Concussion is a frequent injury in contact sports and especially in ice hockey where the incidence ranges from six to 17.6 concussions per 1000 player-game hours; however, the true incidence may be even higher (1-8).

There are a plethora of potential long-term consequences for athletes who sustain a concussion, including: chronic traumatic encephalopathy; second impact syndrome; long-term effects on cognition; postconcussive syndrome; depression; and slower recovery of symptoms after additional concussions (9-13).

Before 2005, rehabilitation of athletes who sustained a concussion in the Swedish Ice Hockey Elite League (SHL) included grading the concussion into three grades. Players experiencing a grade 1 concussion (“bellringer”) could return to play (RTP) the following day; for players with a grade 2 or 3 concussion, RTP was not permitted for seven and 21 days, respectively (4).

The use of the grading of concussions has since been challenged and, based on the consensus reached at the International Conferences on Concussion in Sport held in 2001 and 2004, decisions regarding RTP in the SHL have been individualized (9,14,15).

Over the past 10 years, several studies have shown that postural stability is affected for up to one month after a concussion (16-19). Moreover, return to baseline levels of neurocognitive function is not fully recovered after two weeks (17). Using ApEn, a nonlinear measure of postural control, it has been shown that postural control may be affected for a longer period of time after a concussion than previously believed (20). This may indicate that players occasionally RTP while not fully recovered in neurocognitive function, balance capability or both.

A pilot study we conducted indicated a possibly increased risk for subsequent severe traumatic injuries within three weeks after a concussion (21). For the present study, we hypothesized that when players RTP after a concussion, they are at a higher risk than usual for sustaining additional traumatic injuries.

RESULTS: Players who sustained a cerebral concussion did not have an increased risk for subsequent injuries compared with players who experienced a knee injury; however, concussed athletes experienced significantly more serious subsequent injuries (absence >28 days) within 21 days after return to play.

DISCUSSION: The authors were unable to confirm whether players who return to play following a concussion are at a higher risk for subsequent new injuries. However, a significantly increased risk for a severe subsequent injury after a concussion may exist. There may also be a possibly increased risk for subsequent injury among players who sustained >1 concussion during the study period.

CONCLUSION: The authors were unable to confirm their hypothesis; however, the possibility of a higher risk for a more serious injury following a concussion requires further study.

Key Words: Concussion; Ice hockey; Subsequent injury

METHODS

Study subjects

All players in one ice hockey club in the SHL, from the 1984/1985 season until the 2011/2012 season, were included. All participants provided written consent.

The medical records for these players were reviewed. A computerized injury registration form – the “International Sport Injury System” (ISIS) – was used (22). For the first 15 seasons, data were primarily recorded on paper and later incorporated in ISIS. Attendance records for all games and practice sessions were included. With this system, de-identified data can easily be exported to enable statistical analyses. Participation in games was recorded in all competition games and practice participation data were recorded for 23 of 24 seasons; when an athlete was absent the cause was reported.

All injuries that lead to absence or a medical intervention were recorded in ISIS by the medical team. The same team physician was responsible for the medical team during the entire study period and, consequently, was responsible for all diagnoses. Concussions were diagnosed according to the glossary from the Congress of Neurological Surgeons from the 1985/1986 season (23). Concussion was defined as a “clinical syndrome characterized by immediate and transient impairment of neural functions such as alteration of consciousness, disturbance of vision, equilibrium etc due to mechanical forces” (23). Grading and treatment of concussions, similar to the guidelines proposed by Cantu (24), were introduced in Swedish ice hockey in 1986 (4). Since 2004, the guidelines proposed by McCrory et al (14) have been used. From 1999, the Standardized Assessment of Concussion was used to clear the athletes (25). Computerized neurocognitive testing was not used.

