Heath and Callahan. J Athl Enhancement 2014, 3:4
http://dx.doi.org/10.4172/2324-9080.1000162

Journal of Athletic Enhancement

Research Article A SCITECHNOL JOURNAL

Assessment of Cognitive Functioning in Mixed Martial Arts Athletes

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Abstract

Objective: This is the first study to examine the relationship between the increasingly popular sport of mixed-martial-arts and objective computerized cognitive performance. Specifically, the study examines whether the neuropsychological functioning of MMA athletes differs from athletes who are not exposed to contact striking and associated head traumas. Also assessed is the relationship between cognitive performance and MMA training routines.

Design: Cross-sectional design.

Setting: Participants chose the location where they completed measures.

Participants: 28 MMA athletes and 28 control athletes.

Interventions: Individuals were categorized into one of two groups based on whether they participate in MMA.

Main Outcome Measures: The Immediate Post-Concussion Assessment Cognitive Test (ImPACT) as well as a questionnaire on training routines.

Results: No neuropsychological differences were found between groups of athletes. Additionally, no aspects of MMA training regimen shared a reliable relationship with neuropsychological performance or subjective concussive symptoms.

Conclusions: Results from this first study to assess cognitive profiles of MMA athletes' using an objective computerized neuropsychological assessment instrument suggests participation in MMA is not related to neuropsychological task performance. Furthermore, the neurocognitive performance of MMA athletes was indistinguishable from control athletes not regularly exposed to repeated head trauma.

Keywords

Martial arts; Sporting injuries; Concussion; Head injuries; Combat sports

Introduction

Interest in sport-related concussion has grown in the past two decades, in both academic literature as well as popular press [1-3]. As a result of this interest, valuable information has been learned about the concussions commonly seen in athletes including estimated recovery times and risks of cumulative injuries [4-9]. Within the growing research in sport-related concussion neuropsychological testing has been considered a cornerstone for concussion management given its high utility for diagnosing concussion, monitoring subsequent recovery, and objectivity [10,11].

Whether it is in part due to, or despite, its violent nature, combat and fighting sports have appealed to athletes and audiences throughout history, and have garnered significant attention from the standpoint of sport-related brain injury [12]. Although some organizations have suggested these sports be banned—the British Medical Association in particular [13], the head trauma inherent to a sport such as boxing offers a unique opportunity to assess neuropsychological effects that result from repeated, subconcussive blows to the head [14,15]. Head injuries that result from boxing have been estimated to occur in up to 20% of boxers [16], and are known to have a variety of neurocognitive sequela including chronic traumatic encephalopathy, neuropathologic injury, as well as long-term cognitive impairment [14,17].

While some research has suggested these injuries are uncommon in amateur boxing [16,18], opposing research has claimed amateur boxers do show neurocognitive evidence of chronic injury [17]. However, recent large-scale reviews concluded that under appropriate safety precautions [17,19], there is no strong association between chronic brain injury and amateur boxing [18]. Despite the disagreement of whether boxers are vulnerable to long-term effects of concussive injury it is particularly troubling that half the injuries are incurred by these athletes are cerebral in nature [20] and the traumas incurred during training may be especially problematic [15].

Mixed-martial-arts (MMA) differs from Western boxing in that while it is a full-contact fighting sport, it also includes elements of other martial art disciplines, including Thai boxing, submission wrestling, judo, and others. Since its American debut in the early 1990's [21] MMA has become a pop-culture phenomenon [22] showing increases in both popularity and participation. Accompanying this popularity has been a surge of facilities and gyms that offer MMA training.

Unlike traditional boxing, which uses 8-10 oz protective gloves, the gloves worn by MMA athletes weigh only 4 oz [23], offering significantly less protection to competitors. With this difference in equipment it is possible that the cerebral injuries and concussions that account for half of the injuries in boxing [20] may be even higher in MMA athletes. In fact, traumatic head injury was the reason approximately 1/3 of televised matches was stopped over a 10-year period [24], Like boxing, the injuries that are sustained during training may be even greater [15], as the number of days that MMA athletes spar during the week has shown to be associated with their number of head injuries [25], Given that MMA athletes typically train between 3-12 times per week and spar for approximately an hour per day [25,26] their training routines alone may place them at risk for concussive trauma, regardless of whether they actually compete in the sport [25].

