Current Concepts in Concussion Rehabilitation

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Active rehabilitation of sport injuries is a concept familiar to athletes and those caring for them. Rehabilitation goals aim to optimize recovery efficiency and diminish chances of repeat injury. Rehabilitation programs take many aspects of recovery and wellness into consideration including physical, social, and psychologic components. Ultimately, this is important in the recovery process after concussion. In this article we introduce the largely unexplored concept of multidimensional concussion rehabilitation and discuss physical, psychologic, social, and sport-specific issues. As well, we propose future directions in this field.

How poor are they that have not patience! What wound did ever heal but by degrees?
William Shakespeare (Othello)

Introduction

Management of concussion injury in sport remains one of the biggest challenges faced by those caring for athletes, partly due to the high incidence and prolonged recovery period. Concussion may demand a lengthy recovery with prolonged down time and may impede many aspects of a player's life including career, sociability, family relations, professional and social relationships, and finances. Concussion largely remains the invisible injury that has no fixed timeline for recovery and, until resolved, oppresses the player with fear of the long-term consequences of the impact. That said, the concept of rehabilitation from concussion is relatively new, a surprising notion given that rehabilitation from injury plays a significant role in the life of most elite-level athletes. Of course most of what the athlete knows about rehabilitation has been learned from experience with orthopedic injury, not brain injury. In contrast, the concept of rehabilitation is familiar to those caring for brain-injured individuals, but it is applied more often after moderate or severe brain trauma rather than following mild head injury or concussion. James Garrick reminds us that there has been an evolution in the management of sports injury with "the employment of earlier and more active rehab programs" [1]. How then can we transpose that progressive thinking to concussion?

Rehabilitation Strategies

DeLisa *et al.* [2] describe six strategies to help mitigate disability from injury: 1) prevent or correct additional disability, 2) enhance systems unaffected by the pathologic condition, 3) enhance functional capacity of systems affected by the disease, 4) use adaptive equipment to promote function, 5) modify social and vocational environment, and 6) use psychologic techniques to enhance patient performance and education. We look at each of these in the context of concussion injury with the goal being to develop a sport concussion rehabilitation program.

Prevent or correct additional disability

It has long been recognized that even when the athlete is asymptomatic at rest, postconcussion symptoms may return with exertion, particularly if the athlete has been symptomatic for a prolonged period of time. The pathophysiology underlying this finding has not been elucidated; however, a clue may be gleaned from the work of Haykowsky *et al.* [3]. With resistance and Valsalva maneuvers (*eg*, biceps curl), significant elevations in intracranial pressure have been documented. This mirrors the experience of athletes who have recurrent symptoms with resistance training (many of whom associate only aerobic activity as exertion, not weight lifting). This finding of symptom aggravation with increasing levels of exertion is the basis for the graded return to activity programs currently in place (Table 1) [4•,5,6•,7]. The importance of being solidly asymptomatic prior to embarking on such a program cannot be overstated. Proactive measures must be taken at each step to ensure that the athlete's symptoms remain at bay throughout the process, not just during exertion, but also later the day of exertion, as well as the next

Table 1. Return to play protocol

The return to play following a concussion follows a stepwise process:
1. No activity, complete rest; once asymptomatic, proceed to level 2
2. Light aerobic exercise such as walking or stationary cycling
3. Sport-specifc training (*eg*, skating in hockey, running in soccer)
4. Noncontact training drills
5. Full contact training after medical clearance game play
6. Game play

(*Adapted from* the Canadian Academy of Sports Medicine [4•].)

morning. Depending on duration of symptomatic status (weeks to months) the length of this program may vary (days to weeks). For the obvious reasons described above, resistance training is added late in the protocol. Whereas an orthopedic model serves well for certain aspects of concussion rehabilitation, there is a potential trap here. An athlete is used to rehabilitating through pain, a strategy that often succeeds in orthopedic rehabilitation. However, the same strategy of pushing through pain originating from concussion (headaches, dizziness) is more likely to lead to a "one step forward, two steps backward" situation with resulting setback. From the outset, the athlete should be made aware of this clear difference (Table 1).