For all injuries, data regarding activity (league game, exhibition games, play-off games, ice practice, other practices or preseason practices), situation, player’s reaction, recurring injury and diagnosis were recorded.
Within 42 days after

Period seven and zero to 21 days post-RTP. A database analysis program included in the analysis for the first two follow-up periods (zero to seven days, zero to 21 days and zero to 42 days). Analysis was also related to follow-up time, which was divided into three intervals: zero to seven days, zero to 21 days and zero to 42 days post-RTP. Some players were not available for the full follow-up time during the study period were treated separately in some of the analyses. Knee injuries were registered with only one concussion. Fifty-seven knee injuries were diagnosed as MCL injuries and the remaining 47 as knee distortions. Four knee injuries and four concussions were registered as subsequent injuries. Consequently, the analysis was based on 144 concussions in 81 individuals. Fifty of 81 players were registered with only one concussion.

Players who sustained a cerebral concussion did not suffer statistically significantly more often from subsequent injuries compared with players who experienced a knee injury (Table 1). The same was true for players who sustained >1 concussion during the study period. However, there was a tendency for more players who sustained >1 concussions to experience a subsequent injury during a game or practice within 42 days compared with those with a knee injury (49 of 85 versus 34 of 89; P=0.06).

Significantly more players with a concussion had subsequent severe injuries (>28 day absence from play) within 21 days after RTP compared with players with a knee injury (P<0.05) (Table 2). For the corresponding results of zero to seven and zero to 42 days, no significant differences were found.

TABLE 1
Subsequent injuries for concussions and knee injuries

<table>
<thead>
<tr>
<th>Period</th>
<th>Type of injury</th>
<th>Players with concussions</th>
<th>Players without concussions</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Players with subsequent injury, n</td>
<td>Players without subsequent injury, n</td>
<td></td>
</tr>
<tr>
<td>Within 7 days after</td>
<td>Concussion</td>
<td>12</td>
<td>128</td>
<td>0.17</td>
</tr>
<tr>
<td>RTP (game injuries)</td>
<td>Knee injury</td>
<td>4</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Within 21 days after</td>
<td>Concussion</td>
<td>27</td>
<td>111</td>
<td>0.55</td>
</tr>
<tr>
<td>RTP (game injuries)</td>
<td>Knee injury</td>
<td>16</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Within 42 days after</td>
<td>Concussion</td>
<td>41</td>
<td>81</td>
<td>0.28</td>
</tr>
<tr>
<td>RTP (game injuries)</td>
<td>Knee injury</td>
<td>24</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Within 7 days after</td>
<td>Concussion</td>
<td>13</td>
<td>127</td>
<td>0.12</td>
</tr>
<tr>
<td>RTP (game and practice injuries)</td>
<td>Knee injury</td>
<td>4</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Within 21 days after</td>
<td>Concussion</td>
<td>35</td>
<td>103</td>
<td>0.64</td>
</tr>
<tr>
<td>RTP (game and practice injuries)</td>
<td>Knee injury</td>
<td>22</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Within 42 days after</td>
<td>Concussion</td>
<td>56</td>
<td>66</td>
<td>0.31</td>
</tr>
<tr>
<td>RTP (game and practice injuries)</td>
<td>Knee injury</td>
<td>35</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

RTP Return to play

Validation
The first and the senior author, and an assistant validated the database independently by comparing injury protocols with attendance records, and by the first and the senior authors collectively reviewing all players’ medical records. For some games, the team line-up was missing in the records of the hockey club. For these games, the local newspapers’ archives were searched for the line-up. For the season lacking practice participation records, data were reconstructed using the injury or illness duration that was recorded in the medical records, and line-ups were reconstructed using data from the local newspapers. Consequently, all absences except for vacations were collected.

Analysis
Only new traumatic injuries were included in the study and injuries caused by chronic overuse were excluded from all analyses.