In light of the existing literature, mixed-martial-artists appear to be a unique and vulnerable population of athletes. Therefore, participants and proponents of the sport stand to benefit from research that expands previous sport-concussion literature to these

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Received: March 31, 2014 **Accepted:** June 29, 2014 **Published:** July 03, 2014

Table 1: Mean, Standard Deviation, and Range for Training Routines and Post Concussion Scale Scores Among MMA Athletes (n=28).

Variable	*M*	*SD*	Range
Weekly days sparring	2.6	1.1	1 - 6
Weekly minutes sparring	109.3	95	15 - 390
Knockouts	0.36	0.6	0 - 2
Technical Knockouts	1.0	1.5	0 - 6

Table 2: Correlations Among Neuropsychological Variables.

Variable	Verbal Memory	Visual Memory	Reaction Time	Visual Processing
Verbal Memory	–			
Visual Memory	0.45*	–		
Reaction Time	-0.04	-0.29*	–	
Visual Processing	0.37*	0 .45**	-0.63**	–

Note: N=56
**p<0.05*
***p<0.001*

specific athletes. The aim of the current study was to more closely examine the relationship between MMA participation and cognitive performance. It was expected MMA athletes would perform more poorly on neurocognitive performance tasks than athletes that do not regularly endure repeated head traumas. Additionally, it was expected that a longer history of MMA involvement and more frequent training routines would be associated with poor neurocognitive performance.

Methods

Participants

Participants included 28 males who participate in full-contact mixed-martial-arts and 28 males who participate in exercise regimens that do not involve repeated head traumas (*e.g.*, submission grappling or high intensity interval training). The mean age for the mixed-martial-arts athletes was 28.9 years (range=19-58), which was nonsignificantly different from the comparison group of athletes who, on average, were 31.7 years (range=23-51). Additionally, a measure of general intellectual functioning (the Shipley Institute of Living) suggested the athletes were also comparable in cognitive ability, as the MMA athletes scored comparably (M=48, SD=5.2) to the control athletes (M =49, SD =5.4). Table 1 displays the mean, standard deviation, and range for the MMA athletes training routines, and the average number of knockouts and technical knockouts. As shown in the table 1, the MMA athletes reported training an average of 2.6 days per week and sparring approximately 109 minutes each week, with approximately 29% (n=8) of the mixed-martial arts athletes reported experiencing a knockout and nearly half (n=13) reported a technical knockout.

Measures

In addition to reporting basic demographic information, participants were asked to provide details regarding their routine training schedules. MMA athletes were asked to report their length of involvement with MMA, the number of days and time spent training in MMA per week, the number of times they have been declared knocked out (KO) or technically knocked out (TKO), and the amount of time spent in general fitness training (*e.g.*, weightlifting, running, swimming). Non-MMA, control, athletes were asked to assess the amount of time spent in general fitness training. All athletes then completed a cognitive evaluation, using the measure detailed below.

Immediate Post-concussion assessment cognitive test (ImPACT; version 2.0.): ImPACT (NeuroHealth System, LLC, Pittsburgh, PA) is a brief computerized neuropsychological test battery designed to assess neurocognitive functioning and concussion symptoms by measuring verbal memory, visual memory, reaction time, and visual processing speed [27]. Additionally, ImPACT also contains the Post-Concussion Symptoms Scale (PCS) [28], a subjective self-report scale designed to measure the severity of 22 commonly reported concussion symptoms (*e.g.*, headache, dizziness, etc.) in the acute stages of concussion recovery. The ImPACT program has been used in a variety of sport-concussion research [6,8,11].

Shipley institute of daily living (Shipley): The Shipley was also presented to measure general mental abilities and determine whether pre-existing differences in intellectual abilities may have impacted performance difference on the ImPACT measurements. The Shipley measure contains 40 questions of vocabulary knowledge and 20 abstraction questions. The total score of both subscales were combined to compute the total score.

Procedures

Athletes were recruited from local gyms offering mixed-martial-arts and/or alternative types of exercise such as submission wrestling or high intensity interval training (*i.e.* CrossFit). A combination of in-person announcements and fliers were used to inform individuals of the opportunity to participate in the research study in exchange for monetary compensation. For approximately 12 months, individuals were recruited with the opportunity to be placed in a raffle drawing for one of three $50 gift cards. Following these 12 months, procedures were revised to offer individuals a $20 participation fee. The same examiner assisted all participants throughout the completion of the study by providing web-based materials needed to complete the basic training questionnaire and Shipley cognitive measure at a convenient time of their choosing. Upon completion, participants were provided web-based materials to complete the ImPACT measure in a similar fashion. All participants and their data were treated in accordance with the Ethical Code [29] and with approval of the Institutional Review Board.