Enhance systems unaffected by the pathologic condition

Unlike most sport injuries, concussion has a global, diffuse effect on the athlete's function and well being. Generalized fatigue may be an important component to the symptomatology accompanied by specific sensory and neurocognitive changes. Therefore, concussion must be considered more of a systemic rather than a local problem and the value of rest, withdrawal from demanding environments, and general health advocacy measures must be emphasized. Rather than enhancing or maintaining other systems, measures to minimize activity are called for. This approach creates its own difficulties for the athlete given that physical fitness has generally been a lifelong commitment; therefore, new strategies at early levels of rehabilitation are now being explored (*eg*, yoga, pilates) in an effort to provide both ongoing fitness maintenance and a structured physical program that does not exacerbate the problem. Endeavors of this type have led to some success. Such programs must be carefully monitored and adjusted to the athlete's tolerance on an individual basis, with a high level of input from medical staff.

Enhance functional capacity of systems affected by the disease

Strategies to cope with neurocognitive effects of head injury have met with success and are well documented in the head injury literature. Similar strategies have potential value in concussion although they have not been systematically explored. Balance deficits are commonly seen in concussion and balance retraining may have a role to play in recovery [8]. Although pharmacologic management of associated headache is commonly unsuccessful, treatment of associated sleep disruption has met with some success. In general, however, the common recurring theme of improvement with rest is documented and remains the mainstay of early management.

Use of adaptive equipment to promote function

In isolated situations systems retraining (*eg*, vestibular, visual systems) may offer some advantage if that function is notably affected. Adaptive equipment may also be incorporated into the rehabilitation protocol with the use of sport-specific equipment such as a skating treadmill in hockey.

Modify social and vocational environment

Considering that interaction in a team environment is a critical dimension in the life of an athlete, this strategy deserves consideration given its potential to either benefit or further harm the athlete. Team interaction provides the social and career milieu in which the athlete develops, all the while imposing its own supports and stressors [9•]. A balance of the "pros and cons" of that environment must be weighed for each individual case. In certain circumstances it may be best for an athlete to stay with the team whereas for another, temporary return to a home environment may be the best option. Despite the team environment, the athlete needs direct access to health care givers (athletic therapists, trainers, team doctors, consultants). Such contact, in person or by phone or electronic mail, will permit regular follow-up evaluation and provide a venue for questions and concerns. Other contributing factors in the environment are related to lifestyle issues and substance use. Frank discussion is mandated to minimize the impact of such factors on concussion recovery.

Psychologic techniques to enhance patient performance and education

In our rather limited armamentarium, this strategy may be the single greatest tool currently available to help recovery. Other than rest, what else helps? Interest in this area has stemmed and developed from the observation that there is significant overlap between some symptoms of concussion and affective disorders such as depression, anxiety, irritability, insomnia, and personality change.

Depression

Our clinical observations have shown that concussed athletes often report symptoms of depression. Neuroimaging studies of patients suffering from depression of different etiologies have consistently identified metabolic abnormalities involving frontal, cingulate and temporal cortices suggesting common disruption of specific frontalstriatal and basotemporal limbic pathways. Across studies, the most robust and consistent find-

