Can a fighter develop glass jaw? Statistical evidence from mixed martial arts

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ORIGINAL PAPER

Abstract

This paper deals with a phenomenon in combat sports called the glass jaw or glass chin. It is the ability of a fighter to withstand punches to the jaw area without falling unconscious and thus receiving a knockout. The main objective of this paper is to investigate the possibility of developing a glass jaw over the course of a fighter's career, and whether certain fighters are more predisposed to experiencing knockouts. Utilizing data from the largest Mixed Martial Arts organization, the Ultimate Fighting Championship, spanning from 2010 to 2021, statistical models reveal that certain fighters may be more susceptible to knockouts compared to others. Conversely, it could not be shown that the probability of a future knockout loss, that is developing a glass jaw, increased with the number of knockouts received. However, there remains space for a more detailed investigation of this phenomenon. The historically debated resistance training of punches to the head area cannot be recommended. Conversely, it is advisable to observe the fighters' reactions to punches to the head in order to pick out those with a greater predisposition for a knockout. They should then be especially cautious when practicing combat sports.

Keywords: Martial arts; combat sports; mixed martial arts; MMA; performance; knockout.

¿Puede un luchador desarrollar mandíbula de cristal? Evidencia estadística en artes marciales mixtas

Resumen

Este artículo trata de un fenómeno en los deportes de combate denominado "mandíbula de cristal" o "barbilla de cristal". Es la capacidad de un luchador para resistir golpes en el área de la mandíbula sin caer inconsciente y recibir un KO. El objetivo principal de este estudio es investigar la posibilidad de desarrollar una mandíbula de cristal a lo largo de la carrera de un luchador y si ciertos luchadores están más predispuestos a experimentar nocauts. Utilizando datos de la organización de artes marciales mixtas más grande, Ultimate Fighting Championship, que abarcan desde 2010 hasta 2021, los modelos estadísticos revelan que ciertos luchadores pueden ser más susceptibles que otros a los nocauts. Por el contrario, no se pudo demostrar que la probabilidad de una futura derrota por KO, es decir, desarrollar una mandíbula de cristal, aumentara con el número de KO recibidos. Sin embargo, este fenómeno puede ser objeto de investigaciones más exhaustivas. El entrenamiento de resistencia de golpes en el área de la cabeza, históricamente debatido, no puede recomendarse. Por el contrario, es recomendable observar las reacciones de los boxeadores ante los golpes en la cabeza para identificar a aquellos con mayor predisposición al nocaut. Estos deben ser especialmente cautelosos cuando practiquen deportes de combate.

Palabras clave: Artes marciales; deportes de combate; artes marciales mixtas; MMA; rendimiento; noquear.

Um lutador pode desenvolver mandíbula de vidro? Evidências estatísticas em artes marciais mistas

Resumo

Este artigo trata de um fenómeno nos desportos de combate denominado "mandíbula de vidro" ou "queixo de vidro". É a capacidade de um lutador resistir a socos na região da mandíbula, sem cair inconsciente, e, assim, receber um KO. O objetivo principal deste trabalho é investigar a possibilidade de desenvolver uma mandíbula de vidro ao longo da carreira de um lutador, e se alguns lutadores estão mais predispostos a sofrer nocaute. Utilizando dados da maior organização de mixed martial arts, Ultimate Fighting Championship, abrangendo os anos de 2010 a 2021, modelos estatísticos revelam que certos lutadores podem ser mais suscetíveis a KO em comparação com outros. Por outro lado, não foi possível demonstrar que a probabilidade de uma futura derrota por KO, ou seja, o desenvolvimento de uma mandíbula de vidro, aumentou com o número de KO recebidos. No entanto, ainda há espaço para uma investigação mais detalhada desse fenómeno. O treino de resistência de socos na região da cabeça, historicamente debatido, não pode ser recomendado. Por outro lado, é aconselhável observar as reações dos lutadores aos golpes na cabeça para identificar aqueles com maior predisposição para o KO. Eles devem, então, ser especialmente cautelosos ao praticar desportos de combate.

Palavras-chave: Artes marciais; desportos de combate; artes marciais mistas; MMA; rendimento; nocaute.

