

"What's that Smell?" Brain Injury May Cause Alarming Problems for Your Nose

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Abstract

The purpose of this research was to determine the relationship between olfactory damage and mild traumatic brain injury, or concussion, that exists in the general population, and whether the population is aware of either the concussion or olfactory deficiencies. The hypothesis of this study is that olfactory dysfunction will be present in a significant number of participants who have experienced concussion, and that participants will not be aware of this olfactory deficit if it exists. Seventy-seven participants were voluntarily recruited and each participant was given a self-report questionnaire to assess past history of concussion. Then, the participants were given a scratch and sniff smell test called the University of Pennsylvania Smell Identification Test (UPSIT). The results were compared between groups of those who had past concussion, those who had a concussion in childhood and those who did not have a concussion. Significant differences were found between groups, namely those in the concussion group did significantly worse than the other participants. It was also found that most people did not perceive any smell loss, even when it was present. Nearly a quarter of the participants, who experienced a concussive injury, were not aware that there was a concussion and received no medical attention. The hypotheses were supported; however, further research is needed to draw more concrete conclusions regarding causation.

"What's that Smell?" Brain Injury May Cause Alarming Problems for Your Nose

A head injury occurs nearly every 15 seconds in the United States, and the majority of these injuries are mild (Koch, Merz, & Lynch, 1995). A concussion is one form of brain injury that is considered mild. However the definition of a concussion and the lasting impacts of a concussive injury are still under investigation by professionals in the fields of health, psychology, and sports medicine. There have been many different phrases used to describe concussion like injuries such as “trivial head injury,” “minimal head injury,” “minor head injury,” and “minor brain injury;” however, use of the wrong terminology can lead to misdiagnosis and incomplete treatments (Koch et al., 1995).

Another term used to characterize concussion is mild traumatic brain injury, or MTBI (Kushner, 1998). Because this is the most accepted synonym for concussion, MTBI will be assumed to mean the same thing as concussion. According to the Center for Disease Control, 75% of all traumatic brain injuries are MTBIs and the effects of these injuries could be long term or permanent (National Center for Injury Prevention and Control [NCIPC], 2003). Of those who experience MTBI, 25% will have delayed symptoms that impair daily functioning (Koch et al., 1995). Diagnosis and grading for concussions used to be based on loss of consciousness; however, it has been shown that loss of consciousness is not necessarily the best indicator of injury severity (Brooks, 2006).

In 2004 there was an international conference in Prague to discuss the definition and influences of concussion in athletes all over the world. According to

their definition, “concussions may be caused by a direct blow to the head, neck, face, or other area of the body with an ‘impulsive’ force transmitted to the head” and may involve being knocked unconscious, or not (McCroory et al., 2005). Mild concussions, where there is no loss of consciousness, are the hardest to diagnose, yet they are the most common form of MTBI, especially as related to athletes (Leclerc, Lassonde, Delaney, Lacroix, & Johnston, 2001).

The conceptual definition of MTBI that was reported by the Center for Disease Control (CDC) is “an injury to the head as a result of blunt trauma or acceleration or deceleration of forces” resulting in observed or self-reported disorientation, confusion, impaired consciousness, memory dysfunction, loss of consciousness for less than 30 minutes, seizures following injury, irritability, lethargy, vomiting, headache, dizziness, fatigue, or poor concentration (NCIPC, 2003). Other than the immediate physical symptoms, there are functional limitations that are involved in concussion that often do not appear until a person seems to be fully recovered (Koch et al., 1995). In Koch et al. (1995) they say the most significant lasting side effect is poor concentration, but other side effects include emotional, cognitive, and behavioral changes. The definitions given by the CDC and the Prague council will serve as the basis by which concussion, or MTBI, are assessed in this research.

An emergency department population may be a good place to examine the prevalence of concussion in the general population. It was found that 20% of people involved in a self-report questionnaire, at an emergency room in Montreal, Canada,

had suffered symptoms of a concussion, and of those 88% did not recognize that they had suffered a concussion (Delaney, Abuzeyad, Correa, & Foxford, 2005). Though this data may not be representative of the true population, it is a good estimate of how many people in the general public might have suffered a concussion without being diagnosed. Those who experienced a concussion were more likely to have experienced multiple concussions, which could be due to the fact that 28% of the respondents were involved in some form of sport activity that increased risk for a concussive injury (Delaney et al., 2005).

It is possible that athletes who participate in strenuous, physical activities will be more at risk for injuries like MTBI than others. Some of the most dangerous sports to participate in are rugby, soccer, ice hockey, football, boxing, and tae kwon do (Brooks, 2006). Athletes participating in any of these sports are likely to experience some head trauma, and possibly multiple injuries. According to a study done in Canada, 70% of football players and almost 63% of soccer players suffered a concussion in the previous year (Delaney, Lacroix, Leclerc, & Johnston, 2002). Delaney et al. (2002) also concluded that the risk of concussion is higher for those who have a history of recognized concussion. If an athlete returns to play before a concussion has fully healed he or she is at risk for developing "Second Impact Syndrome." If the brain is injured a second time, it causes a brain edema, herniation, and death within 2-5 minutes of the second impact (Delaney et al., 2005). This dangerous prognosis can be avoided with proper care and knowledge of the severity of MTBI. However, as indicated by Delaney's et al. (2005) research, many who have

had an injury do not understand that it was a concussion and, therefore, may not receive treatment or medical advice about returning to play sports, or other dangerous activities.

Part of the problem is there is no universally accepted way to diagnose and grade the severity of concussions in athletes, or non-athletes (Leclerc et al., 2001). Different definitions of concussion have already been discussed; however the confusion does not end with defining the term. Koch et al. (1995) provides suggestions for screening patients for MTBI which include observation, interviews, and cognitive testing. There have been at least 16 different ways of grading concussion developed, yet only one has been tested and validated experimentally, the Glasgow Coma Scale. (Leclerc et al., 2001). The Glasgow Coma scale is used for moderate to severe brain trauma, and lacks the specificity to grade mild concussions, which are the majority of all injuries (Leclerc et al., 2001). Most of the other scales recognize three levels of concussion severity. The McGill Grading System, which was developed by Leclerc et al. (2001), breaks each severity level (grade 1, 2, or 3 concussion) down into subsets of A, B, or C for more precise diagnosis within categories. It is important that injuries are diagnosed correctly so that medical procedures are correctly followed and the injury is not trivialized (Koch et al., 1995).

Cognitive deficits caused by MTBI can be extensive and long term. It is plausible that some athletes, who have no reported history of concussion, simply did not get diagnosed for past injuries, because of the confusion of the definition and grading scale for concussion. It has been shown that concussed athletes and athletes

who had no reported history of concussion performed significantly worse on the memory portion of the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) than did control subjects who were non-athletes with no history of concussion (Killam, Cautin, & Santucci, 2005). The purpose of the Killiam et al. (2005) study was to determine the extent of long term damage caused by concussion, and was conducted on a college campus with athletes competing at the college level. If that is so, it would seem that negative effects on memory function are caused by concussive injuries in college sports. This leads to more questions concerning other symptoms that might persist, past the point of complete recovery, as defined by coaches or trainers.