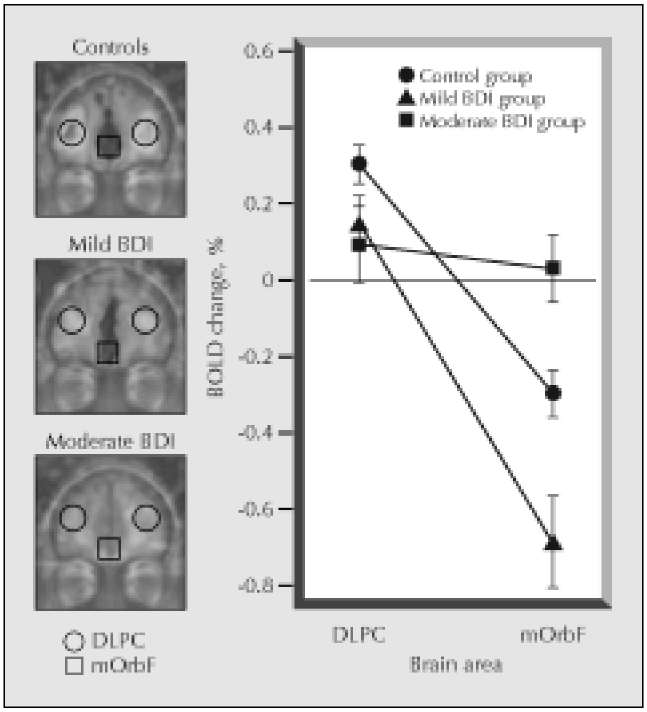


Figure 1. Percent blood oxygen level-dependent (BOLD) signal change in the dorsolateral prefrontal cortex (DLPC) and medial orbitofrontal cortex (mOrbFC) associated with a verbal working memory task for three groups: normal controls (*n* = 25), mildly depressed (*n* = 7), moderately depressed (*n* = 5). Mean behavioral results are as follows: normal control group = 73%; mildly depressed group = 80%; moderately depressed group = 76%. Irrespective of the behavioral scores, normal Beck Depression Inventory (BDI) scores obtained by control subjects correlate positively with an increase in DLPC and a decrease in mOrbFC. Concussed athletes with mild BDI scores show only a slight increase in DLPC and a marked decrease in mOrbFC. Those with moderate BDI scores show almost no activation in DLPC and no change in mOrbFC.

ing is decreased frontal lobe function, although normal as well as hyper frontal activity has also been reported [10]. Our research with concussed athletes with persistent postconcussive symptoms (PCS) who do or do not complain of symptoms of depression has yielded interesting and convergent preliminary results. Recently, we ran a study aiming to confirm our previous results [11] and to quantify with functional MRI (fMRI) changes in brain activity in concussed athletes with persistent PCS. Regional brain activations associated with a working verbal and visual memory task were acquired from a group of 12 concussed athletes and 25 matched control subjects, using blood oxygen level-dependent (BOLD) fMRI. The results obtained have confirmed that verbal and visual working memory tasks in conjunction with fMRI may be useful in identifying an underlying frontocortical dysfunction following concussion. Analysis of fMRI data revealed that the athletes as a group had weaker BOLD changes within the dorsolateral prefrontal and orbitofrontal cortices, and this observation was true for both the verbal and the visual versions of the task. With respect to depression, the athletes were administered the Beck Depression Inventory (BDI) and an analysis was run to establish whether a correlation existed between the scores obtained on the BDI and the cerebral activation patterns associated with the working memory tasks. Interestingly, those athletes who obtained normal scores or who had results consistent with only a mild depression (< 22/63; *n* = 7) showed similar patterns of activation as the control group, albeit with generally weaker percent signal changes in the regions of interest. In contrast, those athletes who had BDI scores (> 22/63; *n* = 5) suggestive of a moderate depression showed atypical patterns characterized in general by a lack of BOLD signal change in dorsolateral prefrontal as well as in medial orbitofrontal cortices (Fig. 1). Thus, these preliminary results suggest that in the presence of depression, there is a lack of activation in those frontal regions typically activated when a working memory task is being performed. Studies in this field are in their infancy and these relationships are not yet well understood. It is notable that even when some concussion symptoms of somatic origin are decreasing with recovery (headache, dizziness) others involving mood states may increase (Meeuwisse W, Leclerc S; Personal communication).

Sport psychology

Recent work with sport psychology colleagues documented early evidence that mental training techniques used for other sport injuries, and familiar to many sport medicine doctors, may have a role to play in concussion management. More specifically, Horton *et al.* [12] hypothesized that concussed athletes who participated in an athlete support intervention group would improve their psychologic state by reducing effects such as anger, confusion, frustration, anxiety, depression, and isolation (*ie*, total mood disturbance [TMD]) compared with those in a control group. These authors felt that support groups would help concussed athletes by educating them on their injury and by helping to prevent isolation while dealing with the demands of rehabilitation and at the same time not participating in their sport [13,14]. Participants in the study by Horton *et al.* [12] were elite-level athletes who sustained a concussion while participating in their sport and who showed persistent postconcussion symptoms, loss of consciousness, or post-traumatic amnesia.

The authors' hypothesis was supported as athletes in the experimental group reported lower TMD scores [12]. Interestingly, their results also indicated that simply putting subjects in a support group may have improved their psychologic state, as evidenced by better TMD scores at pretesting compared with the control group. These results need to be viewed with caution as the number of participants were small (*n* = 14) and some factors were not controlled for, including the provision of social support, trait characteristics of the athletes, past experiences, other stressors, sex, and injury severity. Nonetheless, the results of this research offer initial support for the suggestion by Bloom *et al.* [9•] about including psychologic techniques in the rehabilitation of concussed athletes. In sum, although research studies in sport psychology approaches