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1. Introduction

One of the fundamental issues addressed in combat sports for over 100 years is the existence of the "iron" or "glass" jaw or chin. It is the resistance of a fighter to withstand hits just to the jaw or chin area without falling unconscious. If a fighter has a glass jaw, then the probability of a knockout (KO) is high and if they have an iron jaw, then they can withstand a large number of blows to the jaw. This notion is based on a retrospective analysis of boxing matches, where KOs are most often caused by a hook to the jaw (Hånell & Rostami, 2020; Kaplan & Browder, 1954).

First of all, it is necessary to clarify the fact that the chin characteristics are not behind the unconsciousness after a hard punch on the jaw. The cause of KO must be sought in the impact on the brain. However, a punch to the jaw causes rapid head rotation, which has a direct impact on the brain and can cause unconsciousness. More accurately, it has been suggested that the loss of consciousness is caused by the disruption of axons within the ascending reticular activating system (Jang et al., 2019). If anything would make you more prone to KOs, it would be the neck muscles (Hånell & Rostami, 2020). But even these do not prove to be the most important. Every fighter has a natural ability to absorb punches, but everyone has it differently. So some are naturally more prone to KOs (Giza & Hovda, 2014; Seifert & Shipman, 2015).

Journalists covering combat sports often address another factor related to the glass jaw and that is whether fighters develop a glass jaw late in their careers (Kesting, 2015). That is if more KOs increase the probability of losing to KOs in future fights. Research papers addressing the differential predisposition of athletes to experience KOs can be found in literature, including works by Giza and Hovda (2014), Kaplan and Browder (1954), and Seifert and Shipman (2015). Additionally, studies explaining the reasons behind the occurrence of KOs have been conducted, such as the work by Hånell and Rostami (2020). The present paper builds upon and is grounded in the theoretical framework established by these studies.

This paper delves into the aforementioned phenomenon using data from one of the fastest-growing sports in the world, Mixed Martial Arts (MMA). As such, it becomes an integral addition to the body of research within the field of MMA. This area is receiving increasing attention in the literature. Papers dealing with the psychology of fighters, influences on their performance and their mental toughness (Andrade et al., 2020; Chen & Cheesman, 2013; Chernozub et al., 2018; Massey et al., 2013; Mickelsson & Shaw, 2020; Vaccaro et al., 2011), the status of men and women in this area (Hirose & Pih, 2010; Mierzwinski et al., 2014), fans' characteristics and behavior (Deng, 2022; Devlin et al., 2016; Kirkwood et al., 2019; Seungmo et al., 2008), economic issues (Camilo & Spink, 2018; Gift, 2018, 2020), and the injuries (Bledsoe et al., 2006; Del Vecchio et al., 2018; Hammami et al., 2018; Jensen et al., 2017; Karpman et al., 2016; Lystad et al., 2014) which is topic most closely related to this paper.

In view of the long-standing debate surrounding the glass jaw in combat sports, this paper aims to shed light on the phenomenon of developing a glass jaw and its potential impact on future knockout losses. With the objective of empirically validating or refuting developing the glass jaw, statistical methods are employed to analyze data from the rapidly growing sport of MMA. To the best of the author's knowledge, there is currently no research that directly addresses the development of a glass jaw, making this paper the first of its kind in this direction. The hypotheses to be addressed are as follows:

- H1: There is a positive correlation between the number of KOs a fighter has experienced in the past and the likelihood of them experiencing future KO losses.

- H2: Certain fighters exhibit a higher susceptibility to receiving KOs compared to others.

For the purposes of this paper, technical knockouts (TKOs) are counted in the KO category. This merging is standard in MMA. By investigating these hypotheses, this study contributes to the emerging field of combat sports research (Giza & Hovda, 2014; Kaplan & Browder, 1954; Seifert & Shipman, 2015), offering valuable insights for coaches and trainers in identifying fighters prone to knockouts and implementing appropriate precautions.