One possible symptom of MTBI that has not been added to any professional definition is impairment of olfactory ability. The first documented case of smell loss due to head injury was in the 19th century when a man suffered from severe concussion after falling from a horse (Costanzo & Zasler, 1991). Smell loss has been noted as a possible side effect of MTBI, especially if there is damage to the olfactory nerve, nasal bones, sinuses, and anterior frontal or temporal lobe damage (Kushner, 1998). The coup contre coup forces exhibited by a blow to the head can also lead to olfactory nerve damage (Costanzo & Zasler, 1991). Complete smell loss, or anosmia, is most often caused by the shearing of olfactory nerves at the cribriform plate, and scarring of the cribriform plate can cause new nerve axons in the olfactory epithelium to be unable to reach the olfactory bulb, causing permanent damage (Geisler, Schlotfeldt, Middleton, Dulay, & Murphy, 1999). In the future, perhaps surgery will

be able to repair damage to the cribriform plate; however, at this point, restoration of smell is not medically possible (McIntosh, 1997). Now, there is no required test for signs of smell dysfunction included in any concussion screening. If smell loss is an indicator of concussion, the screenings that are available are incomplete.

It is possible that olfactory screenings could help health care practitioners to accurately measure the extent of damage caused by a concussion. Olfactory impairment could be used to indicate impairment to the orbital frontal lobe which is important in executive functions, such as the formation of individual personality traits (Callahan & Hinkebein, 1999). Deficiencies in executive functioning could result in changes to the personality and also problems in frontal lobe functions like learning and problem solving (Callahan & Hinkebein, 1999). Such injuries can lead to social problems as well, such as unemployment, poor empathy and judgment, as well as absentmindedness (Martzke, Swan, & Varney, 1991).

The most common forms of brain imaging, computed tomography (CT) and magnetic resonance imaging (MRI), often cannot detect injuries to the orbital frontal lobe since these injuries usually take the form of lacerations or abrasions (Martzke et al., 1991). This makes them especially hard to diagnose. However, neuroSPECT imaging, or neurological single photon emission computed tomography, has shown damage in the orbital frontal region of confirmed anosmics with a history of traumatic brain injury, or TBI (Varney & Bushnell, 1998). Most of the participants in the Varney & Bushnell (1998) study, 16 out of 18, had head injuries considered mild but that included a loss of consciousness for less than 30 minutes and posttraumatic

amnesia for no more than 24 hours. These criteria may include some people who have suffered a more serious concussion, but it does not address more mild concussions not involving loss of consciousness. Still, it is clear that loss of smell plays some role in determining the position of the injury in post-concussive individuals, and could be a measure of severity in situations where no other symptoms seem severe.

Along with neurological effects, anosmia can cause functional problems as well. There are certain safety risks involved in smell dysfunction. People are at increased risk of injuring themselves due to an inability to detect hazardous scents like smoke, natural gas, or spoiled foods (Costanzo & Zasler, 1991). A person might not realize there is a fire or a gas leak in their home until it is too late, and might even inhale a toxic amount of smoke or gas. Food poisoning can lead to vomiting and fluid loss that often requires hospitalization, and may lead to more serious medical problems. Social concerns also include using too much perfume or having excessive body odor, both of which can interfere with maintaining close contact in personal relationships (Callahan & Hinkebein, 1999). Similarly, smell loss can lead to vocational problems and unemployment. Physical and mental disorders like appetite loss may be attributed to a lack of taste in food, which might be caused by smell loss (Costanzo & Zasler, 1991). These functional deficits should not be overlooked when considering the overall impact of olfactory dysfunction.

A human's ability to predict his own olfactory function has been shown to be less than accurate. In an experiment where participants were asked to rate their

olfactory ability before the administration of a smell test, the ratings of ability did not correlate with the actual performance (Landis, Hummel, Hugentobler, Giger, & Lacroix, 2003). However, in the same experiment by Landis et al. (2003), another group of participants were asked to predict their olfactory ability after the administration of a smell test, and this group did much better. It was proposed that the lack of daily concentration on smell sensation was the cause for poor prediction ability, since those who had a chance to focus on their sense of smell, the second group, were better at predicting their abilities (Landis et al., 2003).

Furthermore, it was shown that participants were more accurate at predicting olfactory dysfunction when they suffered from chronic sinus problems, which decrease airflow in the nasal passages (Landis et al., 2003). Perhaps it is not a loss of smell that these people are aware of but a reduction in nasal patency (Landis et al., 2003). If this theory is applied to MTBI patients, it is understandable why those with no sinus problems would not recognize olfactory deficiencies, even if they were severe. In fact, out of 44 confirmed anosmics, 31 or 70% denied that they had any problems with their sense of smell, when asked in an interview (Callahan & Hinkebein, 1999). Thus, it is plausible to suspect that if there are people in the general population who have some olfactory deficits, they probably do not know about it. These results imply that it would be imprecise to ask people to self-report smell sensation problems as a symptom of concussion. There needs to be a way for professionals to test for problems easily and reliably.

A study conducted in Europe found that patients with a confirmed MTBI had significant olfactory impairment (De Kruijk, Leffers, Manheere, Meerhoff, Rutten, & Twijnstra, 2003). Moderate to severe smell loss was defined as hyposmia, in 22% of participants, and a complete inability to sense smells was defined as anosmia, in 4% of participants (De Druijk, et al., 2003). The method used to measure smell function was a bottle sniff test, in which scents were sniffed from a bottle and identified by the participants (De Druijk, et al., 2003). The sniff bottles may not be the most reliable way to measure olfactory ability, because it is hard to replicate scents created in a diluted aqueous solution, but the findings of this research cannot be discounted.

Most methods of measuring olfactory function have been shown to measure a common source of variance, and this may be why the smell bottles showed valid data (Doty, Smith, McKeown, & Raj, 1994). However, a more systematic method allows for more reliable interpretation of results. The University of Pennsylvania Smell Identification Test was developed as a standardized way to measure olfactory function. The test has been found to be useful clinically for its sensitivity to smell deficits related to numerous problems like Alzheimer's disease, cigarette smoking, industrial chemical exposure, Parkinson's disease, sinusitis, epilepsy, and many others (Doty, 1995). Doty (1995) makes especially clear its sensitivity to frontal lobe dysfunction and psychopathology.

It has also been shown that the UPSIT has a high level of internal consistency reliability, and that individual sections of the test can be used to determine olfactory ability with almost as much accuracy as the whole test (Doty, Newhouse, & Azzalina,

1985). Not only can this test be used as a tool for patients who complain of smell loss, but it can be used as a diagnostic tool for certain diseases such as Parkinson's disease (Doty, Bromley, & Stern, 1995).

Callahan and Hinkebein (2002) used the University of Pennsylvania Smell Identification Test (UPSIT) to determine the extent of damage to olfactory functioning that was caused by traumatic brain injury. Participants were split into three groups based on the severity of their injury. The researchers found that more than half the total participants, 56%, had some form of olfactory damage, while 44.2% of the mild traumatic brain injury group had olfactory impairment (Callahan & Hinkebein, 2002). It is important to note that severity of impairment was related to injury severity as was the person's awareness of his impairment. Interestingly, 23.3% of the MTBI participants who had olfactory dysfunction were not aware of it (Callahan & Hinkebein, 2002). If almost a quarter of the participants who had been diagnosed with MTBI had no idea that they had olfactory deficits, how many more people in the general population might not even know that a common head injury could result in such profound symptoms?