Table 2. Postconcussion symptoms scale

	Rating						
Symptom	**None**			**Moderate**			**Severe**
Headache	0	1	2	3	4	5	6
Nausea	0	1	2	3	4	5	6
Confusion/disorientation	0	1	2	3	4	5	6
Difficulty recalling incident	0	1	2	3	4	5	6
Emesis	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Fatigue	0	1	2	3	4	5	6
Trouble falling asleep	0	1	2	3	4	5	6
Sleeping more than usual	0	1	2	3	4	5	6
Drowsiness	0	1	2	3	4	5	6
Sensitivity to light/noise	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Increased sadness	0	1	2	3	4	5	6
Nervousness	0	1	2	3	4	5	6
Numbness or tingling	0	1	2	3	4	5	6
Feeling slowed down	0	1	2	3	4	5	6
Sensation of being “in a fog”	0	1	2	3	4	5	6
Difficulty with concentration	0	1	2	3	4	5	6
Difficulty with memory	0	1	2	3	4	5	6
Total score							

(*Adapted from* Lovell and Collins [19].)

for concussion are in their infancy, the important role of utilizing psychologic skills and strategies for performance enhancement is not [15].

Goals and Practical Application

With this knowledge base how can we practically apply these principles to improve management and rehabilitation for our athletes? Houts and Scott [16] emphasized that rehabilitation goal planning should 1) involve the patient (athlete), 2) set reasonable goals, 3) describe patient behavior when the goal is reached, 4) set a deadline (timeline), and 5) spell out method.

Use an orthopedic model and ankle injury rehabilitation as an example, Anderson [17] describes a stepwise, multiple-phase, ankle rehabilitation program using a rehabilitation checklist as a measuring tool for progress. This checklist is also an efficient means of communication between the athlete’s health care providers. Anderson emphasizes that the first phase “requires patience and rest.” Within the context of concussion, we (and the athlete) are left to wonder why an investment of 4 months to rehabilitate a high ankle sprain is considered acceptable, whereas 4 months for brain rehabilitation is considered untoward!

The concussion rehabilitation program will therefore be structured and supervised in such a way that it will incorporate the fact that postconcussion symptoms may return with exertion. The checklist will include repeated athlete documentation of the PCS scale submitted on a regular basis. It is Dr. Johnston’s experience that athletes may be more likely to admit their symptoms on a sheet of paper than to an individual. This is a valuable resource in baseline, during resting (step 1) and throughout rehabilitation. A gradual increase in activity is provided with an assurance of no symptoms recurrence and backtracking if they return (Table 2).

Sport-specific programs

Attempts to prepare sport-specific programs offer potential to maximize a particular athlete’s techniques and optimize training efficiency. Practically speaking, the athlete will be concerned with fitness loss and will benefit from reassurance that a rehabilitation plan will include help to get that fitness back. The athlete needs to be informed that the type of activity, intensity, and duration of exercise, as well as the environmental conditions where the exercise is conducted, are factors that must be monitored during the postconcussion period. Before introducing exercise, it is important to be asymptomatic. Table 3 provides guidelines to assist hockey players, trainers, coaches, and physicians in managing the return to play of the concussed athlete. The levels of exercise in the table are graded based on intensity, duration, and specificity to hockey. Each step must be completed as a single workout. A conservative approach is recommended when considering advancement to the next level. If symptoms occur either during or following exercise at a level, then the athlete needs to drop back to a level where there are no symptoms.