2. Methods

2.1 Data

The official Ultimate Fighting Championship (UFC) data openly available on Kaggle (Dabbert, 2021; Warrier, 2021) are used in this paper. The data was verified against official statistics on the official UFC website (UFC.com, 2022). The period selected is from the beginning of 2010 to 2 October 2021, the date of the last update of the dataset. There is more incomplete information in the dataset before 2010.

The full dataset contains 4,896 fights, of which 1,495 ended in KOs. In total there were 515 women fights and 4,381 men fights. These fights involved 1,749 different fighters, 909 of whom received KOs in the period examined. In total, 199 women and 1,550 men fought. Most of the fights were at Lightweight and Welterweight. Two fighters participated in the fights, so the number of observations is equivalent to twice the number of fights.

2.2 Variables and model

The objective of the models is to examine the impact on the occurrence of KOs. The model has *KO loss* as the dependent variable. This variable is binary and takes the value of 1 if the fighter lost on KO and the value of 0 if the fighter won or lost in any other way. The independent effects are the *Number of KOs*, *Fighters FE*, *Weight Classes*, and *Odds*.

The variable *Number of KOs* represents the total number of KOs a fighter has experienced in their career prior to the monitored match. This variable is crucial in determining the potential existence of the glass jaw phenomenon, as a significant and positive correlation would suggest that as the number of KOs in a fighter's career increases, the probability of them losing to a KO also increases.

Several models also incorporate dummy variables for individual fighters, collectively referred to as *Fighters FE*. These variables aim to identify whether specific fighters have a higher susceptibility to losing via KO. This predisposition may be due to innate factors, as suggested in prior research (Giza & Hovda, 2014; Kaplan & Browder, 1954; Seifert & Shipman, 2015), or could be attributed to a fighter's unique fighting style. Econometric models utilizing historical data may reveal such patterns among fighters. Similarly, certain models include dummy variables for *Weight Classes*, as heavier weight classes are known to have a higher likelihood of experiencing KOs (Follmer et al., 2019). Accounting for this effect is essential in the analysis.

Lastly, the independent variable *Odds* is incorporated, which reflects the probability of victory calculated based on the pre-fight betting odds, as per the following formula.

$$Odds = \frac{European\ betting\ odds\ on\ the\ opponent\ to\ win}{European\ betting\ odds\ on\ the\ opponent\ to\ win + European\ odds\ to\ win} \qquad (1)$$

It can be inferred that in a fight where one fighter is a clear favorite, the probability of the match ending in a KO is higher. Overall, the model has the following form.

$$KO\ loss = f(Odds, Number\ of\ KOs, Fighters\ FE, Weight\ Classes) \qquad (2)$$

2.3 Specific models

The model is applied in various concrete forms, with Model 1 including the variables *Odds* and *Number of KOs*, and applied to the entire dataset. This serves as a starting model that can be further refined by incorporating additional factors. Model 1 is formulated as follows.

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \varepsilon \qquad (M1)$$

Furthermore, Model 2 incorporates *Fighters FE*, which aims to capture the individual characteristics of each fighter. Model 2 is formulated as follows.

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \beta_{3-1751} Fighters\ FE + \varepsilon \qquad (M2)$$

Model 3 includes *Weight Classes* as compared to Model 1. The objective of this model is to differentiate the outcomes for each weight class. Given that many fighters compete in the same weight class, including *Fighters FE* and *Weight Classes* together in the models would not be appropriate. Model 3 is formulated as follows.

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \beta_{3-15} Weight\ Classes + \varepsilon \qquad (M3)$$

Models 1, 2, and 3 are applied to the entire dataset. However, there are cases in the dataset where a fighter does not receive a KO throughout the observation period, which could potentially bias the phenomenon of developing a glass jaw. To address this potential imperfection, additional models 4, 5, and 6 are constructed and applied only to a subset of the dataset, specifically fighters who received at least one KO during the observation period. Models 4, 5, and 6 are formulated as follows.

