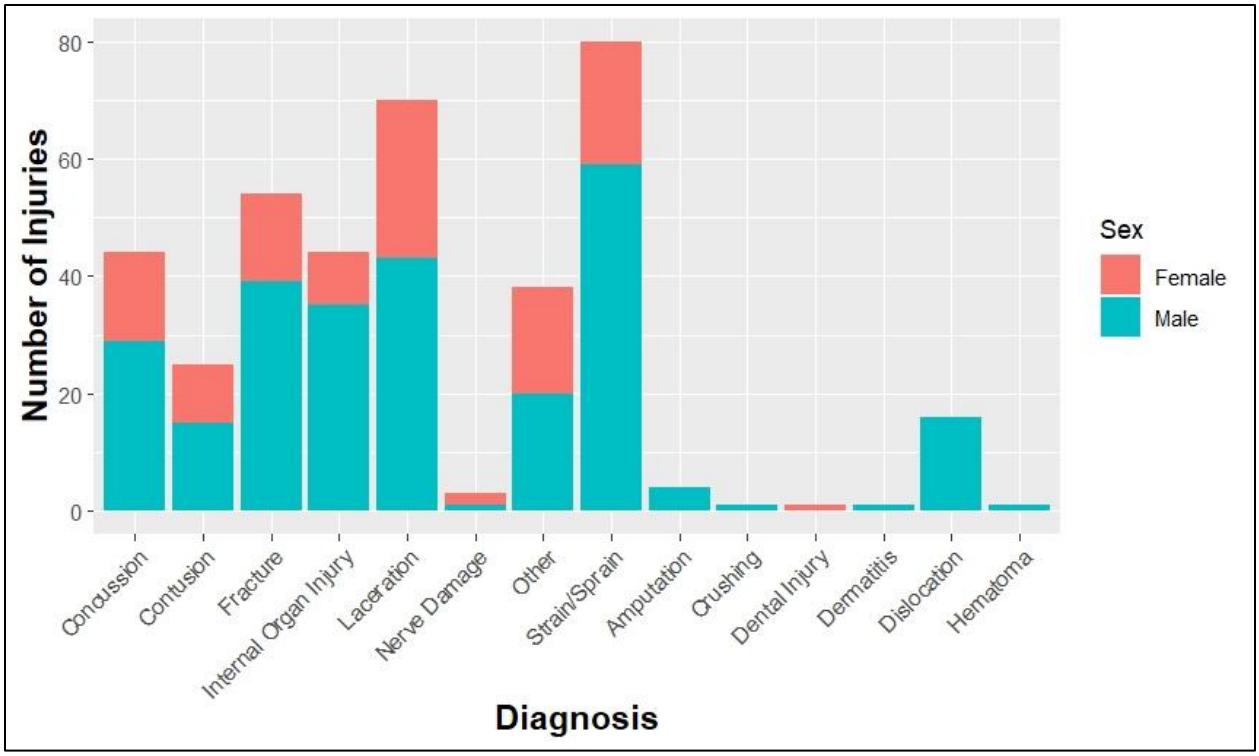

Figure 4b: *Wakeboarding injuries based on body part injured from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 10 injuries. Sex had no impact on injuries based on diagnosis in wakeboarding.*