Table 3. Monitoring exercise progression

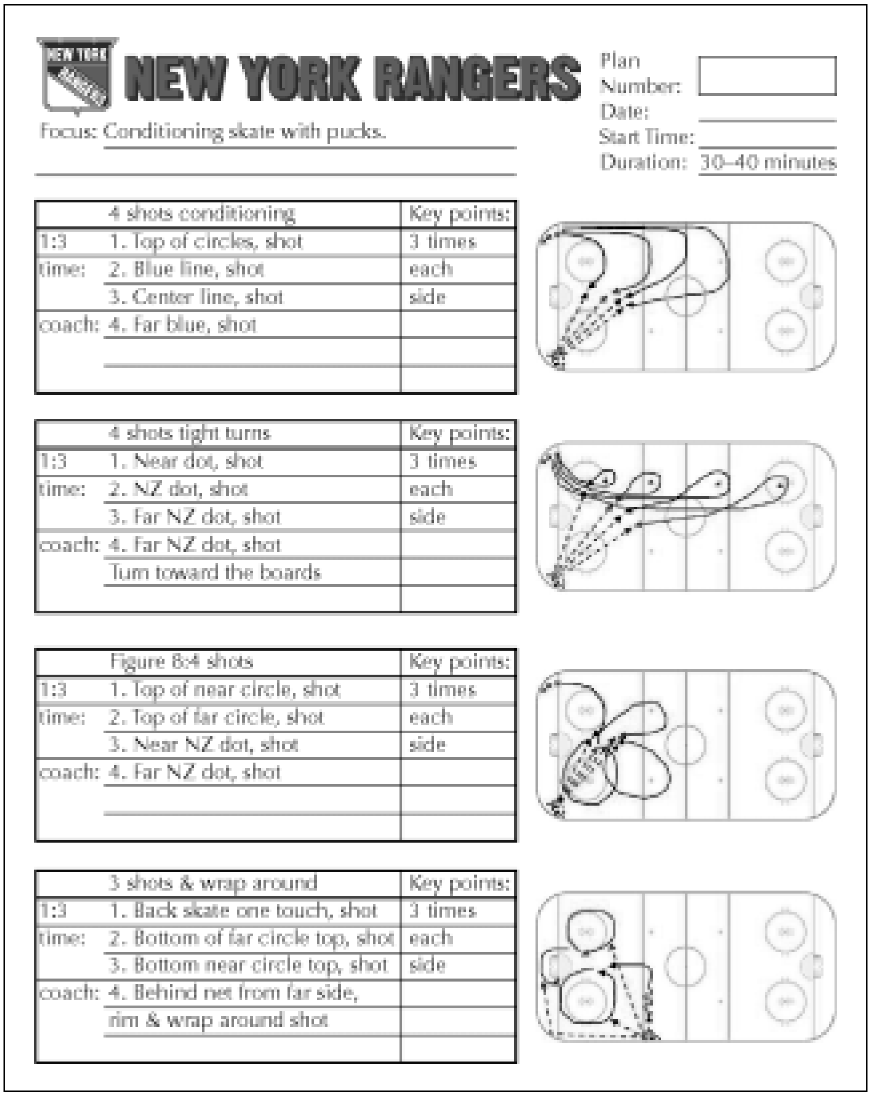
Step	Mode of exercise	Intensity, %	Duration, *min*	Symptoms during/ after/next day
1	Walking	< 50	10–15	If no symptoms, move to next level
2	Continuous aerobic	50–55	10–15	
			15–20	
			20–30	
3	Continuous aerobic, weights (low repetitions & low resistance)	60–70	20–30	
			30–40	
			40–50	
4	Treadmill skating, on-ice skating (no equipment)	60–70	30–40	
			40–50	
		70–75	40–50	
5	On-ice skating drills	70–80	30–40	
	(With equipment)		40–50	
	(No contact)		50–60	
6	On-ice skating drills	Anaerobic	60	
	(With equipment)	80–100	60	
	(No contact)		60	
7	On-ice skating drills	Anaerobic	60	
	(With equipment & contact)	80–100	60	
	(Scrimmage with contact)		60	

Training-induced physiologic adaptations depend primarily on the intensity of overload. Heart rate is a good means to monitor exercise intensity. Most players will have access to a heart rate monitor that can be used to gauge exercise stress. If the player exercises in a warm environment, the heart rate responds as a function of the environmental stress and the exercise intensity. Thus, heart rate reflects total stress, which makes it a desirable variable to monitor. If the athlete does not know his or her maximum heart rate, then use the age-predicted formula (220 minus age) to estimate the maximum heart rate. In step 2 of the program, the appropriate exercise intensity for a 20-year old would be 50% to 55% of heart rate maximum, or 100 to 110 beats/min. Examples of continuous aerobic exercise appropriate for the hockey player are fast walking, slow jogging, cycling on a stationary bicycle, and exercise machines such as an elliptical trainer, rowing ergometer, stepper, and skating treadmill. The skating treadmill offers the opportunity to monitor and control the workload while mimicking in many ways the athlete's familiar exertion pattern. When resistance exercise is added to the program, start with a low weight (about 50% of 1-repetition maximum [1RM]) and low repetitions ([reps] about 6–10 reps). If resistance exercise is included in steps 4 through 7, the progression should increase the number of reps with each exercise to about 20 reps before proceeding to increase the load. Because both intracranial and diastolic blood pressure increase during resistance exercise, take the cautious approach to avoid recurrent symptoms.