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \varepsilon \qquad (M4)$$

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \beta_{3-1751} Fighters\ FE + \varepsilon \qquad (M5)$$

$$KO\ loss = \beta_0 + \beta_1 Odds + \beta_2 Number\ of\ KOs + \beta_{3-15} Weight\ Classes + \varepsilon \qquad (M6)$$

2.4 Data analysis

As the dependent variable KO loss is binary, it was crucial to select an appropriate regression method for estimating the parameters. Considering the suitability and drawing inspiration from previous literature (Faro et al., 2023; Miarka et al., 2017), a binary logistic regression analysis was employed to determine the impact of previous knockout experiences on the likelihood of a knockout loss. The significance of the effects was assessed using the Wald test statistics, and *p*-values were subsequently derived from these statistics.

3. Results

The resulting coefficients can be found in Table 1.

Table 1. The effect of previous KOs received on a KO loss.

	(M1)	(M2)	(M3)	(M4)	(M5)	(M6)
Odds	−2.852*** (−17.06)	−3.709*** (−16.42)	−2.939*** (−17.36)	−3.027*** (−17.28)	−3.446*** (−13.73)	−3.100*** (−17.49)
Number of KOs	0.249*** (8.362)	−0.300*** (−6.672)	0.175*** (5.666)	−0.121*** (−3.632)	−0.375*** (−8.148)	−0.168*** (−4.941)
Constant	−0.509*** (−6.299)	−1.586*** (−11.48)	−1.084* (−1.752)	0.328*** (3.729)	23.047 (1.405)	−0.134 (−0.1984)
Fighters FE	N	Y	N	N	Y	N
Weight Classes	N	N	Y	N	N	Y
Sample of fighters with KO	N	N	N	Y	Y	Y
Observations	9,792	9,792	9,792	6,334	6,334	6,334

Note: M = model. FE = fighters' fixed effects. *p < .10. **p < .05. ***p < .01. Z statistics values are in parentheses.

The subsequent lines provide the statistical results along with their practical interpretation. The results are presented with a breakdown of individual effects, i.e. variables, accompanied by commentary that pertains to all the models. All models are statistically significant at 1%. The *Odds* variable is found to be stable and significant (*p*<.01) in all models. The direction of the dependence shows that the bigger the fighter is the favorite in the fight, the lower the probability of losing on KO.

The situation regarding the number of past losses on KO is more complicated. The *Number of KOs* variable is significant ($p<.01$) in all models, but the direction of the dependence varies. In models (1) and (3), the direction is positive, which would suggest that the probability of another KO loss increases with the number of KOs. Thus, the existence of a developing glass jaw. In contrast, the remaining models do not support this conclusion. The direction of dependence is opposite in them. These are models containing *Fighters FE* or models with a selection of fighters who received KOs in the observation period. This suggests that the reason for more frequent KO losses can be found in the individual characteristics of the fighters rather than directly in the effect of the past number of KOs. A closer look at individual *Fighters FE* shows that for 308 fighters there is a significant effect supporting a greater propensity to lose on KO. This is therefore almost 18% of the total. These fighters then also determine the direction of the dependence in models (1) and (3). Overall, the different abilities of fighters to resist KOs can be statistically confirmed. In contrast, the development of the glass jaw cannot be directly confirmed in this way. The results of the statistical analysis indicate that hypothesis H1, which posits the development of a glass jaw in fighters, can be rejected. However, hypothesis H2, which pertains to the individual susceptibility of fighters to receive a KO, cannot be rejected.

4. Discussion

4.1 Results interpretation

A unique treatment of the statistical perspective is presented, showing that past losses by KO cannot explain future losses by KO with sufficient precision. At the same time, the effect of fighters' fixed effects (FE) is controlled for and it is shown that nearly 18 % of fighters have a glass jaw, that is, a higher probability of losing on KO.

Based on the models, the paper yields evidence to reject the notion of a glass jaw development in fighters. However, it does highlight that individual susceptibility to receiving knockouts cannot be dismissed. These findings align with the theoretical framework established by prior literature, wherein studies by Giza and Hovda (2014), Kaplan and Browder (1954), and Seifert and Shipman (2015) explored the varying predisposition of athletes to experience knockouts, while Hånell and Rostami (2020) provided insights into the reasons behind their occurrence.

In contrast, statistical evidence does not support journalistic assumptions regarding the development of a glass jaw (Kesting, 2015). Thus, it appears that journalists may inadvertently conflate the individual predisposition of fighters to receive knockouts with the concept of a developing glass jaw.