Study subjects were divided into two groups: players who sustained a cerebral concussion; and players who experienced knee injuries, diagnosed as an isolated medial collateral ligament (MCL) tear or a knee distortion (defined as a knee sprain without clinical instability). Knee injury was chosen to be the reference injury because it has been a common knee injury in previous studies. Analysis of subsequent knee injuries was based on 144 concussions in 81 individuals. Fifty of 81 players were registered with only one concussion. Fifty-seven knee injuries were diagnosed as MCL injuries and the remaining 47 as knee distortions. Four knee injuries and four concussions were registered as subsequent injuries. Consequently, the analysis was based on 144 concussions in 81 individuals. Fifty of 81 players were registered with only one concussion.

In our pilot study, a significantly increased risk for a subsequent injury after a concussion may exist. There may also be a possibly increased risk for subsequent injury among players who sustained >1 concussion during the study period. The reason for this increased risk is unclear. The rehabilitation protocol for both the concussed and knee-injured athletes was similar: initial rest followed by gradually increased exertion.

Conversely, Pellman et al (26) considered it safe for adult athletes to RTP more quickly – as soon as the same game – based on their finding that players who returned to play in the same game did not show an increased risk for subsequent or more severe concussions.

These findings have to be interpreted with great caution. Although these data regarding concussions have been collected over 28 seasons, and includes 264 players and 148 cerebral concussions in 1700 games and 6185 practices, the sample size is too small to answer our research question with certainty. This is the main limitation of the study.

One strength, on the other hand, is that due to including only one elite ice hockey club, which, unlike many other clubs, has been playing uninterrupted in the Swedish elite division since the beginning of

Statistics and ethics
The results were treated as binary (ie, injury/no injury). Statistics were calculated using SPSS version 17 (IBM Corporation, USA) using a χ² test or Fisher’s exact test.

The study was approved by the Ethics Committee in Umeå (Sweden) (Dnr 09-135M).

Study design
A prospective cohort study was conducted over several years. All patients were enrolled at the same time in the injury history.

RESULTS
A total of 264 players and 28 seasons were included in the study; 1700 games were played and 6185 practices were held. A total of 2033 injuries occurred; 316 were due to chronic physical overuse and excluded. There were 148 cerebral concussions and 104 knee injuries. Fifty-seven knee injuries were diagnosed as MCL injuries and the remaining 47 as knee distortions. Four knee injuries and four concussions were registered as subsequent injuries. Consequently, the analysis was based on 144 concussions in 81 individuals. Fifty of 81 players were registered with only one concussion.

Sixteen concussions were only available for follow-up for the first and second period (zero to seven and zero to 21 days), two for only the first period (zero to seven days) and four not at all. Seven knee injuries were only available for follow-up for the first and second period (zero to seven and zero to 21 days), one for only the first period (zero to seven days) and three not at all. Loss from follow-up was due to the season ending before the end of the follow-up period.

Players who sustained a cerebral concussion did not suffer statistically significantly more often from subsequent injuries compared with players who experienced a knee injury (Table 1). The same was true for players who sustained >1 concussion during the study period. However, there was a tendency for more players who sustained >1 concussions to experience a subsequent injury during a game or practice within 42 days compared with those with a knee injury (49 of 85 versus 34 of 89; P=0.06).

Significantly more players with a concussion had subsequent severe injuries (>28 day absence from play) within 21 days after RTP compared with players with a knee injury (P<0.05) (Table 2). For the corresponding results of zero to seven and zero to 42 days, no significant differences were found.

DISCUSSION
The present study was performed to test the hypothesis that when players RTP after a concussion they run a higher risk than usual for sustaining additional traumatic injuries; however, we were not able to confirm this. For most of our analysis, no significant differences were found compared with players returning after a knee injury.

However, as in our pilot study, a significantly increased risk for a severe subsequent injury after a concussion may exist. There may also be a possibly increased risk for subsequent injury among players who sustained >1 concussion during the study period. The reason for this increased risk is unclear. The rehabilitation protocol for both the concussed and knee-injured athletes was similar: initial rest followed by gradually increased exertion.