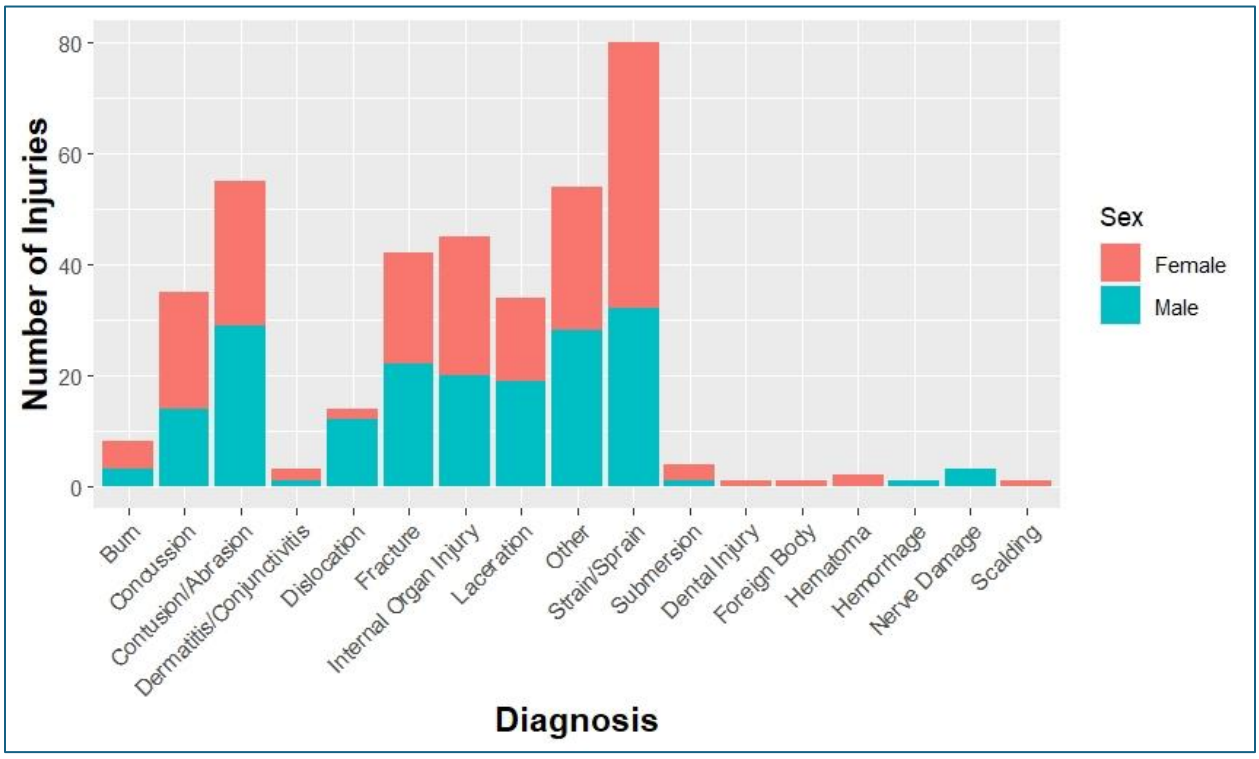

Figure 5a: *Water tubing injury diagnoses from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 10 injuries. Sex had no impact on injuries based on diagnosis in water tubing.*