The purpose of this research is to determine the relationship between olfactory damage and concussion, or MTBI, that exists in the general population, and whether the population is aware of either MTBI or olfactory deficiencies. The hypothesis of this study is that olfactory dysfunction will be present in a significant number of participants who have experienced concussion, and that participants will not be aware

of this olfactory deficit if it exists. Therefore, this study seeks to understand the extent to which damage occurs, but also the extent to which this damage is perceived.

Method

Participants

Seventy-seven participants were voluntarily recruited from the University of Tennessee at Chattanooga. They ranged in age from 18 to 55 ($M = 22.14$, $SD = 4.801$). Although most were under 25 (89 %) there were five participants between 25 and 29 years (6.5 %), and three participants were 30 years or older (3.9%). The distribution of male and female participants was slightly uneven, with 40.3 % male and 59.7 % female. Participants were recruited from upper level psychology courses, graduate physical therapy classes, and a fraternity house. The majority of participants were in their 4th year or more, in college (67.5%). Freshman made up 16.9 % of the sample, sophomores 3.9%, and juniors 11.7%. All participants agreed to and signed a letter of consent to participate, and all individual results on both the questionnaire and the UPSIT were completely anonymous.

Materials

Each participant was given a self-report questionnaire to assess past history of concussion. The Think First Concussion Questionnaire was developed in Canada for experimental research and to assist sports trainers and coaches to better diagnose past concussions (Delaney & Johnston, 2004). This Delaney & Johnston (2004) questionnaire consists of 20 questions, 5 of which ask about past sports involvement and 15 of which ask about past concussions and concussion symptoms (see Appendix

A). An example of the type of questions asked is “In the past few years after being hit in the head playing sports did you ever experience a concussion?” If the participant answered “yes”, he was asked to complete the following information:

“a) List the number of times you had a concussion while playing sports in the past few years.

b) List the longest duration you experienced symptoms from a concussion in the last few years.

c) List the longest time you were not allowed to play sports because of a concussion in the past few years.

d) Please indicate who usually told you that you were unable to play sports because of a concussion.” (Delaney & Johnston, 2004).

Questions were also added to the end of the questionnaire to obtain demographic information about participants who completed the survey. There were also questions added to assess whether participants were aware of any symptoms of smell loss related to a concussive injury. Because this research hopes to explore injuries in the larger population of college students most of whom are non-athletes, all participants were told to answer all the questions in the survey about any injury they had incurred, even if it was not sports related. Thus if a person had a concussion as a result of a car accident, or any other activity, they were to answer each symptom question about that injury. This was done so that accurate information was gathered about all concussive injuries, not only those related to sports.

The University of Pennsylvania Smell Identification Test (UPSIT) was used to assess true olfactory ability in participants. The UPSIT is a scratch and sniff test consisting of four booklets with ten microencapsulated scents in each booklet (Doty et al., 1984). Norms for each different scent were based on scores from over 1600 people who participated in experiments conducted by the test creators (Doty et al., 1984). Along with the four-part scratch and sniff test, a table was created to interpret results based on individual age and gender differences, which makes scoring easy enough for almost anyone to administer the test (Doty et al., 1984). For financial reasons, only 35 UPSIT test could be ordered. Since it has also been shown that the UPSIT has a high level of internal consistency reliability, and that individual sections of the test can be used to determine olfactory ability with almost as much accuracy as the whole test, participants were given only half the test (Doty, Newhouse, & Azzalina, 1985).

Procedure

Testing occurred in two steps. Most participants completed both parts of the experiment during one session, though, for information gathered in classrooms, time constraints forced the procedure to be completed over two class periods occurring within the same week. Students completed the questionnaire on the first day of testing and then completed the UPSIT on the second day of testing. This led to some dropouts who completed the questionnaire and did not complete the UPSIT.

First, participants were given the concussion questionnaire which asks them to self-report past injuries. The questionnaires each had a different number printed on

them for identification purposes. Along with the questionnaire, each person was given an index card with the same number that appeared on his or her questionnaire and a line on which students were asked to write down their student ID numbers. This index card was not used to identify participants, but was used for those participants who could not complete both tests on the same day. When participants returned to take the UPSIT, their card was handed back to them so they could write the number, which was the same as the number on the questionnaire (not the student ID) on their individual UPSIT. This was done so that participants' questionnaires could be matched with their UPSIT results without using personally identifying information. Participants were allowed to keep or dispose of the index cards themselves.

Second, the participants were asked to complete a portion of the UPSIT to accurately determine actual smell ability. Each participant was given two randomly selected booklets of the test, either books 1&2, books 1&3, books 1&4, books 2&3, books 2&4, or books 3&4. This randomization allowed for an accurate counterbalance of results within the sample. They were also given a pencil which was used to scratch off the scents and told to answer each question, even if they could not smell anything.

Scoring

Participants were put into groups based on the results of the Think First Concussion Questionnaire. Those who had a history of recent concussion or concussion symptoms were put into the experimental group, while those who had no

history of concussion were put into a control group. A small group of participants who had a history of concussion, but it was more than five years prior, were put into a third group. The UPSIT results of those who had a concussion were compared with those who did not, and those who had a concussion in the more distant past.

Scoring for the UPSIT was done using the key and table provided in the Smell Identification Test Administration Manual (Doty, 1995). There were two tables used for scoring, one for males and one for females, both of which established normal scores for specific age ranges (Doty, 1995). However, because the table was set up for scoring of the complete 40 item test and this experiment used only a 20 item test, each participant's score was multiplied by two to determine where he or she fell on the table. Thus if a 20-year-old male had a score of 17 on the UPSIT, he would have been given a score of 34 ($17 \times 2 = 34$) and would have fallen into the 6th percentile, or mild microsmia category, for his age and gender (see Appendix B).

Participants' UPSIT scores were matched with their questionnaire scores and put into SPSS to be analyzed. Answers to each question on the questionnaire as well as UPSIT scores were used to determine the relationship between concussion in the general population and olfactory function.

Results

Participants were put into one of three groups based on their answers to the self-report questionnaire. Those who had no history of concussion or concussion symptoms were put in the no concussion, or control, group and those who had a history of recent concussion or significant concussion symptoms were put into the

concussion, or experimental, group. All others who had a history of concussion, but it was in the distant past (more than five years), were put into the group concussion in childhood. The third group was added to help account for the confounding variables of time since injury, and age at which the injury occurred.

Of the 37 participants who were put into one of the concussion groups (concussion group or concussion in childhood group), 21% were not aware that they had experienced a concussion. This was determined based on answers to the concussion questionnaire symptom review. Although they may not have answered “yes” to the question “Have you had a concussion?” they did have significant symptoms of a concussion that resulted from MTBI. Thus almost a quarter of the concussive injuries were not diagnosed or treated by a medical professional. When asked, in the questionnaire, if they had ever experienced problems with their sense of smell, only 6 participants (7.8 %) were aware of any type of smell dysfunction after a concussive injury.