4.2 Validity

This paper employs standard econometric analysis, wherein the dependent variable is identified and hypothetical influences on this variable are examined. Based on these influences, a model is constructed and applied to the available data (Dabbert, 2021; Warrier, 2021). A logit regression method is chosen, considering the characteristics of the dependent variable, which is in line with previous research in combat sports that has investigated the influences on performance and match-winning (Faro et al., 2023; Miarka et al., 2017).

4.3 Limitation and future research

The current paper is presented based on the largest and most complete freely available datasets. It should be noted, however, that it does not include data related to fighters' careers before joining the UFC. Thus, the biggest shortcoming is that KOs received before entering this competition are not recorded. However, this fact does not affect the proven conclusion of the different dispositions of fighters to resist KOs. This characteristic is evident in such a dataset and adding additional information could only confirm it.

A more complicated situation arises with the number of KOs received. If the information on the number of KOs received before entering the competition were available, it would be possible to better quantify this effect. Thus, this paper cannot confirm the development of the glass jaw, but there remains space for future research that might seek to investigate this phenomenon in more detail.

4.4 Implications

The findings of this research may have implications in several areas. First and foremost, recommendations for coaches can be addressed. In sports, many things can be practiced to improve a particular characteristic of an athlete. Historically, it has been debated whether it is possible to practice KO resistance in combat sports. The results of this research show that this is not the way to go, as the effect of past KOs on future KOs cannot be clearly demonstrated. Rather, the specifics of individual fighters and the disposition they carry from their past prevail. Given that head strikes generally have a negative effect on many aspects of the health of a fighter (Lota et al., 2022; Lystad et al., 2014), resistance training to absorb more head strikes is more likely to cause harm to the fighter.

Another implication of this research may be to recommend closer monitoring of the effects of head strikes on individual athletes during fights. With a more detailed history of these strikes, it may be possible to better identify individuals who will be less able to withstand these strikes. Of course, head strikes are not appropriate for anyone, however, some individuals with inappropriate dispositions may produce more frequent unconsciousness and KOs in a fight. These individuals should guard their health even more closely. If they wish to continue to participate in combat sports, they should at least be aware of their disposition which makes this sport more difficult for them.

A potential strategy to mitigate head strikes in combat sports is to transition the fight from standing to the ground and utilize grappling techniques, such as Brazilian jiu-jitsu, wrestling, or sambo. When fighting on the ground, the likelihood of a devastating blow to the head and subsequent KO is reduced. While it's still possible for a fighter to receive head strikes even on the ground, the impact of such blows is typically diminished. Therefore, fighters who are more susceptible to KOs may benefit from focusing on grappling training in MMA and adopting a strategy that involves taking the fight to the ground. It's also crucial to train takedowns, which involve specifically bringing the fight to the ground. In the UFC, there are many fighters, such as Islam Makhachev, Magomed Ankalaev, and retired Khabib Nurmagomedov, who excel in ground fighting and prioritize taking the fight to the ground early on.

5. Conclusion

This paper adds its findings to several studies showing the existence of different dispositions of fighters for absorbing punches and resisting KO (Giza & Hovda, 2014; Seifert & Shipman, 2015). On the contrary, the phenomenon of developing a glass jaw, which is often presented in the press, that the probability of losing on KO increases with the higher number of KOs received, could not be proven.

References

Andrade, A., Silva, R. B., & Dominski, F. H. (2020). Application of Sport Psychology in Mixed Martial Arts: A Systematic Review. *Kinesiology*, *52*(01), Article 01.

Bledsoe, G. H., Hsu, E. B., Grabowski, J. G., Brill, J. D., & Li, G. (2006). Incidence of Injury in Professional Mixed Martial Arts Competitions. *Journal of Sports Science & Medicine*, *5*(CSSI), 136–142.

