Adolescent Concussions

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ABSTRACT—*Background:* The amount of literature dealing with the diagnosis and treatment of adolescent concussions is considerable. Most articles focus on the athlete. This study examines both sports-related and nonsports-related concussions in adolescents, their etiology, mechanisms of injury (categorized by sport), symptoms exhibited, physical findings, computerized tomography scan results and the problem of prolonged recovery (persistent postconcussion syndrome used in this article to mean symptoms lasting over four weeks.)

***Objective:* The purpose of this study is to present the data, their significance and a new method of management that has successfully allowed the author's concussed patients to recover more rapidly.**

***Method:* A retrospective review of 863 adolescent concussions, in 11-year-old to 19-year-old patients, from July 2004 through December 31, 2008. Subjects were seen as a result of referrals largely from the author's practice (Pediatric Healthcare Associates), other physicians, athletic trainers or patients previously treated. All concussions, including nonsports-related concussions, were included in the study. Some patients had multiple concussions; 774 individuals accounted for the 863 concussions. The number of patients by age and the number of concussions they sustained are listed below.**

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Table 1.—Breakdown of Patients by Age

(Only patients aged 11 to 19 years of age were included)

Age	Number of Patients
11	23
12	70
13	89
14	158
15	168
16	169
17	119
18	44
19	23

Table 2.—Percentage of Patients x Number of Concussions

Number of patients	Number of Concussion	Percentage
546	1 concussion	(70.5%)
56	2 concussions	(20.2%)
46	3 concussions	(5.9%)
17	4 concussions	(2.2%)
5	5 concussions	(.06%)
3	6 concussions	(.04%)
1	8 concussions	

Table 3.—Nonsports Concussions (Number of patients)

	(13% of male concussions n=70)	(32% of female concussions n=106)
Fall	21	32
Fight	8	4
Hit by object	27	41
Motor Vehicle Accident	14	29

Table 4.—Multiple Concussions by Sport

Sport	Multiple Concussions	Total Concussions	Percent
Football	70	182	38.5%
Rugby	6	18	33.3%
Hockey	20	62	32.3%
Basketball	15	51	29.4%
Soccer	36	125	28.8%
Baseball	3	14	21.4%
Cheerleading	4	30	13.3%

Males accounted for 62.6%, females, 37.4%. In males, sports injuries accounted for 87% of concussions (non-sports-related concussions accounted for only 13% of injuries). This is in contrast to females, in which 68% of concussions occurred in sports activities and the rest were nonsports related. The breakdown of nonsports-related injuries are as shown in Table 3.

Loss of Consciousness and Amnesia

Loss of consciousness in 209 patients (24.2%)

Retrograde amnesia in 238 patients (27.6%) with 37 having amnesia lasting more than one hour

Post-traumatic amnesia in 239 patients (27.7%) with 50 having amnesia lasting more than one hour

Mechanism of Injury

The mechanism of the injury to the head was evaluated in each sport. Comparison between males and females is shown in the same or similar sports. In instances where the mechanism was unknown they were denoted as such. (H-H = Head-to-head or Helmet-to-helmet)

Male Sports		Female Sports	
Baseball	**14 (3%)**	**Softball**	**12 (5.5%)**
Baseball	7	Softball	7
Body part	4	Body part	3
Ground	2	H-H	2
Bat	1		
Basketball	**30 (6.4%)**	**Basketball**	**21 (9.7%)**
Body part	12	Floor	12
Floor	11	Body part	7
H-H	2	Wall	2
Ball	2		
Wall	2		
Object	1		
Football	**180 (38.3%)**	**Cheerleading**	**30 (13.8%)**
H-H	101	Body part	21
Ground	38	Ground	8
Body part	15	Unknown	1
Wall	2		
Ball	1		
Unknown	23		
Hockey	**44 (9.4%)**	**Hockey**	**17 (7.8%)**
Boards	19	Ice	15
Ice	12	Boards	1
Body part	4	Stick	1
Stick	4		
H-H	1		
Body part	3		
Goal post	1		
Puck	1		
Unknown	2		