Two out of four UPSIT booklets were randomly given to 65 of the original 77 participants. All booklet pairs were evenly distributed. The results do not indicate a significant difference in scores related to which booklets the participants received. Results were scored using a master key and percentile values were given to each raw score based on male and female norms represented in two tables provided in the administration manual (Doty, 1995) (see Appendix B). It was found that raw UPSIT scores were significantly correlated with UPSIT percentile scores at the .01 (2-tailed) level, with a Pearson product correlation coefficient of $r = .698$ ($N = 65$).

All participants did relatively poorly, based on the percentile rankings given to each UPSIT raw score (see Figure 1). Most participants scored in the 1st percentile (31.3%). Other common percentile scores were the 6th percentile (15.6%) and the 29th percentile (17.2%). Only 12.5% of participants scored above the 50th percentile ranking. Participants who participated in the questionnaire but did not take the UPSIT are represented as missing (16.9%) (See Table 1).

Figure 1

Percentile Scores on UPSIT

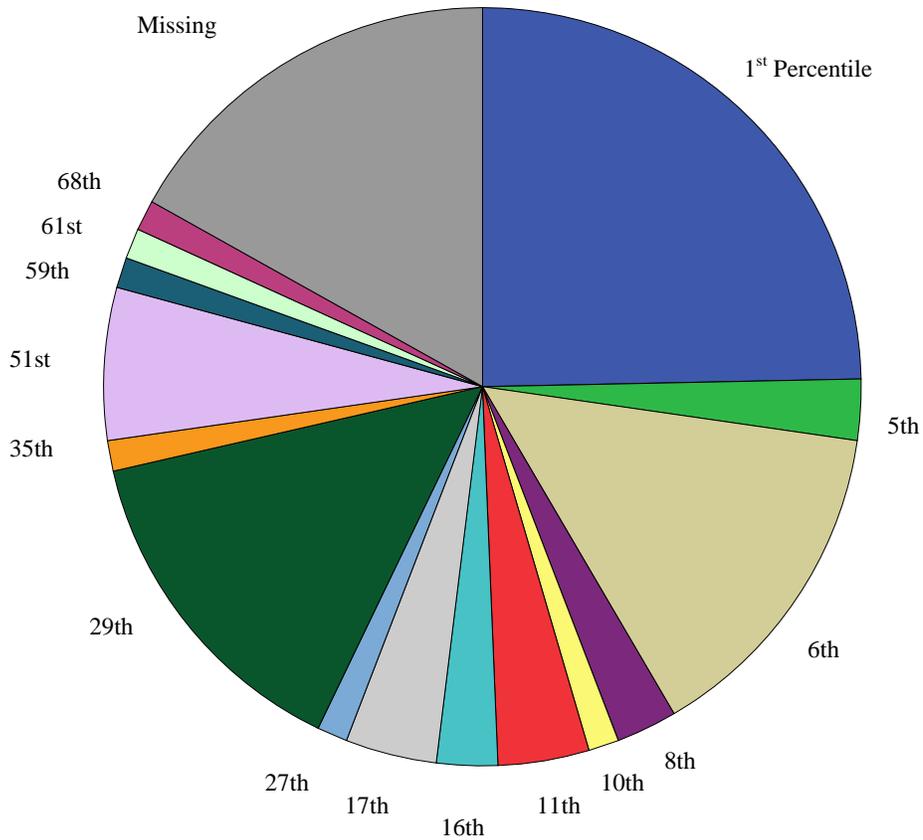


Table 1**Percentile Score Frequencies**

<i>Percentile Scores</i>	<i>Frequency</i>	<i>Percent of Participants</i>
1	20	26
5	2	2.6
6	10	13
8	2	2.6
10	1	1.3
11	3	3.9
16	2	2.6
17	3	3.9
27	1	1.3
29	11	14.3
35	1	1.3
51	5	6.5
59	1	1.3
61	1	1.3
68	1	1.3
Missing	13	16.9
Total	77	100

Category classifications were given to each participant based on their individual percentile score to determine the severity of smell loss (See Appendix B). The categories included: normosmia, mild microsmia, moderate microsmia, severe microsmia, anosmia, and probable malingering. Based on these classifications, the only participants to score in the severe microsmia grouping, severe smell loss, ($n = 2$) and the anosmia grouping, complete smell loss, ($n = 2$) had at least one recent concussion. Most of the participants who had no history of concussion fell into the normosmia grouping, normal smell function, ($n = 15$). None of the participants that experienced a concussion in childhood ($n = 6$) scored below the mild microsmia level, a small amount of smell loss (See Table 2).

A similar relationship is also present when analyzing UPSIT raw score data. The only participants to score below 14 out of 20 had suffered at least one recent concussion. All of the participants from the group who experienced a concussion in childhood scored at least 16 out of 20. Overall, 53.8% of participants scored between 17 and 19 out of 20.

A one-way analysis of variance test (ANOVA) showed that there was a significant difference between the mean UPSIT scores of each group at the .05 level; thus the variability is likely not due to chance (see Table 3). A positive relationship exists between the groups and their UPSIT scores. The Pearson product moment correlation coefficient $r = .314$ describes this relationship, and is also significant at the .05 level ($n = 65$). The variance within groups can be best understood visually (See Figure 2).

Table 2

Diagnosis Classifications by Group

<i>Group</i>	<i>Normosmia</i>	<i>Mild Microsmia</i>	<i>Moderate Microsmia</i>	<i>Severe Microsmia</i>	<i>Anosmia</i>	Total
Concussion	8	9	4	2	2	25
No Concussion	15	12	7	0	0	34
Concussion in Childhood	3	3	0	0	0	6
Total	26	24	11	2	2	65