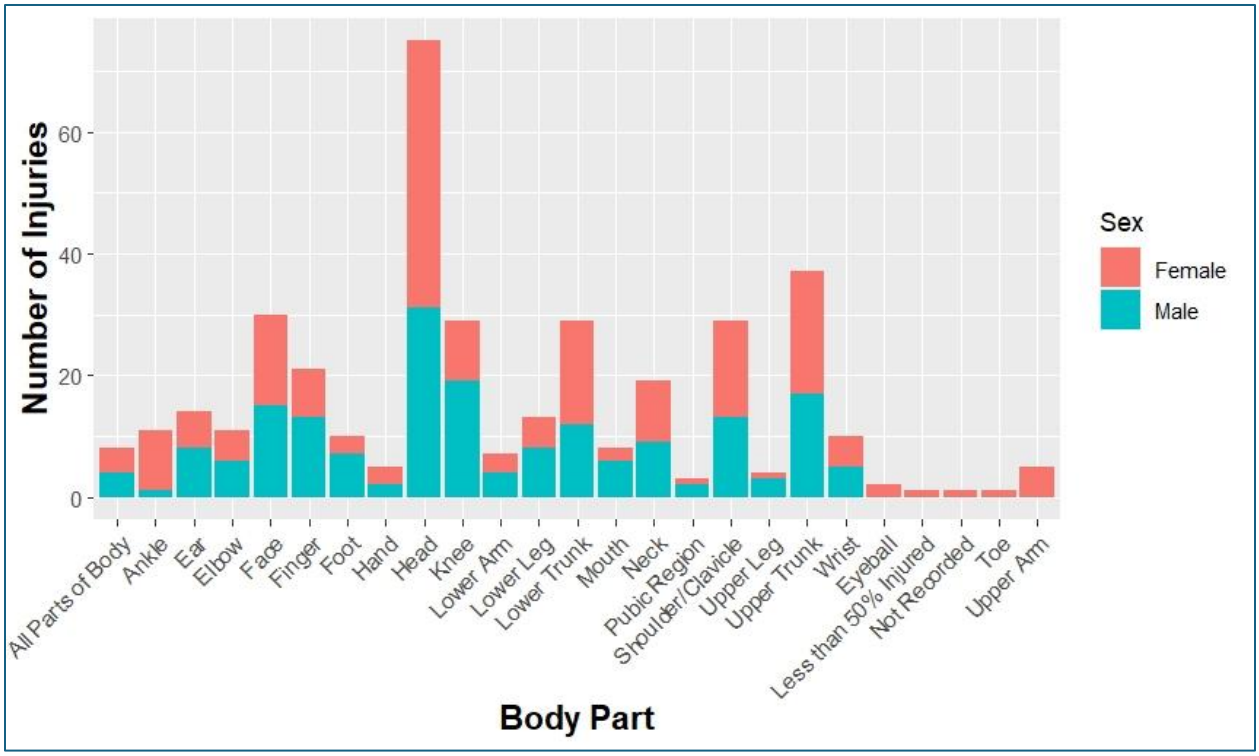

Figure 5b: *Water tubing injuries based on body part injured from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 10 injuries. Sex had no impact on injuries based on body part in water tubing.*