Male Sports		Female Sports	
Lacrosse	**55 (11.7%)**	**Lacrosse**	**12 (5.5%)**
H-H	22	Stick	10
Ground	13	Ball	1
Stick	7	Ground	1
Body part	7		
Ball	1		
Unknown	5		
Soccer	**54 (11.5%)**	**Soccer**	**71 (32.7%)**
Body part	17	Ball	23
Ball	13	Ground	17
H-H	10	H-H	16
Ground	8	Body part	10
Goal post	1	Goal post	1
Unknown	5		
Rugby	**17 (3.6%)**	**Field Hockey**	**10 (4.6%)**
Body part	8	Ball	3
Ground	5	Stick	3
H-H	2	Body part	2
Unknown	2	Ground	1
Wrestling	**20 (4.3%)**	**Gymnastics**	**7 (3.2%)**
Ground (mat)	14	Ground	3
Body part	2	Own body part	2
H-H	2	Unknown	2
Hit object or wall	2		
		Volleyball	5 (2.3%)
		Ball	3
		Ground	2

Table 5.—Sports Concussions
(Number of patients)

Male Sports Concussions n=470		Female Sports Concussions n=217	
Football	181 (38.5%)	Soccer	71 (32.7%)
Lacrosse	55 (11.7%)	Cheerleading	30 (13.8%)
Soccer	54 (11.5%)	Basketball	21 (9.7%)
Hockey	44 (9.4%)	Ice Hockey	17 (7.8%)
Basketball	30 (6.4%)	Winter Sports	15 (6.9%)
Winter sports	26 (5.5%)	Lacrosse	12 (5.5%)
Wresting	20 (4.3%)	Softball	12 (5.5%)
Rugby	17 (3.6%)	Field Hockey	10 (4.6%)
Baseball	14 (3.0%)	Gymnastics	7 (3.2%)
Biking	14 (3.0%)	Horseback	5 (2.3%)
		Volleyball	5 (2.3%)

Continued to Play in Same Game

Three hundred twenty-six athletes continued to play in the same game after sustaining an injury.

Multiple Blows to the Head

One hundred nine athletes sustained more than one blow to the head in the same game and 35 (32%) developed persistent postconcussion syndrome (PPCS) [Table 6].

Second Blow to the Head within Two Weeks of Concussion

Thirty-seven athletes sustained a second blow to the head within two weeks of the first blow while they were still experiencing symptoms from the first concussion. No cases of second impact syndrome occurred.

Twenty-five were males and 13 developed PPCS (52%)

Twelve were females and eight developed PPCS (67%)

Significant Symptoms in Concussion Patients

Headaches:

Headache was the most common symptom reported by concussed patients. Headaches initially were present on awakening and were described as "dull and achy" but became throbbing with cognitive or physical exertion, light or noise. Only two patients in this study did not report headaches but reported lightheadedness as their main concussion symptom.

Tiredness (Sleep Problems):

Many patients felt tired and wanted to sleep during the first 24–48 hours with the need for more sleep persisting for several days. During the second or third week many patients in this study had difficulty falling asleep and required the use of Melatonin.

Feeling "Foggy and Slowed Down":

This symptom appeared to be difficult for patients to understand or describe. Some reported that they felt as if they were "a dial-up connection instead of a broad band" (DSL) connection to the internet or that their "brain was functioning like a computer infected with a virus." Patients who did not report this symptom after the concussion usually recovered rapidly. This symptom usually resolved one to two days before the headache disappeared and served as an indicator of when patients would recover.

Lightheadedness and Nausea:

Some patients confused lightheadedness with dizziness. They said that they felt lightheaded during positional changes (not present prior to the concussion) or when the headache became severe. Both lightheadedness

Table 6.—Multiple Hits to the head by Sport:

Sport	Multiple Hits	Total Concussions	Percent
Basketball	9	51	17.6%
Soccer	16	125	12.8%
Football	21	182	11.5%
Cheerleading	3	30	10.0%
Hockey	6	62	9.7%
Baseball	1	14	7.1%
Rugby	1	18	5.6%

and nausea occurred when the headache increased after physical or cognitive over-exertion (reading, computer use, text-messaging, etc.).