Camilo, J. A. de O., & Spink, M. J. P. (2018). Las Artes Marciales Mixtas (MMA): Deporte, espectáculo y economía. *Revista de Artes Marciales Asiáticas*, *13*(1), 20–34. https://doi.org/10.18002/rama.v13i1.5188

Chen, M. A., & Cheesman, D. J. (2013). Mental Toughness of Mixed Martial Arts Athletes at Different Levels of Competition. *Perceptual and Motor Skills*, *116*(3), 905–917. https://doi.org/10.2466/29.30.PMS.116.3.905-917

Chernozub, A., Korobeynikov, G., Mytskan, B., Korobeinikova, L., & Cynarski, W. J. (2018). Modelling mixed martial arts power training needs depending on the predominance of the strike or wrestling fighting style. *Ido Movement for Culture. Journal of Martial Arts Anthropology*, *18*(3), 28–36. https://doi.org/10.14589/ido.18.3.5

Dabbert, M. (2021). *Ultimate UFC Dataset*. https://www.kaggle.com/datasets/mdabbert/ultimate-ufc-dataset

Del Vecchio, F. B., Farias, C. B., de Leon, R. C., Rocha, A. C. C. A., Galliano, L. M., & Coswig, V. S. (2018). Injuries in martial arts and combat sports: Prevalence, characteristics and mechanisms. *Science & Sports*, *33*(3), 158–163. https://doi.org/10.1016/j.scispo.2018.02.003

Deng, J. (2023). Race, gender and MMA fandom – imagining Asian masculinities in the online forum of the UFC fan club. *Sport in Society, 26*(4), 671-686. https://doi.org/10.1080/17430437.2022.2033218

Devlin, M., Billings, A. C., & Leeper, J. (2016). Fighting Fandom: How Fan Identity Influences Self-Reported and Physiological Arousal During Exposure to Violent Sports Imagery. *Journal of Sports Media*, *11*(2), 159–185. https://doi.org/10.1353/jsm.2016.0016

Faro, H., de Lima-Junior, D., & Machado, D. G. da S. (2023). Rapid weight gain predicts fight success in mixed martial arts – evidence from 1,400 weigh-ins. *European Journal of Sport Science*, *23*(1), 8–17. https://doi.org/10.1080/17461391.2021.2013951

Follmer, B., Dellagrana, R. A., & Zehr, E. P. (2019). Head Trauma Exposure in Mixed Martial Arts Varies According to Sex and Weight Class. *Sports Health*, *11*(3), 280–285. https://doi.org/10.1177/1941738119827966

Gift, P. (2018). Performance Evaluation and Favoritism: Evidence From Mixed Martial Arts. *Journal of Sports Economics*, *19*(8), 1147–1173. https://doi.org/10.1177/1527002517702422

Gift, P. (2020). Moving the Needle in MMA: On the Marginal Revenue Product of UFC Fighters. *Journal of Sports Economics*, *21*(2), 176–209. https://doi.org/10.1177/1527002519885432

Giza, C. C., & Hovda, D. A. (2014). The New Neurometabolic Cascade of Concussion. *Neurosurgery*, *75*, S24. https://doi.org/10.1227/NEU.0000000000000505

Hammami, N., Hattabi, S., Salhi, A., Rezgui, T., Oueslati, M., & Bouassida, A. (2018). Combat sport injuries profile: A review. *Science & Sports*, *33*(2), 73–79. https://doi.org/10.1016/j.scispo.2017.04.014

Hånell, A., & Rostami, E. (2020). How Can a Punch Knock You Out? *Frontiers in Neurology*, *11*. https://www.frontiersin.org/articles/10.3389/fneur.2020.570566

Hirose, A., & Pih, K. K. (2010). Men Who Strike and Men Who Submit: Hegemonic and Marginalized Masculinities in Mixed Martial Arts. *Men and Masculinities*, *13*(2), 190–209. https://doi.org/10.1177/1097184X09344417

Jang, S. H., Kim, O. L., Kim, S. H., & Kim, J. B. (2019). The Relation Between Loss of Consciousness, Severity of Traumatic Brain Injury, and Injury of Ascending Reticular Activating System in Patients With Traumatic Brain Injury. *American Journal of Physical Medicine & Rehabilitation*, *98*(12), 1067–1071. https://doi.org/10.1097/PHM.0000000000001243