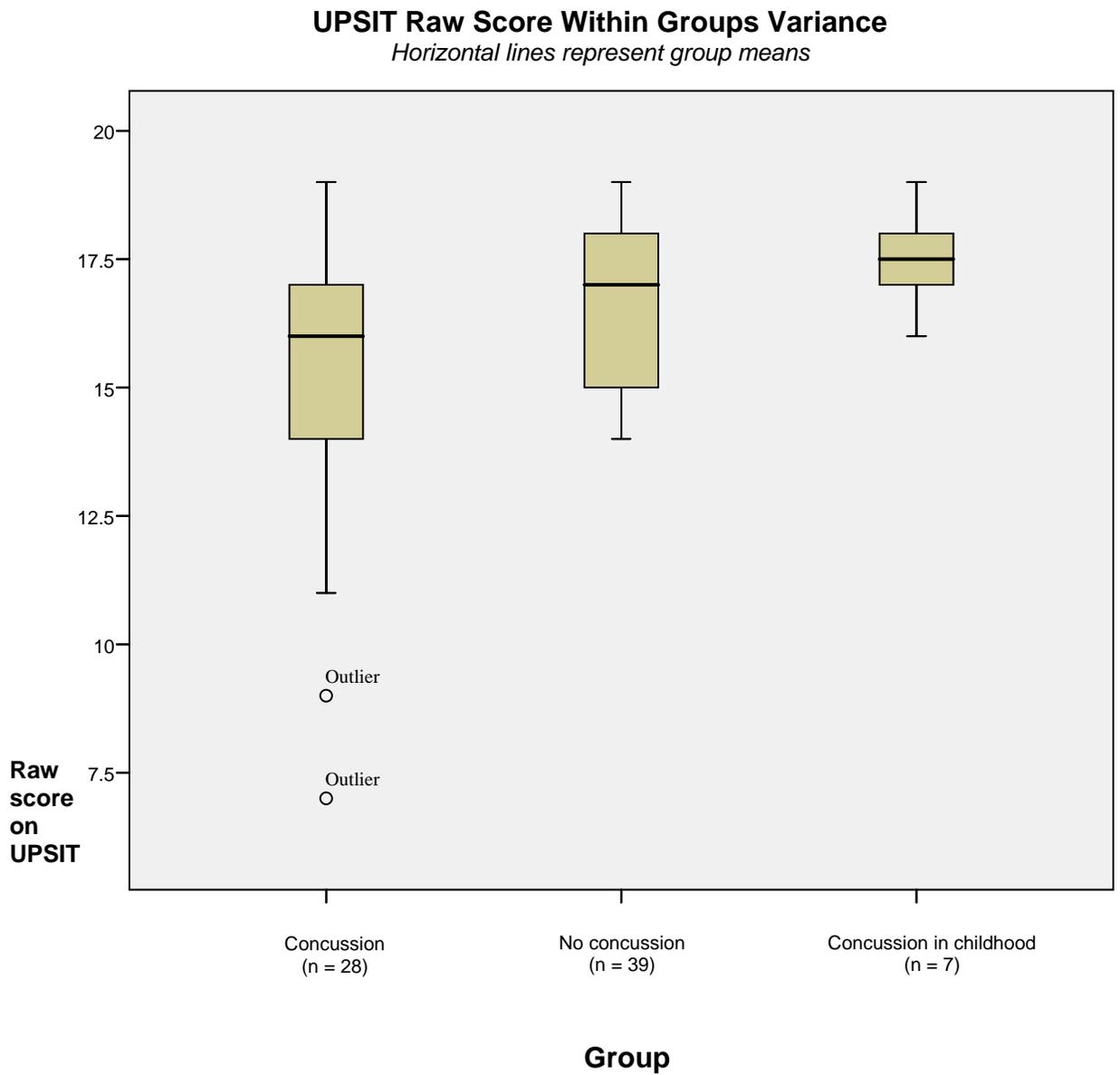
Table 3

Analysis of Variance for UPSIT Raw Scores

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Between Groups	35.360	2	17.680	3.483*	.037
Within Groups	314.701	62	5.076		
Total	350.062	64			

*p < .05

Figure 2



Headaches were the most commonly reported symptom experienced by participants. In fact, almost half of participants (49.4%) had headaches after a blow to the head. The second most common symptom was confusion, or having your bell

rung (45.5%) of participants experienced this after a blow to the head. Yet, there was no significant correlation between confusion and UPSIT scores. Dizziness and balance problems after a blow to the head were the fourth most common symptom (35.1%) following closely behind being knocked out or knocked unconscious (36.4%). Only 14.3% of participants experienced hearing problems after a blow to the head, yet this symptom correlated significantly higher with UPSIT scores than dizziness or being knocked out. Other less common symptoms include hearing problems, memory problems, blurred or abnormal vision, and nausea.

Pearson product-moment correlations were found to be significant at the .01 level (2-tailed) for some symptoms when compared to raw UPSIT scores. Significant symptoms included the number of headaches after a blow to the head ($r = -.375$, $N = 65$) and number of hearing problems after a blow to the head ($r = -.328$, $n = 65$). Some Pearson correlations were also found to be significant at the .05 level (2-tailed). This included number of dizzy spells or balance problems after a blow to the head ($r = -.306$, $n = 65$) and the number of times knocked out or knocked unconscious after a blow to the head ($r = -.249$, $n = 65$). The number of times a specific symptom was present could be a significant indicator of smell dysfunction. Although not all the participants were willing to report whether they smoked cigarettes or not, it was found that smokers did significantly worse on the UPSIT at a .05 level ($r = -.262$, $n = 59$).

Discussion

The focus of this research was to draw the attention of other researchers to the area of smell perception as it is related to a specific common injury, the concussion. A concussion is the most commonly diagnosed form of MTBI in the world, and if medical professionals are not identifying and treating all the symptoms correctly, they are leaving a lot of patients open to significant dangers. Smell loss should be assessed when patients are treated for any brain injury no matter how seemingly mild it is.

According to the results of this project, the original hypothesis asserted was supported. The participants who were in the concussion group did significantly worse on the UPSIT than did the participants in the no concussion group, or the concussion in childhood group. It is quite obvious that concussion does have an impact on smell function, since those who had an injury scored lower. However, not all who had a concussion scored low and none of those who had a childhood injury scored much lower than normal. Thus it seems that if the smell dysfunction is caused by a concussive injury, sensation may return after a certain period of time. This may explain why some participants who had a concussion did relatively well on the UPSIT. The third group (concussion in childhood) was created to help control for this phenomenon. But, since the amount of time necessary for regeneration of smell function is not known, there needs to be more research done to support this argument.

If the olfactory nerves are able to regenerate after such an injury, it is important for scientists to investigate how this occurs. It is commonly known that

central nervous system nerves do not regenerate; however, if smell is returning to some of these concussed individuals perhaps there is some central nervous system healing happening. Further research should investigate if people who had a concussion in childhood recover more fully because their brains are not fully developed before the injury.

It is perhaps equally as interesting to note that many of the “normal” control participants, who were put into the no concussion group, did very poorly on the UPSIT. There were 34 participants in this group who took the UPSIT. Of those, 20% scored in the moderate microsmia percentile range, and 35% scored in the mild microsmia percentile range. There must be something that has caused such significant smell loss in apparently healthy, young college students. It seems that smoking may explain some of these differences, since there was a significant correlation between smoking and lower scores. However, I do not believe the behavior of smoking is pervasive enough in college students to cause such extreme scores for so many individuals. In the last twenty years there has been more information available about the harmful effects of smoking, thus fewer people pick up the habit.

It is possible that such dysfunction is an indicator of the way in which humans have evolved to use our senses. Perhaps the sense of smell is no longer as important in the perception of the environment. There may even be genetic factors involved in smell function from birth that prevent some people from ever having a normal sense of smell. It is impossible to say whether these theories of why such deficiencies exist

are legitimate unless scientists begin to investigate this phenomenon more fully. In fact, this sample may not be generalizable at all.

This experiment was conducted in downtown Chattanooga, a city that has had many problems with pollution. In the past thirty years the city has worked hard to improve the problems, and has in many ways succeeded in becoming a sustainable, thriving community. What was once called the dirtiest city in America by the EPA has become a hot spot for tourists using electric-powered buses (Cryderman, 2001).