Dizziness:

This symptom was rare and only two patients studied presented with dizziness. It is important to distinguish dizziness from lightheadedness due to the possibility that the patient sustained cochlear damage which may require vestibular rehabilitation therapy. Spinning movements need to be avoided

Two patients reported that their symptoms worsened after riding on spinning carnival rides and two patients had a marked increase in symptoms after having chiropractic adjustments to their necks.

Balance Problems:

Initially some patients had difficulty with gait (ataxia) or experienced balance problems. They reported that their "balance was off" and some were unsteady and bumped into objects in their path. This symptom usually resolved fairly quickly in most patients.

Light and Noise Sensitivity:

Light, whether from sunlight, bright fluorescent light or from car headlights at night often caused the headache to increase. This was seen with injuries involving the back of the head. Some patients' headaches intensified when exposed to excessive noise at home, school or in movie theaters.

Concentration and Memory Loss:

After their concussions, many patients were unable to read a paragraph or page of text without an increase in the severity of their headaches. Computer use for even five to 10 minutes markedly increased headaches. Cognitive concentration increased concussion symptoms and patients reported having trouble focusing. Some patients could not remember what was said a few minutes before, could not select the correct word to use in conversation, or lost track of what they were saying in the middle of a sentence. Some had difficulty remembering where they put things.

No Symptoms:

Two patients with loss of consciousness reported no symptoms following their concussions and took two to three weeks to recover as determined by ImPACT (neurocognitive) testing.

Significant Physicial Findings in Concussion Patients

Horizontal nystagmus occurred in 41 (33 male) or 0.048% of patients.

Balance problems were found in 172 (101 male) or 19.9% of patients.

Rapid lateral eye/head movements resulting in the complaint of lightheadedness was initially evaluated in 2008 and was found in 133 of the 295 patients seen (45%). This finding usually did not resolve until the patient was almost fully recovered. This is the most common positive physical finding in this series of concussion patients and the last to resolve.

Neck symptoms and findings (trapezius muscle spasm and tenderness, loss of range of motion and an occasional positive Spurling's sign) were present in some patients but were not included in this study. (Any patient sustaining a concussion should be evaluated for a neck injury.)

Computerized Tomography Scans Performed on the Head

Two hundred seventy-one CT scans of the head were performed on the patients evaluated in this study (31.4% of the patients) and all were normal (Two CT scans showed a neck injury). These CT scans were performed prior to being seen in the author's office, usually in the Emergency Room of a hospital.

Persistent Postconcussion Syndrome

This is the term used to describe patients in this study who experienced concussion symptoms lasting longer than four weeks. The length of time that patients took to recover was calculated based on the cessation of symptoms and return to normal as shown by the results of the ImPACT test. The four-week designation could not be measured exactly since patients were seen every seven to 10 days. Only patients who clearly took more than four weeks to recover were included in this group of persistent postconcussion syndrome.

The persistent postconcussion syndrome **(**PPCS) patient's symptoms can usually be divided into four categories with some overlap. Several patients required more than one year to recover from their concussions. The categories and their associated symptoms are shown in Fig. 1.

In this study 211 patients (24.4%) developed persistent postconcussion syndrome. This percentage may show a slight selection bias since some patients were referred by other physicians or friends because they were not recovering from their concussions. Most patients fell into either the somatic symptoms or the cognitive symptoms category.

Somatic Symptoms:

Of the somatic symptoms, the most common was headache. The medications that have traditionally been used to treat this group of patients generally include amitriptyline (Elavil), Topamax and Inderal.