Conversely, Pellman et al (26) considered it safe for adult athletes to RTP more quickly – as soon as the same game – based on their finding that players who returned to play in the same game did not show an increased risk for subsequent or more severe concussions.

These findings have to be interpreted with great caution. Although these data regarding concussions have been collected over 28 seasons, and includes 264 players and 148 cerebral concussions in 1700 games and 6185 practices, the sample size is too small to answer our research question with certainty. This is the main limitation of the study.
the study period, decreases the risk for variations in diagnostic criteria, handling and data collection. Furthermore, this was reinforced by the fact that the same team physician was responsible for the club’s medical team during the entire study period. In addition, all data were cautiously validated. Moreover, the study did not include measurements of balance and neurocognitive impairment. Consequently, the cause behind an increased risk for subsequent severe injuries is not at all possible to elucidate from the present study.

The control group was chosen to include players with MCL tears and knee distortions. They had a similar time frame until RTP; a neg-
ligible risk for a concurrent undiagnosed concussion and a low risk for recurrent injury.

There are only a few previous studies examining subsequent injur-
ies after a concussion. “Australian football”-players returning to play
after a concussion had no increased risk for injury or reduced perform-
ance, measured as completions per game (27). There was, however,
a trend, although not statistically significant, that concussed players
experienced more injuries (72.5 versus 32.5 injuries per 1000 games).

In another study of soccer teams in the Champions League, an
increased risk for all types of subsequent injuries were found up to one
year after a concussion (28). We believe that this difference, compared
with our results, could be due to two important circumstances. In our
study, the diagnostic criteria were the same for all concussions over the
entire study period and the same team physician made the diagnoses.
We also only included subsequent traumatic injuries and no overuse
injuries because both the onset and the mechanism behind overuse
injuries are much more unclear compared with traumatic injuries.

Recently Pietrosimone et al (29) reported that retired National
Football League athletes with a history of concussion reported more
orthopedic injuries than those without a history of concussion (29).
Therefore, it appears that athletes with concussion can be more injury
prone. This is in accordance with another study from our group (30).

The question of whether athletes should in fact rest longer or
shorter be to be answered. Our study does not add to the evidence of
either, but may indicate a parameter that needs to be researched fur-
ther to ascertain a safe RTP protocol, namely the risk for serious new
traumatic injuries. Relying only on athletes’ symptoms for guiding
RTP is probably inadequate; however, other reliable and validated
methods are currently lacking.

Another possible explanation for a possible increased risk for new
consecutive traumatic injuries after a concussion is that players who

sustain concussions are generally more injury prone. The results by
Northern et al (28) may indicate that this is true. This may be due to a
risk-taking playing style. The present cohort of ice hockey players
and injuries is not suitable to examine this; however, such a study
would also be of great value.

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forming the validation of all injuries and attendance records.

DISCLOSURES: The authors have no financial relationships or con-
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CONTRIBUTORSHIP: Gusten Nyberg – validated and analyzed the
data from the database, wrote the first manuscript and performed the statisti-
cal analyses. Karl Hjort – performed the statistical analyses, and wrote and
corrected the manuscript. Jack Lysholm – designed the study and corrected
the manuscript. Yelverton Tegner – came up with the initial idea, designed
the study, corrected the manuscript and supervised the process

<table>
<thead>
<tr>
<th>Period</th>
<th>Type of injury</th>
<th>Players with severe injuries</th>
<th>Players with non-severe injuries</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 7 days after RTP (game and practice injuries)</td>
<td>Concussion</td>
<td>2</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee injury</td>
<td>13</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Within 21 days after RTP (game and practice injuries)</td>
<td>Concussion</td>
<td>7</td>
<td>0.037</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee injury</td>
<td>33</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Within 42 days after RTP (game and practice injuries)</td>
<td>Concussion</td>
<td>6</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Knee injury</td>
<td>62</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

Data presented as n unless otherwise indicated. RTP Return to play