However, the lasting effects of harmful pollutants are still unknown. It is known that inhaling pollutants in the air, organic and inorganic, can cause damage to the olfactory system (Bisesi & Rubin, 1994). But most of the participants in this study were born after many of the improvements had taken place in the city. A more recent study that looked at over 300,000 births in the Northeast found that exposure to air pollution, even if it was not at high levels, during pregnancy can lead to low birth weights (Barry, 2007). This shows that air quality can affect an unborn fetus; it does not prove any specific effects on the olfactory system, but the possibility exists. Perhaps the dysfunctions in smell perception would be adaptive in a city that was as dirty as Chattanooga once was. Again, this has not been proven, and is another example of where further research is needed.

The second part of the hypothesis was that very few people would be aware that they had any smell dysfunction. This was supported by this project, since only 6 out of all 77 participants had any perception of smell dysfunction at any time, and yet, the greatest number of participants that took the UPSIT fell into the 1st percentile

ranking. Less than half of all the participants who took the UPSIT scored in the normosmia range of percentile scores. This is clear evidence of perceptual problems, whether in the nasal passage or in the brain. Wherever the problem stems from, most of these students have no idea that their smell function is not in the normal range of functioning for their age and gender.

In fact, nearly a quarter of all the concussed participants were not aware that their injury was a concussion, and were not treated by a doctor. This can be extremely risky when dealing with a brain injury, because you cannot simply look and see where the major injury lies. It is important for young people, especially those who participate in contact sports, to be aware of the dangers of untreated injuries. Perhaps the answer to this problem is to provide better information about the symptoms of a concussion, so that people will be more likely to identify a concussion themselves, and so seek out medical attention. Smell dysfunction may be a side effect that is not noticed until other problems are discovered, but it could be a significant indicator of concussion severity, or the location of the injury in the brain.

Medical professionals and athletic trainers who are highly involved with people who are prone to concussive injuries, such as athletes, need to be aware of the impact such injuries may have to olfactory functioning. This may mean that a new definition is needed that includes smell loss as a symptom of MTBI. Doctors who treat patients with concussions need to start screening for smell loss as an indicator of damage to important parts of the brain that control many different functions. Coaches need to be aware that players who are still experiencing smell dysfunction, even

weeks after a concussion, may be more at risk for dangerous brain injuries and even death if they are allowed to play and receive another compounding injury.

This research indicates significant disabilities in the average population. However, there is no baseline for individual ability on which to base each person's deficiency. There is a need for screening to be done for smell function as systematically as it is done for hearing and sight. The only way professionals can truly measure loss is to know the pre-injury smell function of each individual. It is possible that further research in this area could reveal an ability to re-learn how to smell. Thus, we could train individuals to use their sense of smell more reliably, whether they have a deficiency or not.

It is imperative that scientists begin to study this sensitive sensation more carefully and extensively. There is less research done on the sense of smell than any other human sense. Perhaps we, as humans, need to start appreciating our nose more before we start losing functioning. If any one of us lost even a fraction of our eye sight or our hearing, we would at once be aware of the deficit. However, most people do not even perceive any difference when they lose some of their smell function. Why is this? Scientists need to stop ignoring this important sense and begin investigating its disappearance in seemingly healthy individuals. Concussion may help explain some of the loss that is evident in this research, but it by no means explains everything.

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Appendix A

Questionnaire A1

Concussion Questionnaire

Thank you for participating in this study. This questionnaire consists of questions developed by myself and the Think First Concussion Questionnaire, developed in Canada for student athletes. You do not need to be an athlete to participate in this study. Some of the questions in this questionnaire will include references to sports related injuries. Whether you are an athlete or not, please answer the questions as honestly as possible. If you had an injury that was not sports related please answer the questions about that injury.

1. Please indicate your sex. Male _____ Female _____

2. Please indicate your age. _____

3. Please indicate your year in school. _____

4. In the past few years, after being hit in the head, have you ever experienced an inability to smell?

YES _____ NO _____

If YES:

a) List the number of times you experienced an inability to smell after being hit, in the past few years. _____

b) List the number of times that you experienced a concussion with an inability to smell after being hit, in the past few years. _____

c) List the longest duration you experienced an inability to smell after being hit, in the past few years. _____

5. In the past few years, after being hit in the head, have you ever experienced a weakening of your sense of smell? This might include an inability to smell as well as others and/or the loss of some but not all smell sensation.

YES _____ NO _____

If YES:

a) List the number of times you experienced a weakened sense of smell after being hit, in the past few years. _____

b) List the number of times that you experienced a concussion with a weakened sense of smell after being hit, in the past few years. _____

c) List the longest duration you experienced a weakened sense of smell after being hit, in the past few years. _____

6. In the past few years, after being hit in the head, have you ever experienced changes in the way things smell? This might mean that you can still smell but the scents do not smell like they used to before the injury.

YES _____

NO _____

If YES:

a) List the number of times you experienced a change in scents after being hit, in the past few years. _____

b) List the number of times that you experienced a concussion with changes in scents after being hit, in the last few years. _____

c) List the longest duration you experience changes in scents after being hit, in the last few years. _____



ThinkFirst Concussion Questionnaire

J.Scott Delaney, MD and Karen M. Johnston, MD, Ph.D

on behalf of the

ThinkFirst-SportSmart Concussion Education and Awareness Committee



*Members of the College of Family Physicians of Canada
may claim Mainpro-M2 credits for this unaccredited educational program.*

<i>GENERAL HISTORY</i>		
1. How do you currently reside?	a) Alone b) With spouse/ relatives	c) Roommate (s) d) Other: _____
2. At what age did you start playing organized sports?		
3. How many of the following activities do you presently participate in? (<i>Circle your response - may circle more than one answer</i>)	a) Boxing b) Martial arts (judo/karate) c) Wrestling d) Football e) Ice hockey f) Basketball g) Rugby h) Soccer i) Equestrian j) Snowboarding k) Skiing	l) Inline skating m) Mountain biking n) Gymnastics o) Cheerleading p) Trampoline q) Diving r) Motorcycle or automobile racing s) Skydiving t) Mountain climbing u) Other sports: _____ ** Main sport currently is: _____
4. For those activities in which you are actively participating, please indicate those activities in which you usually wear a helmet or head protection ? (<i>Circle your response - may circle more than one answer</i>)	a) Boxing b) Martial arts (judo/karate) c) Wrestling d) Football e) Ice hockey f) Basketball g) Rugby h) Soccer i) Equestrian j) Snowboarding k) Skiing	l) Inline skating m) Mountain biking n) Gymnastics o) Cheerleading p) Trampoline q) Diving r) Motorcycle or automobile racing s) Skydiving t) Mountain climbing u) Other sports: _____
5. For those activities in which you are actively participating, please indicate those activities in which you usually wear a mouthguard ?	<u>List Activities</u>	
a) Which type of mouthguard do you usually wear while participating in sports? (<i>Circle your response - may circle only one answer</i>)	i) stock type (no molding to teeth needed before use) ii) boil and bite (molds to teeth after immersion in boiling water) iii) custom made type that covers front teeth mainly custom made type that covers all teeth including back teeth (molars)	