Forty-eight patients needed medication to control their headaches and 44 were given Elavil only, three had Elavil and subsequently Topamax, and one patient was given Topamax only. Patients usually responded well to low doses of Elavil (amitriptyline), beginning with 10 mg at bedtime and gradually increasing the amount every few days in 10 mg increments. Electrocardiograms (EKG) were not performed on patients taking Elavil since the dosage used was well below the therapeutic dose used to treat depression. The four patients receiving Topamax, did not have an improvement of their headaches, and no patients received any beta-blockers such as Inderal.

Cognitive Symptoms:

This group had difficulty with concentration and memory. They usually responded well to the use of attention deficit disorder (ADD) medication. Fifty-three patients required medication. Eight patients in this group were previously diagnosed with ADD and were already taking medication at the time of their concussion. Of the rest, 20 were treated with Adderall, eight were given Vyvanse, two Strattera, one Concerta and one Focalin. In the early part of the study, Adderall was used, but in the past two years Vyvanse has been used as the initial drug of choice because it has fewer side effects and a longer action time. A small subset of 13 patients, who described themselves as "feeling like they are in a cloud" were given Amantadine, five of these patients were subsequently switched to an ADD medication as the Amantadine treatment was unsuccessful.

Sleep Disturbance:

Some patients required the use of Melatonin to help them fall asleep. If, after three to four weeks, headaches were associated with difficulty in falling asleep, Elavil was started to remedy this problem. Trazodone, which can be used for this problem was not used in any patients in this study.

Emotionality:

No patients required drug or psychiatric treatment for symptoms in this group although some patients were on psychiatric medications prior to their recovery which they continued to take.

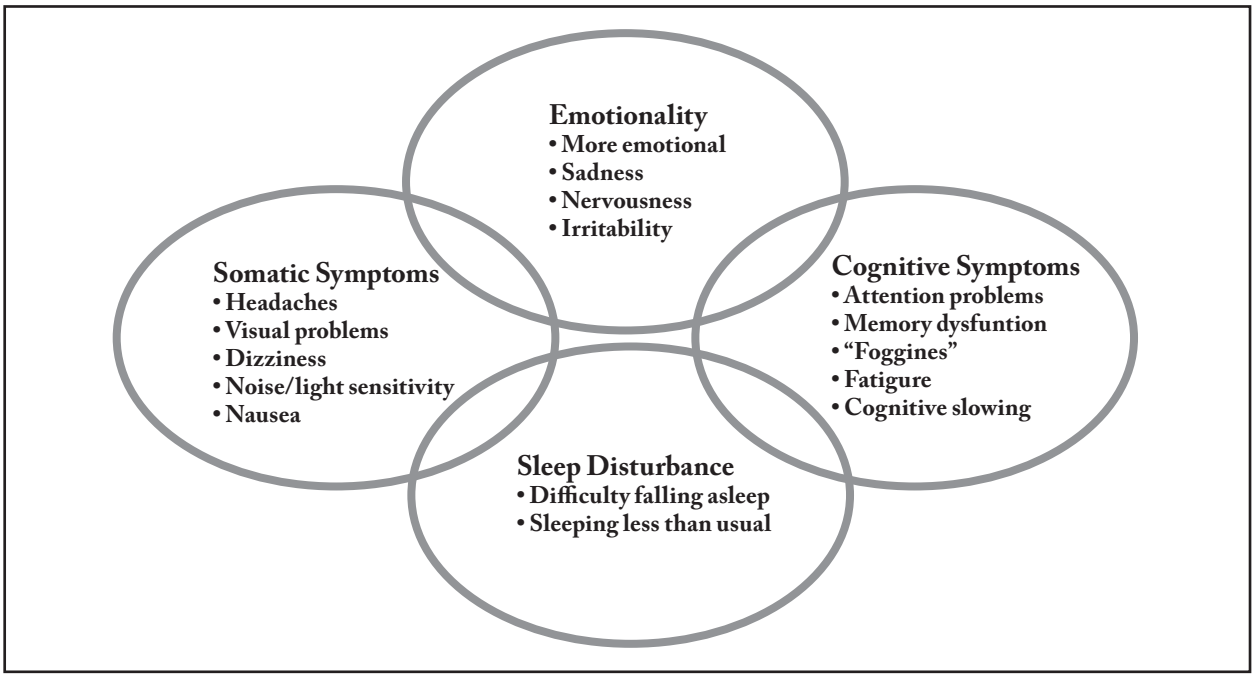
Statistical Data Analysis for Persistent Postconcussion Syndrome—Overall Summary

Several statistical tests were conducted to determine significant effects in the development of PPCS and the overall recovery time.