Results

Preliminary analysis assessed the associations among the neuropsychological variables of verbal memory, visual memory, reaction time, and visual processing speed. As shown in Table 2, each of the variables was moderately correlated with each other (range of p's =<0.001 -0.03), with the exception of reaction time not varying systematically with verbal memory. The variable for reaction time was transformed by applying an inverse transformation to normalize the distribution. Additionally, the distribution of verbal memory was transformed by applying a squared transformation. However, these transformations had no effect on conducted analyses and are therefore reported in their original units of measurement.

Of primary interest was whether the performance of MMA athletes differed from non-MMA athletes on neuropsychological tasks, as it was hypothesized that MMA athletes would demonstrate significantly poorer performance on these tasks. However, t-tests for independent samples revealed no significant differences between the athlete groups on measures of verbal memory, visual memory, reaction time, or visual processing speed (all p's>0.05; mean and standard deviation values shown in Table 3). Additionally, a series of univariate ANCOVA's also demonstrated no significant differences between MMA and non-MMA athletes on these measures when

Table 3: ImPACT Composite Variables Among Athletes in this Sample, Compared to Normative Data.

	Athlete Group		
Variable	**MMA Athletes *(m / SD)***	**Control Athletes *(m / SD)***	**Normative Rangea**
Verbal Memory	84.49/10.7	88.4/9.5	83-94
Visual Memory	71.3/13.1	74.8/14.9	69-94
Reaction Time	.63/.1	.61/.1	.52-.60
Visual Processing	35.5/6.1	38.7/6.7	32.5-42
Post-Concussion Scale	12.3/15.8	6.3/10.5	1-5

[a]The average range of scores from a non-injured normative sample of 410 college-aged men [27].

Table 4: Correlations Among Training Variables and Neuropsychological Outcomes.

Variable	Verbal Memory	Visual Memory	Reaction Time	Visual Processing	Shipley	PCS
Days[a]	-.22	.02	-.01	.01	-.31	.07
Minutes[a]	.07	.21	-.20	.13	-.02	-.13
Total History[b]	-.14	-.21	-.07	.05	.07	.05

Note: N=28

[a]Athletes were asked to estimate the amount of each measure of time they spend sparring each week.

[b]Athletes were asked to estimate the total amount of time they have been involved with MMA by providing as specific unit of measurement as possible (i.e., years, months, days). All responses were then converted to a continuous measure of days.

controlling for general cognitive ability, as measured by the Shipley Institute of Daily Living (all *p*'s>0.05). Moreover, a logistic regression containing sport group as the dependent variable and the four ImPACT outcome variables as predictors failed to reliably predict performance. Although no reliable relationships were found in these analyses, any substantial relationship would have been difficult to detect. For example, power analysis indicates that a sample of this size has a 45% chance of detecting a medium effect size (*d*=0.5) in performance difference between groups at the 0.05 confidence level. Additionally, a more modest effect size (*d*=0.25) in performance difference between the two groups would have a 15% chance of being detected.

Secondary hypotheses suggested a negative relationship would exist between aspects of weekly training regimen and neuropsychological performance, as well as total duration of MMA participation and neuropsychological performance. Therefore, additional analyses were conducted to assess the relationships among the amount of time spent sparring each week, the number of days sparred each week, and the length of involvement with MMA, with neuropsychological task performance. However, as seen in Table 4 no aspects of training regimen shared a significant correlation with any of the neuropsychological tasks or a measure of cognitive ability (all *p*'s>0.05). That is, the number of days per week an athlete reported sparring, the amount of time they spent per week sparring, and the total number of days they reported being involved in MMA were not significantly related to verbal memory performance, visual memory performance, reaction time, visual processing speed, or general cognitive ability. Similar to the primary set of analyses, the likelihood of detecting a reliable relationship was low, as a sample of this size has a 26% chance of detecting correlation a modest correlation (*d*=0.25) at the 0.05 confidence level.