SYMPTOM HISTORY		
Questions 6-15: Refer to symptoms from <u>all</u> sports and activities played in the LAST FEW YEARS		
<p><u>Note:</u> A - "After being hit in the head playing sports" refers to any contact with your head; either from another player, yourself, the ground or another object (ex. goal posts, ball, puck, stick, etc.) that may have occurred while playing sports or during another athletic activity.</p> <p>B - Duration of symptoms for the following questions can be listed in number of seconds, minutes, hours, days, weeks, etc.</p>		
6. In the past few years, after being hit in the head playing sports, did you ever suffer a concussion ?	YES _____	NO _____
<p>If YES:</p> <p>a) List the number of times you had a concussion while playing sports in the past few years: _____</p> <p>b) List the longest duration you experienced symptoms from a concussion in the past few years: _____</p> <p>c) List the longest duration you were unable to play sports (had to "sit out") because of a concussion in the past few years: _____</p> <p>d) Please indicate who usually told you that you were unable to play sports because of your concussions (ex. trainer, nurse, doctor, parent, decided yourself, etc.): _____</p>		
7. In the past few years, after being hit in the head playing sports, were you ever " knocked out " or knocked unconscious ?	YES _____	NO _____
<p>If YES:</p> <p>a) List the number of times you were knocked unconscious in the past few years: _____</p> <p>b) List the number of times that you experienced a concussion that included being knocked unconscious in the past few years: _____</p> <p>c) List the longest duration you were knocked unconscious in the past few years: _____</p> <p>d) List the longest duration you were unable to play sports (had to "sit out") after being knocked unconscious in the past few years: _____</p>		
8. In the past few years, after being hit in the head playing sports, did you ever feel confused for a period of time? This feeling is sometimes referred to as getting " dinged " or having your " bell rung ". You may have felt lightheaded, not remembered the play, not known where you were, etc.	YES _____	NO _____
<p>If YES:</p> <p>a) List the number of times you were "dinged" in the past few years: _____</p> <p>b) List the number of times that you experienced a concussion with confusion in the past few years: _____</p> <p>c) List the longest duration you felt confused after being "dinged" in the past few years: _____</p> <p>d) List the longest duration you were unable to play sports (had to "sit out") after being "dinged" in the past few years: _____</p>		

9. In the past few years, after being hit in the head playing sports, did you ever experience headaches ?	YES _____	NO _____
If YES : a) List the number of times you experienced headaches after being hit in the past few years: _____ b) List the number of times that you experienced a concussion with headaches after being hit in the past few years: _____ c) List the longest duration you experienced headaches after being hit in the past few years: _____ d) List the longest duration you were unable to play sports because of these headaches in the past few years: _____		
10. In the past few years, after being hit in the head playing sports, did you ever experience dizziness or balance problems ?	YES _____	NO _____
If YES : a) List the number of times you experienced dizziness or balance problems after being hit in the last few years: _____ b) List the number of times that you experienced a concussion with dizziness after being hit in the last few years: _____ c) List the longest duration you experienced dizziness after being hit in the last few years: _____ d) List the longest duration you were unable to play sports because of dizziness after being hit in the last few years: _____		
11. In the past few years, after being hit in the head playing sports, did you ever have memory difficulties (difficulty remembering things) after you were hit? This may have included not being able to remember the plays that were called, forgetting where you were, forgetting the score, etc.	YES _____	NO _____
If YES : a) List the number of times you experienced memory difficulties after you were hit in the last few years: _____ b) List the number of times that you experienced a concussion with memory difficulties after being hit in the last few years: _____ c) List the longest duration you experienced memory difficulties after being hit in the last few years: _____ d) List the longest duration you were unable to play sports because of memory difficulties after being hit in the last few years: _____		

<p>12. In the past few years, after being hit in the head playing sports, did you ever experience blurred or abnormal vision? This may have included a feeling of having tunnel vision, having difficulty focusing on objects, seeing abnormal colours, etc.</p>	<p>YES _____</p>	<p>NO _____</p>
<p>If YES, explain what kind of vision changes occurred:</p> <p>_____</p> <p>_____</p>		
<p>If YES:</p> <p>a) List the number of times you experienced blurred or abnormal vision after you were hit in the last few years: _____</p> <p>b) List the number of times that you experienced a concussion with blurred or abnormal vision after being hit in the last few years: _____</p> <p>c) List the longest duration you experienced blurred or abnormal vision after being hit in the last few years: _____</p> <p>d) List the longest duration you were unable to play sports because of blurred or abnormal vision after being hit in the last few years: _____</p>		
<p>13. In the past few years, after being hit in the head playing sports, did you ever experience nausea (feeling sick to your stomach or wanting to vomit)?</p>	<p>YES _____</p>	<p>NO _____</p>
<p>If YES:</p> <p>a) List the number of times you experienced nausea after being hit in the last few years: _____</p> <p>b) List the number of times that you experienced a concussion with nausea after being hit in the last few years: _____</p> <p>c) List the longest duration you experienced nausea after being hit in the last few years: _____</p> <p>d) List the longest duration you were unable to play sports because of nausea after being hit in the last few years: _____</p>		
<p>14. In the past few years, after being hit in the head playing sports, did you ever experience hearing problems (including ringing in the ears)?</p>	<p>YES _____</p>	<p>NO _____</p>
<p>If YES:</p> <p>a) List the number of times you experienced hearing problems after being hit in the last few years: _____</p> <p>b) List the number of times that you experienced a concussion with hearing problems after being hit in the last few years: _____</p> <p>c) List the longest duration you experienced hearing problems after being hit in the last few years: _____</p> <p>d) List the longest duration you were unable to play sports because of hearing problems after being hit in the last few years: _____</p>		

15. Are there any other symptoms you experienced in the last few years after being hit in the head playing sports? These may have included inability to tolerate bright lights, irritability or emotional changes, slurred speech, etc.	YES _____	NO _____
If YES, explain what kind of symptoms occurred: _____		
<p>If YES:</p> <p>a) List the number of times you experienced these symptoms after being hit in the last few years: _____</p> <p>b) List the number of times that you experienced a concussion with these symptoms after being hit in the last few years: _____</p> <p>c) List the longest duration you experienced these symptoms after being hit in the last few years: _____</p> <p>c) List the longest duration you were unable to play sports because of these symptoms after being hit in the last few years: _____</p>		

SYMPTOM HISTORY

Questions 16-19: Refer to your PAST EXPERIENCE (as far back as you can remember):

Note :

Duration of symptoms for the following questions can be listed in number of seconds, minutes, hours, days, weeks, etc.