Of the 864 patients 208 patients developed PPCS for an overall rate of 24%. This gave a 95% confidence interval for the development of PPCS as 21.2% to 26.8%. There were no statistically significant differences between males and females.

The only significant factor affecting the development of PPCS (and also on overall recovery time) was multiple hits. There were 108 incidences of multiple hits and 36 developed PPCS for a rate of 33%. For those patients with only single hits there was a PPCS development rate of 23%. This difference was significant with a *P*-value of

Figure 1.—Post-Concussion Syndrome Scale (Pardini, et al, 2004)



.01. The conclusion is that the development of PPCS is higher among those patients with multiple hits. There was no difference in the PPCS rate between those who had amnesia and those who continued to play and those who did not. (Of course, there could not be multiple hits if they did not continue to play.)

The Effect of Continuing to Play on the Development of PPCS Rate:

Two hundred eight patients developed PPCS. Three hundred twenty-six continued to play. Seventy-seven of the patients who continued to play developed PPCS while 131 of those who did not continue to play developed PPCS.

The PPCS Rate for the Continuing to Play group was 77/326 = .24 = 24%

The PPCS Rate for the Not Continuing Play group was 131/538 = .24 = 24%

A difference of proportions test was conducted to compare these two rates. At a 5% level the difference in rate was not significant. The conclusion is that the rate of development of PPCS is the same whether patients continue to play or not.

There were differences (not statistically significant) across sports. Hockey had the highest PPCS rate of 35% while football had only 22%. This was, however, not significant with a *P*-value of .06.

The overall average recovery time was 5.4 weeks with a standard deviation of 9.4 weeks (due to the presence of some large outliers). This produced an overall 95% confidence interval for recovery time of 4.8 weeks to 6.0 weeks. This included both those who developed PPCS and those who did not. For patients who did not develop PPCS the average recovery time was 2.4 weeks with a standard deviation of 1.2 weeks. This produced an overall 95% confidence interval for recovery time of 2.3 weeks to 2.5 weeks.

The only significant factor affecting overall recovery time was also multiple hits. For those patients with multiple hits the average recovery time was 6.9 weeks with a standard deviation of 8.2 weeks while for those patients without multiple hits the average recovery time was 5.2 weeks with a standard deviation of 9.6 weeks. This difference was significant with a *P*-value of under .01 indicating that patients with multiple hits had longer overall recovery time. There were no differences in developing PPCS between males and females or if they continued to play after their injury.

There was a 5% rate of ADD symptoms above those already diagnosed. Of the 863 patients 52 were treated for ADD symptoms. Of these, nine were previously diagnosed with ADD. Hence, 43 patients developed ADD symptoms post concussion trauma. This rate of 5% was very statistically significant (*P*-value <.001) indicating a higher rate of ADD symptoms post trauma.

Discussion

The majority of the patients in this study were high school students. Boys had an almost two to one ratio for sustaining concussions when compared to girls. Girls tended to have more concussions from nonsports related activities than boys. Concussions caused by motor vehicle accidents were more frequent in girls. This may possibly be due to the fact that females have weaker neck muscles than males and their concussions were due to whiplash injuries.