Discussion

Previous research has suggested boxing athletes may incur more head injuries during routine sparring sessions as opposed to actual competition matches [15]. Similarly, the amount of time mixed-martial-arts athletes' spar each week has been linked to their frequency of knockouts [25]. Taken together, this emerging line of research suggests the possibility that training in the sport of MMA might place athletes at a heightened risk for neuropsychological deficits as a result of repeated head trauma.

However, performance on neurocognitive tasks by MMA athletes in this sample was comparable to that of athletes not regularly exposed to repeated head trauma. Similarly, the subjective concussion symptoms reported by MMA athletes were comparable to those reported by non-MMA athletes. Although previous research has linked MMA training regimens to the number of knockouts experienced [25], no such relationships were found in the current sample of athletes. Additionally, no reliable relationships were found between MMA training regimens and neurocognitive task performance or self-reported concussive symptoms. The neuropsychological performance by both groups of athletes in the current sample was within the average level of performance in non-injured samples [30], with the exception of evidencing marginally slower reaction time. Results from this study suggest findings from boxing literature that conclude participation in a sport with routine training sessions exposing an athlete to repeated head trauma does not pose unique risk for neuropsychological deficit [16,18], can be expanded to the growing sport of MMA.

Although some research has concluded amateur boxing to be a relatively safe sport, basic precautionary restrictions and protective requirements remain prerequisites [18,19] particularly in regard to head injuries. Athletes experiencing symptoms of concussion are strongly advised to refrain from physical exertion prior to the resolution of such symptoms [31-33]. Athletes who return to sport participation prior to being asymptomatic place themselves at particularly high risk for subsequent traumatic brain injuries [34]. However, it has been suggested that MMA athletes may have "aggressive personalities," and disregard such restrictions in order to return to sport participation against medical advice, rather than interrupting regular training schedules [35].

Although MMA athletes in this study showed neuropsychological task performance and postconcussion symptoms rating scores comparable to athletes not exposed to regular head trauma, this finding bears important limitations that must be considered. In particular is the retrospective self-report methodology, which may have led to participants misinterpreting survey questions or providing biased/inaccurately recalled information. Additionally, characterizing the frequency and intensity at which athletes' spar is a complex task, as is differentiating amateurs versus professionals. Either of these factors may be related to the level of head trauma incurred and subsequently effect vulnerability to injury [16,18].

Additionally, a limited self-selected sample may not accurately represent a population of athletes, as it is possible an athlete's motivation to participate in a study assessing brain function is confounded with adherence to regular safety precautions, when at least a subset of MMA athletes have been reported to favor returning to training over complying with medical advice [35]. Further research is necessary to prospectively quantify training regimens and establish a more accurate assessment of exposure to head trauma and associated effects from this trauma on neuropsychological functioning and concussive symptoms.

A final possibility no reliable relationships were found is due to

the limited size of the sample. In fact, power analyses suggest that even modest differences in neuropsychological performance differences between athlete groups, or, between aspects of training regimen and performance would have been difficult to detect given the size of the current sample. Although samples of this size are not atypical in sport concussion research these findings suggest any neuropsychological deficits MMA athletes do have may not be readily detectable in the absence of large samples.

Previous research has suggested MMA athletes may be a particularly at-risk population given their regular training regimens exposes them to repeated subconcussive head traumas [25]. This is particularly problematic when considered with novel research that has shown the subconcussive traumas athletes endure may result in structural and neuropsychological consequences [36]. However, in this study of what is believed to be the first research of MMA athletes using objective computerized neuropsychological assessment measures the neuropsychological task performance and postconcussion symptom rating scores of MMA athletes were comparable to athletes not exposed to recurrent head traumas. This finding suggests participation in the growing sport of MMA by a typical athlete may not pose significant—or at least unique- neuropsychological risk. Given the novelty of research in MMA along with the growing popularity of the sport, additional research is warranted to further assess the general neuropsychological functioning and vulnerabilities of this population, similar to what has been conducted in other popular sports (*e.g.*, football, soccer, hockey). The emerging sport of MMA stands to benefit from continued research in the areas of particular training regimens, longitudinally based neuropsychological profiles of participants, as well as information within the sport culture about concussive injury, brain trauma, and protocol for treating suspected concussive injury.

Conflicts of Interest

The authors report no conflicts of interest.

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