Jensen, A. R., Maciel, R. C., Petrigliano, F. A., Rodriguez, J. P., & Brooks, A. G. (2017). Injuries Sustained by the Mixed Martial Arts Athlete. *Sports Health*, *9*(1), 64–69. https://doi.org/10.1177/1941738116664860

Kaplan, H. A., & Browder, J. (1954). Observations on the Clinical and Brain Wave Patterns of Professional Boxers. *Journal of the American Medical Association*, *156*(12), 1138–1144. https://doi.org/10.1001/jama.1954.02950120012004

Karpman, S., Reid, P., Phillips, L., Qin, Z., & Gross, D. P. (2016). Combative Sports Injuries: An Edmonton Retrospective. *Clinical Journal of Sport Medicine*, *26*(4), 332–334. https://doi.org/10.1097/JSM.0000000000000235

Kesting, S. (2015, September 12). *Does MMA Make You Stupid? Impact, Concussions and Brain Damage in Mixed Martial Arts*. Grapplearts. https://www.grapplearts.com/does-mma-make-you-stupid-impact-concussions-and-brain-damage-in-mixed-martial-arts/

Kirkwood, M., Yap, S.-F., & Xu, Y. (2019). An Exploration of Sport Fandom in Online Communities. *International Journal of Sport Communication*, *12*(1), 55–78. https://doi.org/10.1123/ijsc.2018-0133

Lota, K. S., Malliaropoulos, N., Blach, W., Kamitani, T., Ikumi, A., Korakakis, V., & Maffulli, N. (2022). Rotational head acceleration and traumatic brain injury in combat sports: A systematic review. *British Medical Bulletin*, *141*(1), 33–46. https://doi.org/10.1093/bmb/ldac002

Lystad, R. P., Gregory, K., & Wilson, J. (2014). The Epidemiology of Injuries in Mixed Martial Arts: A Systematic Review and Meta-analysis. *Orthopaedic Journal of Sports Medicine*, *2*(1), 2325967113518492. https://doi.org/10.1177/2325967113518492

Massey, W. V., Meyer, B. B., & Naylor, A. H. (2013). Toward a grounded theory of self-regulation in mixed martial arts. *Psychology of Sport and Exercise*, *14*(1), 12–20. https://doi.org/10.1016/j.psychsport.2012.06.008

Miarka, B., Brito, C. J., & Amtmann, J. (2017). Performance probabilities and outcome effects in technical–tactical factors with bout phase changes of mixed martial arts. *International Journal of Performance Analysis in Sport*, *17*(4), 510–520. https://doi.org/10.1080/24748668.2017.1360103

Mickelsson, T. B., & Shaw, V. (2020). Performance increments without audience: Paired data from mixed martial arts fighters during COVID-19. *Revista de Artes Marciales Asiáticas*, *15*(2), Article 2. https://doi.org/10.18002/rama.v15i2.6294

Mierzwinski, M., Velija, P., & Malcolm, D. (2014). Women's Experiences in the Mixed Martial Arts: A Quest for Excitement? *Sociology of Sport Journal*, *31*(1), 66–84. https://doi.org/10.1123/ssj.2013-0125

Seifert, T., & Shipman, V. (2015). The Pathophysiology of Sports Concussion. *Current Pain and Headache Reports*, *19*(8), 36. https://doi.org/10.1007/s11916-015-0513-0

Seungmo, K., Greenwell, T. C., Andrew, D. P. S., Lee, J., & Mahony, D. F. (2008). An Analysis of Spectator Motives in an Individual Combat Sport: A Study of Mixed Martial Arts Fans. *Sport Marketing Quarterly*, *17*, 109–119.

UFC.com. (2022). *The Official Home of Ultimate Fighting Championship | UFC.com*. https://www.ufc.com/

Vaccaro, C. A., Schrock, D. P., & McCabe, J. M. (2011). Managing Emotional Manhood: Fighting and Fostering Fear in Mixed Martial Arts. *Social Psychology Quarterly*, *74*(4), 414–437. https://doi.org/10.1177/0190272511415554

Warrier, R. (2021). *UFC-Fight historical data from 1993 to 2021*. Kaggle. https://www.kaggle.com/datasets/rajeevw/ufcdata

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