Since boy's sports may involve more physical contact than girls' sports, more male concussions were caused by a body part striking the head than were seen in girls. Almost all the lacrosse injuries seen in girls were caused by a blow from a lacrosse stick to the head. This raises the question of whether girls playing lacrosse should be wearing protective headgear as do boys. The rise in the number of cheerleading concussion injuries indicates the need for measures such as decreasing the height of pyramids in order to prevent these injuries. Approximately 50% of the deaths in women's college sports occur from cheerleading injuries according to NCAA data.[1] The slightly higher rate of PPCS in ice hockey players may support the prohibition of checking in youth ice hockey.

While headache is the symptom that is most associated with a concussion, the symptom of fogginess (feeling hazy, vague and slowed down) is the most significant in determining how rapidly one will recover from a concussion. In the author's experience, if this symptom is not present or disappears rapidly, the concussed patient will recover rapidly, often within a week or less. Fogginess may resolve suddenly on awakening or resolve more gradually. The headache usually will disappear one or two days after the fogginess resolves.

The majority of patients in this study had headaches that were usually dull and achy on awakening and became throbbing with any physical or cognitive activities, light or noise. It is important to prevent the headaches from becoming throbbing. Throbbing headaches signaled the onset of worsening symptoms (lightheadedness, nausea, fogginess and inability to concentrate). To prevent this, it is suggested that initially students not attend school, do no cognitive exercise or physical exertion. Sunglasses should be worn if photophobia is present and noise should be kept to a minimum. Patients in this study appeared to recover more rapidly if they slept in a darkened room as much as possible for the first day or two after the concussion.

The most helpful physical finding in assessing concussions was lightheadedness with rapid lateral eye or head

movements. If this was present the patient was still not recovered.

No CT scans of the head were positive in any patients who sustained a concussion. This finding would indicate that CT scans are not needed unless one is concerned that the patient may have a bleed. Some patients with PPCS had subsequent MRIs. The only positive MRIs in patients included in this group were two patients with brain cysts and occasional sinus disease that appeared to be unrelated to the injury.

There was no statistical difference between males and females for developing PPCS. Multiple blows to the head, occurring either initially or within two weeks of the initial injury, indicated patients who would have a more protracted recovery and would be more likely to develop PPCS. This was statistically significant. Amnesia (brief or greater than one hour) and continuing to play were not statistically significant for causing PPCS. There were no cases of Second Impact Syndrome in the 37 patients who had the potential for this to occur indicating that this syndrome may be a more random occurrence than previously described in the literature.

Persistent postconcussion syndrome patients with headaches responded well to amitriptiline (Elavil) in low doses. Many patients with no previous history of attention-deficit hyperactivity disorder (ADHD) developed ADHD symptoms after their concussions and responded well to treatment with medications typically used to treat ADHD patients. While eight patients in this group had symptoms of ADHD prior to their concussions and were taking ADHD medication, the rest of the patients had no ADHD symptoms before their injury. This raises the possibility that concussions may have a causal relationship with ADHD in some patients. (A recent article by Kubetin[2] noted that among youths 12 to 17 years of age, ADHD increased annually by 4% a year from 1997–2006 while the rate remained the same for younger children.)

The use of neuro-cognitive testing has been a major step forward in helping to manage concussions. The recent article by Dr. Collins comparing ImPACT testing with fMRI demonstrating that the ImPACT test returns to normal at the same time the fMRI becomes normal validates its use as a tool to manage concussions.[3] Normal neuro-cognitive testing plus the resolution of symptoms and abnormal physical findings are the determinant of when a concussed patient can return to normal activities and contact sports. The concussion symptoms should be resolved, the ImPACT test should be normal and the patient should be off medications before allowing an athlete to return to contact sports. (Patients with previous ADD who were on ADD medication, with no other symptoms, were allowed to return to contact sports). The concussion return-to-play exercise program may be started when the patient is symptom free and is able to attend school symptom free.

Extremely low ImPACT test composite scores (low single digits and 1st percentile or less) on all parameters of the test indicated patients that usually took longer to recover from their concussions. Decreasing serial ImPACT test scores indicated patients who were not complying with activity restrictions.

