

# Use of Supervised Exercise During Recovery Following Sports-Related Concussion

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## Abstract

**Objective:** To assess the safety of supervised exercise (SE) in acute sport-related concussion (SRC) and its influence on recovery.

**Design:** Retrospective cohort study. **Setting:** University SRC clinic at a tertiary care center. **Patients:** One hundred ninety-four consecutive new patient charts were reviewed. Patients were included if they were seen within 30 days of sustaining a SRC, and their medical records included all required data elements. One hundred twenty-six patients were included in the analysis.

**Interventions:** Symptomatic patients who initiated SE within 16 days of SRC ( $n = 24$ ) were compared with those who did not undergo SE or initiated SE after postinjury day 16 ( $n = 84$ ). Age, sex, history of previous concussions, injury severity, relevant comorbidities, and other treatments received were included in the analysis. **Main Outcome Measures:** The association between early SE and clearance for return to sport was determined using a hazard ratio (HR). The number of days from SRC until clearance for return to sport and the number of days symptomatic from concussion were also compared between early SE and nonearly SE cohorts. **Results:** No serious adverse events occurred in the early SE group. Early SE was associated with earlier return to sport ( $HR = 2.35$ ,  $P = 0.030$ ). The early SE group had fewer days from SRC until clearance for return to sport (mean  $26.5 \pm 11.2$  days vs  $35.1 \pm 26.5$  days,  $P = 0.020$ ). There was a trend toward fewer symptomatic days in the early SE group ( $P = 0.054$ ).

**Conclusion:** Early SE performed in the symptomatic stage of SRC was safe and associated with earlier return to sport.

**Key Words:** sport-related concussion, exercise, concussion recovery

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## INTRODUCTION

The management of sports-related concussion (SRC) has evolved over time. As recently as the 2012 consensus statement on concussion in sport,<sup>1</sup> postconcussion activity recommendations have been that athletes with SRC should be withheld from physical activity until they are asymptomatic. At that point, a graded return to play process has been recommended, with subsequent return to sport upon successful completion. The initial period of rest could therefore range widely, with some athletes being withheld from exercise for weeks or months depending on the duration of their symptoms.<sup>2</sup>

Studies have now suggested that normal daily activities after SRC are safe and may speed recovery compared with strict rest.<sup>3,4</sup> Several studies in acutely symptomatic athletes have shown that monitored exercise challenges and mild-to-moderate levels of physical exertion during the early period following SRC did not worsen symptoms or prolong

recovery.<sup>4–6</sup> One study in athletes with persistent symptoms lasting longer than 4 weeks found that an active rehabilitation program including closely monitored light aerobic exercise was also safe and appeared to positively influence recovery.<sup>7</sup> Other studies have also demonstrated that subsymptom threshold exercise in postconcussion syndrome is safe and may be associated with improved outcomes.<sup>8–10</sup> There are multiple known beneficial effects of exercise on the brain that could potentially contribute to improved recovery. These include increased synaptic plasticity, increased production of neurotrophic factors (such as brain-derived neurotrophic factor), improved memory, and increased cortical connectivity on functional magnetic resonance imaging.<sup>11–13</sup>

However, a premature return to heavy physical activity (too much and too soon) has conversely been associated with worsening symptoms and a prolonged recovery after SRC.<sup>5,14,15</sup> Some SRC researchers have therefore discussed a “sweet spot” for both the timing and intensity of physical activity following SRC.<sup>5</sup> The most recent consensus statement on concussion in sport recommends return of subsymptom threshold activities after a period of 24 to 48 hours of relative physical and cognitive rest.<sup>16</sup> However, a knowledge gap remains in the optimal timing, mode, duration, intensity, and frequency of exercise during the acute symptomatic period following SRC.

We therefore investigated the application of supervised exercise (SE) in patients with acute, symptomatic SRC. This retrospective review compares recovery outcomes between patients who completed early SE as part of their clinical care and those who either did not perform SE or did not begin it until later than 16 days after injury. We hypothesized that

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SE during the early stages of recovery from acute SRC would be safe and would hasten recovery.

## METHODS

### Participants

Patients were eligible for inclusion if they were seen as a new patient in the Michigan NeuroSport Clinic within 30 days of sustaining a SRC. Exclusion criteria included a non-sport-related mechanism of injury, recovery without intervention before there was an opportunity for SE to be offered, or the absence of one or more required data elements from the medical record. Figure 1 summarizes those patients who were excluded from both groups.

The study population was intended to represent typical patients with acute SRC seen in our clinic. The early SE cohort was defined as those patients who underwent SE in clinic within 16 days of injury while still experiencing ongoing symptoms of SRC. This cutoff date was selected because 16 days is the average time from SRC to the first follow-up visit at which SE is typically performed in our clinic. The nonearly SE cohort was composed of all other eligible patients, including those who did not undergo SE during any clinic visit, those who underwent SE in clinic within 16 days of injury but were already asymptomatic, and those who underwent SE after postinjury day 16.