At this point, sport-specific drills are incorporated into the program. For example, in a current hockey rehabilitation paradigm developed in conjunction with the National Hockey League (NHL) New York Rangers, specific hockey drills may be used to advance through the protocol. The athlete will start on a bike or treadmill, complete control of duration, heart rate, respiratory rate, and resistance being in the hands of the medical supervisor. A skating treadmill may then be added and the athlete will progress to the ice (first in workout clothing followed by full equipment) in a conditioning skate with drills and no pucks. Although there is no difference in VO_2max with or without equipment, hockey equipment decreases speed and mechanical efficiency, all variables which need to be taken into account during rehabilitation [18]. Level 4 has the addition of pucks and shooting, thereby increasing workload in no contact flow drills (Fig. 2). Level 5 incorporates a practice situation with potential for full contact, three against three competition on half ice, and finally game play. Specific positions (*eg*, goal tender) will dictate variations on this general approach.

Similar programs may be developed incorporating maneuvers from soccer (Fig. 3, Table 4), American football, and other sports. Ideally these are developed in a collaborative effort with doctor, therapist, trainer, and coach.

In the course of the rehabilitation program, specific attention should be paid to factors that may negatively influence rehabilitation progress such as fatigue, alcohol or supplement use, previous history of overtraining, and environmental temperature control. Many a rehabilitation program has been compromised with high ambient temperature during exertion as an added stressor. Anecdotally, altitude (including airline travel) may be an aggravating contributor and further research in the area of these potential exacerbating factors is needed.



NEW YORK RANGERS

Plan Number:
Date:
Start Time:
Duration: 30–40 minutes

Focus: Conditioning skate with pucks.

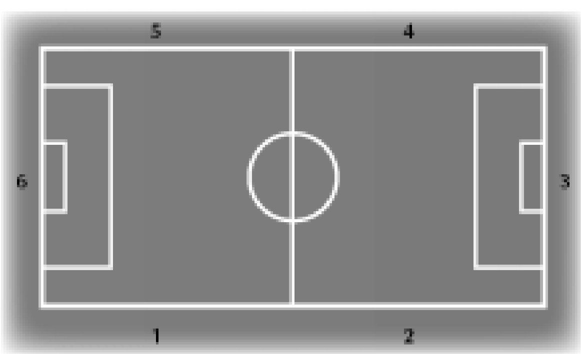
	4 shots conditioning	Key points:
1:3	1. Top of circles, shot	3 times
time:	2. Blue line, shot	each
	3. Center line, shot	side
coach:	4. Far blue, shot	

	4 shots tight turns	Key points:
1:3	1. Near dot, shot	3 times
time:	2. NZ dot, shot	each
	3. Far NZ dot, shot	side
coach:	4. Far NZ dot, shot	
	Turn toward the boards	

	Figure 8:4 shots	Key points:
1:3	1. Top of near circle, shot	3 times
time:	2. Top of far circle, shot	each
	3. Near NZ dot, shot	side
coach:	4. Far NZ dot, shot	

	3 shots & wrap around	Key points:
1:3	1. Back skate one touch, shot	3 times
time:	2. Bottom of far circle top, shot	each
	3. Bottom near circle top, shot	side
coach:	4. Behind net from far side,	
	rim & wrap around shot	

Figure 2. Progressive hockey drills corresponding to step 4 of the rehabilitation protocol. NZ—neutral zone. (Used with permission of the New York Rangers.)



Run	Walk
1	2
3-4	5
6-1-2	3
4-5-6-1	2
3-4-5-6-1	2
3-4-5-6-1-2	3

Figure 3. Soccer interval training (for protocol details see Table 4).

Symptoms may return with exertion; so what is exertion? Certainly aerobic and resistance training are exertion but the athlete may be surprised to learn that activities of daily living (*eg*, mowing the lawn, shoveling snow) may be considered exertion on a background of concussion. Physiotherapy for an associated neck injury (which may have occurred at the time of the concussion) may also represent exertion and should be carefully monitored. To reiterate, one needs to be specific with the athlete in this regard and seek out aggravating activities in the face of persistent or recurrent symptoms.