Cocoon Therapy or Cognitive Brain Rest

For the past year, the author has used the following protocol successfully for managing concussions. Patients must not attend school until they are headache (symptom) free. This protocol involves placing patients on what a colleague coined cocoon therapy immediately after the concussion. The patient should sleep in a darkened room as much as possible for the first 24 to 48 hours. Patients are willing to do this because they are usually tired after their concussion. (If no CT scan was performed, the patient may need to be checked during the first night every few hours to rule out a bleed.) The patient should not attend school, do no reading, not use the computer, and avoid video games. We recommend that that the patient not use I-pods or text messaging. Initially, the patient should not take hot tubs, socialize with friends, go to the movies, or attend team games. Any activity that causes the headache or symptoms to increase should be discontinued. Not allowing headaches to become throbbing should be the cornerstone of managing concussions. If the patient is light sensitive, sunglasses should be worn. Noise should be kept to a minimum.

After the first day or two, brief periods, initially 10 to 15 minutes, may be spent listening to books-on-tape in gradually increasing intervals and, if that is tolerated, watching TV movies (not cartoons) may be tried. Movies may be taped to be watched at 10 to 15 minute intervals initially with gradually increasing intervals subsequently. When this protocol was closely adhered to, most patients usually became headache free in four to five days. Cessation of symptoms was also achieved in patients who had symptoms for a few weeks. This protocol did not work for all patients, especially those with multiple hits to the head. If patients reported that they had lightheadedness and nausea with increasing headaches, this was an indication that they were overdoing their activities.

It was difficult to objectively evaluate the effectiveness of this procedure because of our inability to ensure that patients followed the guidelines exactly and most patients in this study were seen well after the first few days of their injury. Interestingly, athletes followed the regimen much more closely than the other concussion patients because of their strong motivation to return to

competition rapidly and because their fellow athletes reported that this method works . This strong adherence to the rules of cocoon therapy helped many patients with repeat concussions become symptom free in four to five days after taking weeks to recover from their previous concussion.

If this protocol was followed, the ImPACT test seemed to return to normal more rapidly than did the symptoms. Many patients were noted to have normal or almost normal ImPACT tests three to four days after the injury.

Return-to-School Cognitive Exercise Protocol:

On the first day no symptoms or headaches were present, patients were allowed to read and use the computer in gradually increasing increments for the 24 hours before they returned to school (in order to be sure that they would be able to tolerate attending school). They would begin by reading a page or two, take a break and then, double the amount of reading every 10 to 15 minutes. They alternated reading with using the computer (no video game play) starting initially with 10 minutes and progressively adding 10 minutes. If they had no symptoms with cognitive exercise, they then were allowed to attend school with modifications, if needed, gradually increasing the amount of time they spent at school. After they were in school full time and were symptom free for 24 hours they were then allowed to start the concussion return-to-play exercise program as recommended by the Zurich International Concussion Conference.[4] Some patients developed a recurrence of their symptoms if they exercised (especially sprinting) before they were gradually reconditioned.

Even when utilizing this gradual and measured process, some students had a recurrence of their symptoms when they first returned to school. This required a modification of their school day which was discussed in a previous article.[5]

Concussion management has changed dramatically in the last decade to a more individualized approach. While adults tend to recover more rapidly it is becoming increasingly clear that younger patients take longer to recover. Since cognitive exercise is the same as physical exercise in causing symptoms to increase, adolescents with concussions should initially curtail all activities in order to recover more rapidly and this includes not attending school. Hopefully, using the approach outlined, adolescents will recover more rapidly and sustain damage.

Suggestions for Further Study:

Prospective study validating cocoon therapy (currently in progress).

Whether neck strengthening in contact sports will decrease female concussions.

Why there is a higher PPCS rate for ice hockey (helmet, equipment, not doing checking).

A prospective study to evaluate concussions and the development of ADHD.

Final Comment:

The education of athletes participating in high school sports as to the signs, symptoms and consequences of concussions should be a top priority and the National Federation of High Schools may need to mandate that this be done.

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