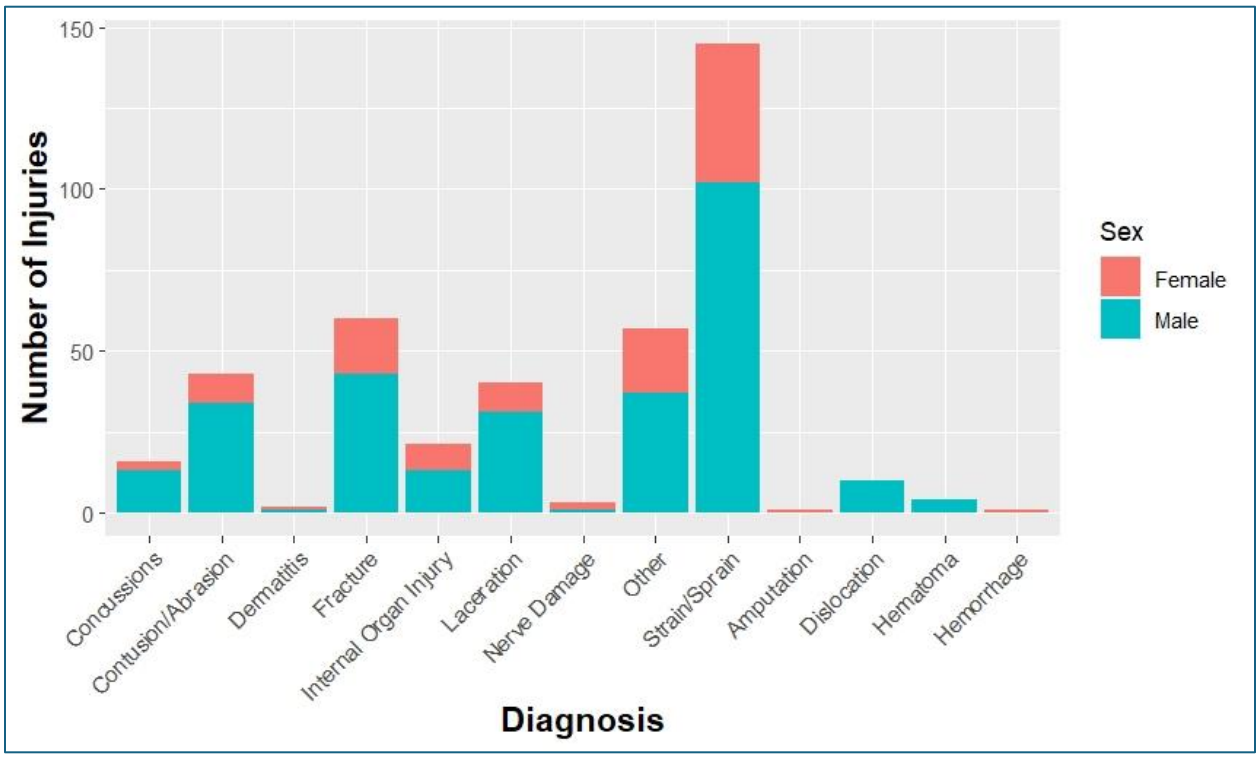

Figure 6a: *Waterskiing injury diagnoses from 2013 to 2022 in NEISS database. Horizontal gridlines represent 25 injuries. Sex had a significant impact on injuries based on diagnosis in waterskiing. Male participants were more affected.*

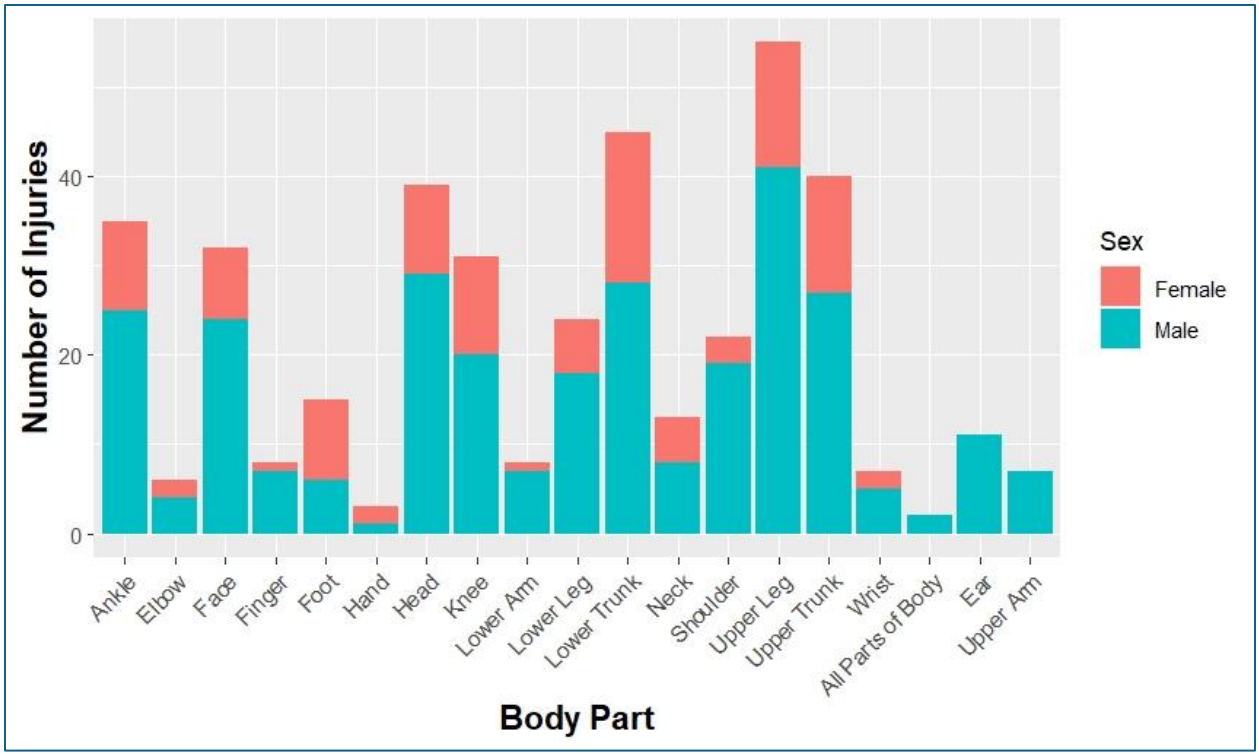

Figure 6b: *Waterskiing injuries based on body part injured from 2013 to 2022 in the NEISS database. Horizontal gridlines represent 25 injuries. Sex had a significant impact on injuries based on body part in waterskiing. Male participants were more affected.*