Neck and Concussion

Finally, increasingly there is an awareness that neck and concussion injury interplay with one another: 1) the neck may be injured at the time of the concussion, 2) a whiplash type of neck injury can also result in a concussion, 3) rehabilitating a neck injury can represent exertion to the point that concussion symptoms may be aggravated, and 4) neck and concussion headache symptoms may be difficult to separate. Therefore, treatment of neck symptoms may sometimes alleviate combined concussion headache

Table 4. Stepwise return to play postconcussion: soccer protocol

Step 1. Rest until asymptomatic; for entire protocol, progress to next step only if no symptoms. If symptoms recur (during activity or later) go back to previous step; if symptoms persist, return to step 1.
Step 2. Very light aerobic activity: walk or bike for 10 min, keep heart rate low (low intensity, less than 50% of maximal effort).
Step 3. Moderate aerobic activity: bike or power walk for 20 min (moderate intensity, 50%–75%).
Step 4. Running, ball drills.
1) Warm-up: 5 min.
2) Interval training: 10–15 min, per Fig. 3, protocol below (75%–85% intensity).
3) Ball work (10 min).
 a) Juggling ball, footwork (2 min).
 b) Dribbling ball, straight line (2 min).
 c) Dribbling between cones (2 min).
 d) Dribbling around cones (2 min): clockwise and counterclockwise.
 e) Dribbling with change of direction (2 min): run forward, backward, sideways.
Goalkeepers: do drills 1–4 above, 1 min dribbling ball, 1 min toss and catch ball (light toss directly in front of goalkeeper only, no neck extension (bending back); drill 5: have partner toss ball while goalkeeper catches at each pylon.
Step 5. Add speed and agility drills; could add weights at this step if desired; low weight/high repetition.
1) Warm-up (5–15 min); can be with team but no contact, no heading.
2) Speed work (5–10 min): goal line to top of 6-yd box and back; goal line to top of 18-yd box and back; goal line to half and back; goal line to opposite goal line and back; increase tempo to 75%–100% (maximum speed).
3) Agility (10–15 min): as per speed-work plan above, run backward, sideways, crossovers.
 a) Sprint out/jog back (recovery).
 b) Sprint out/sprint back.
 c) Changing from backward to sideways to crossovers on longer runs (half field and full field distances).
4) Ball work (30 min).
 a) Independent dribbling drills (as per step 4, increase speed, turns).
 b) Partner.
  i) Pass/ control: short, middle, long distance.
  ii) Shooting on goal.
Goalkeepers: ball work (30 min); no diving, jumping, or heading.
Partner throws ball center, right, left; mid, low, and high (throw instead of kick = better accuracy, softer).
Reaction drill: goalkeeper turned away from partner, turns to catch ball thrown by partner.
Throwing, punting.
Step 6. Progress to team practice, but no contact (suggest wearing different colored jersey to remind other players of precautions). No heading as part of practice drills with team, but begin heading protocol at this step.
Add: plyometrics, rolling, jumping.
Goalkeepers: add diving, jumping, shots on goal, crossing (no contact); goalkeepers should also follow heading protocol.
Heading protocol: There are four steps in the heading protocol, two at step 6, and two at step 7. Progression from one step to the next is just like overall protocol; must be asymptomatic to progress. Each step in heading protocol must take a minimum of 1 day, so must remain at step 6 for 2 days minimum, even if all nonheading activities are asymptomatic.
Heading step 1: Partner and player inside 6-yd box. Partner tosses ball softly to player; controlled, straight header, within box, perfect technique (ball off forehead, eyes open, mouth closed, neck rigid, mouthguard is suggested). Five each straight ahead, then five each slightly to left and right.
Heading step 2: Repeat step 1 to start. After an active rest period (run, ball work), partner and player inside 18-yd box. Partner tosses ball (longer distance, slightly harder), player does controlled header with perfect technique within box. Five each of straight, left, and right. If fitness not adequate, remain at this step until improved, even if asymptomatic.
Step 7. Full practice (before practice, should do heading step 3; if not able, should not progress to full practice).
Heading step 3: Should be done prepractice, following warm-up. Partner and player outside 18-yd box. Partner tosses ball from longer distance, player heads ball greater than 18 yds. Five each straight, right, and left.
Heading step 4: Full practice situation will add more dynamic heading, unpredictability.
Step 8. Game play.

symptoms. Further research is needed to explore these interactions and develop treatment plans.

Conclusions

It comes as no surprise to sport medicine professionals that efficient rehabilitation of an athletic injury optimizes the athlete's ability to recover. Using recovery strategies familiar to those of us caring for athletes in combination with general rehabilitation principles, we are exploring new ground in concussion rehabilitation. As with all other sport injuries, a comprehensive structured rehabilitation program offers advantages in concussion management and may well be the key to successful and timely return to play.

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