16. In your lifetime, after being hit in the head during sports or an athletic activity, have you ever been told that you have had a concussion?	YES _____	NO _____
<p>If YES:</p> <p>a) List how many times you had a concussion: _____</p> <p>b) List the longest duration that you had symptoms from a concussion: _____</p> <p>c) List the longest duration you were unable to participate in sports or activities because of a concussion: _____</p> <p>d) Who usually told you that you had a concussion: (Please check one) Trainer _____ Nurse _____ Doctor _____ Parent _____ Yourself _____ Other (explain) _____</p>		
17. In your lifetime, after being hit in the head during sports or an athletic activity, have you ever been "knocked out" or knocked unconscious?	YES _____	NO _____
<p>If YES,</p> <p>a) List how many times you were knocked out: _____</p> <p>b) List the longest duration that you were knocked out: _____</p> <p>c) List the longest duration you were unable to participate in sports because you were knocked out: _____</p>		

<p>18. In your lifetime have you ever had any concussions that did not occur during sports or an athletic activity? These may have happened during an accident in the car or at home, after a fall, during an assault or a fight, etc.</p>	<p>YES _____</p>	<p>NO _____</p>
<p>If YES, please explain how these occurred and how old you were:</p> <p>_____</p> <p>_____</p>		
<p>If YES:</p> <p>a) List how many times you had a concussion: _____</p> <p>b) List the longest duration that you had symptoms from a concussion: _____</p> <p>c) List the longest duration you were unable to participate in sports or activities because of a concussion: _____</p> <p>d) Who <i>usually</i> told you that you had a concussion: <i>(Please check one)</i> Trainer _____ Nurse _____ Doctor _____ Parent _____ Yourself _____ Other (explain) _____</p>		
<p>19. In your lifetime, after being hit in the head that did not occur during sports or an athletic activity, have you ever been "knocked out" or knocked unconscious? This may have occurred after being hit in the head during an accident in the car or at home, after a fall, during an assault or a fight, etc.</p>	<p>YES _____</p>	<p>NO _____</p>
<p>If YES, please explain how often this occurred, how old you were, what happened, and how long your symptoms lasted.</p> <p>_____</p> <p>_____</p> <p>_____</p>		
<p>If YES,</p> <p>a) List how many times you were knocked out: _____</p> <p>b) List the longest duration that you were knocked out: _____</p> <p>c) List the longest duration you were unable to participate in sports because you were knocked out: _____</p>		
<p>20. Concussions may occur not only with a hit to the head but also a hit to the body (ex body check in hockey, "whiplash"). Did you ever experience any of the symptoms mentioned in this form after a hit to the body? If so, when and which symptoms?</p> <p>_____</p> <p>_____</p> <p>_____</p> <p>_____</p>		

Appendix B

Table B1

MALE NORMS: PERCENTILE VALUES

Age of Examinee

	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	≥85
40	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
39	98	94	77	90	89	85	87	91	90	95	93	97	97	99	99	99	99
38	94	81	59	68	73	70	64	75	70	89	82	92	93	95	98	99	99
37	93	71	44	50	54	53	50	53	58	73	70	78	83	90	95	99	99
36	90	59	35	31	37	37	36	43	49	60	56	66	71	83	87	99	95
35	83	52	26	22	23	25	27	26	31	41	42	56	64	77	74	97	95
34	80	44	17	16	15	18	19	21	22	33	33	47	54	74	65	93	89
33	78	32	11	14	10	11	12	17	15	30	27	34	44	66	53	85	66
32	69	28	08	11	07	10	09	13	11	21	23	26	44	62	44	78	84
31	63	19	06	07	05	08	06	11	10	19	23	22	41	58	35	71	81
30	59	15	05	06		07	05	08	10	18	23	21	36	52	35	65	81
29	49	12		05		05		06	07	14	19	15	31	48	34	63	75
28	45	10						06	07	14	19	15	31	48	34	63	75
27	36	05						06	07	14	19	15	31	48	34	63	75
26	34							06	07	14	19	15	31	48	34	63	75
25	29							06	07	14	19	15	31	48	34	63	75
24	25							06	07	14	19	15	31	48	34	63	75
23	23							06	07	14	19	15	31	48	34	63	75
22	21							06	07	14	19	15	31	48	34	63	75
21	17							06	07	14	19	15	31	48	34	63	75
20	17							06	07	14	19	15	31	48	34	63	75
19	15							06	07	14	19	15	31	48	34	63	75
18	10							06	07	14	19	15	31	48	34	63	75
17	06							06	07	14	19	15	31	48	34	63	75
16	05							06	07	14	19	15	31	48	34	63	75
15								06	07	14	19	15	31	48	34	63	75
14								06	07	14	19	15	31	48	34	63	75
13								06	07	14	19	15	31	48	34	63	75
12								06	07	14	19	15	31	48	34	63	75
11								06	07	14	19	15	31	48	34	63	75
10								06	07	14	19	15	31	48	34	63	75
9								06	07	14	19	15	31	48	34	63	75
8								06	07	14	19	15	31	48	34	63	75
7								06	07	14	19	15	31	48	34	63	75
6								06	07	14	19	15	31	48	34	63	75
5								06	07	14	19	15	31	48	34	63	75
4								06	07	14	19	15	31	48	34	63	75
3								06	07	14	19	15	31	48	34	63	75
2								06	07	14	19	15	31	48	34	63	75
1								06	07	14	19	15	31	48	34	63	75
0								06	07	14	19	15	31	48	34	63	75
N =	126	145	197	148	186	160	129	103	81	80	73	68	59	77	62	68	57

Test Score

NORMAL SMELL

MILD MICROSMIA

MODERATE MICROSMIA

SEVERE MICROSMIA

ANOSMIA

PROBABLE MALINGERING

Table B2

FEMALE NORMS: PERCENTILE VALUES

Age of Examinee

	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	≥ 85
40	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
39	98	96	82	79	88	80	82	84	87	89	89	95	97	98	99	99	99
38	94	74	60	51	61	57	59	60	70	85	73	80	88	91	96	98	99
37	92	57	40	32	40	37	42	39	49	69	51	66	76	86	87	94	98
36	84	42	23	29	27	21	28	26	22	44	34	53	66	77	81	92	95
35	71	31	14	07	16	16	18	17	16	33	28	36	59	70	73	89	92
34	64	23	09	06	09	11	10	15	06	25	23	29	44	63	69	85	90
33	58	16	07	05	05	07	05	11	06	17	18	21	39	55	57	80	86
32	51	10	06			05		10	05	14	14	18	30	44	50	76	86
31	42	07	05					07	09	13	15	26	39	49	69	82	82
30	39	06						05		06	13	14	19	34	42	66	76
29	35	05								05	13	13	18	29	38	62	72
28	31										10	10	16	24	37	60	68
27	30										10	09	16	21	34	54	65
26	24										10	06	15	17	31	46	62
25	23											06	14	17	23	49	59
24	20												11	19	41	57	67
23	17													16	28	38	49
22	16													05	18	24	33
21	15													05	14	21	31
20	14													05	11	21	26
19	11														10	13	23
18	10														05	09	16
17	08															09	16
16	08															09	11
15	06															07	09
14	05															05	08
13																05	04
12																05	03
11																05	02
10																05	01
9																05	00
8																05	00
7																05	00
6																05	00
5																05	00
4																05	00
3																05	00
2																05	00
1																05	00
0																05	00
N =	132	134	212	232	213	174	153	92	90	81	79	80	88	87	77	87	98

MILD MICROSMIA
MODERATE MICROSMIA
SEVERE MICROSMIA
ANOSMIA
PROBABLE MALINGERING