### Supervised Exercise

Our clinical management frequently includes controlled subsymptomatic exercise, defined here as SE. All SE is

supervised by a certified athletic trainer and/or physician. The physician determines when the patient is suitable for SE, typically no sooner than the first follow-up clinic visit. Heart rate, perceived exertion, and patient-rated symptoms are monitored during graded aerobic exertion. The SE protocol used in our clinic is modified from the Buffalo Concussion Treadmill Test<sup>17</sup> by the addition of multiple other exercise modalities aside from treadmill exercise, including use of a stationary bike or elliptical machine, dynamic rotational exercises using medicine balls, as well as agility drills and sport-specific exercises when tolerated. Supervised exercise was performed as part of the routine clinical encounter in a dedicated exercise space (ie, gym) within the clinic.

Supervised exercise is used to determine an athlete's exertional threshold for symptom exacerbation following SRC. Athletes begin SE at a low intensity on a stationary bike. Heart rate, perceived exertion, and self-reported symptom severity are recorded at 2-minute intervals, with the intensity of exercise gradually increased as tolerated every 2 to 4 minutes so long as symptoms do not increase by 3 or more points on a 10-point symptom scale. If symptoms do increase by 3 or more points, the intensity of the exercise is decreased; if symptoms further worsen despite decreased intensity of exercise, SE is then stopped. If stationary bike riding is tolerated, incorporation of other cardiovascular exercises can occur, including elliptical or treadmill training; when these are also tolerated, agility drills and sport-specific exercises may also be performed.

The duration of SE and the type of exercises included are individualized based on each patient's activity tolerance and stage of recovery. Patients may decline to exercise at any visit, and SE may also be deferred at the discretion of the treating

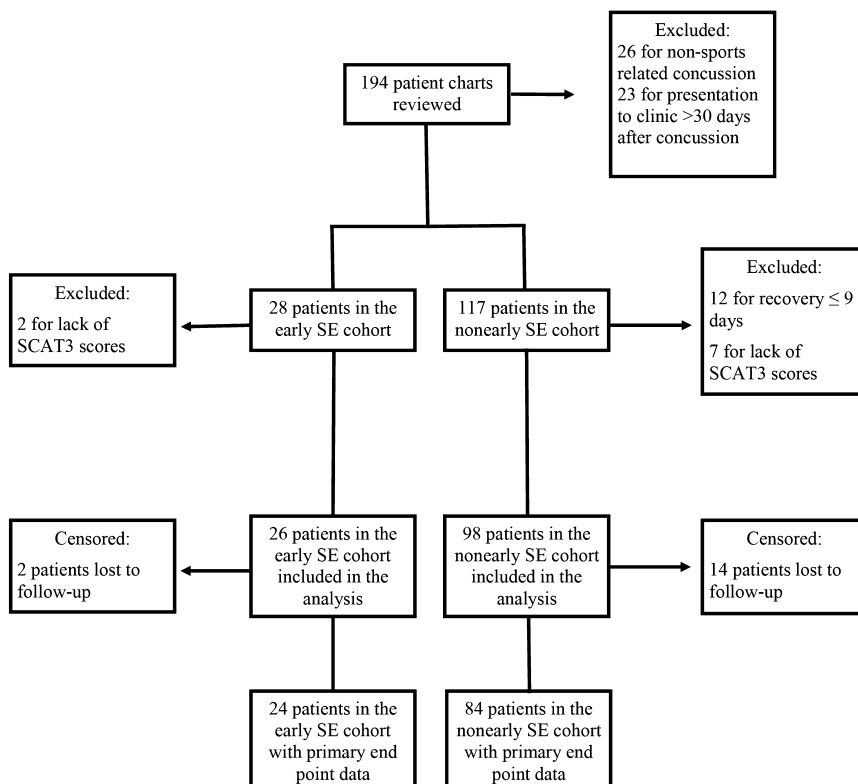


Figure 1. Patient inclusion/exclusion criteria flow chart.

physician based on the patient's symptom burden. The symptom threshold identified during SE is used clinically to guide the patient's subsymptom threshold exercise plan. Exercise prescriptions/recommendations incorporate the type and duration of exercise(s) to be performed, as well as exercise intensity with target heart rate and perceived exertion ranges and limits.

### Data Collection

After IRB approval, data were extracted from the electronic medical record by 2 members of the research team into a secure REDCap database.<sup>18</sup> Variables describing patient demographics, details of the concussion event and the initial clinic evaluation, patient education, and SE data were collected. All eligible new patients seen between September 2016 and January 2017 were included in this review.

### Statistical Analyses

The primary analysis used Cox proportional hazards regression to compare time until clearance for return to sport, measured as a discrete time-to-event endpoint, between the early SE and nonearly SE groups. Hazard ratios greater than 1.0 indicate an earlier return to sport. All assumptions of the Cox model were tested and confirmed, with the exception of proportional hazards due to time dependency in certain variables. For those variables violating the proportional hazards assumption, time-dependent variables were created to account for this violation. Patients lost to follow-up before reaching the primary endpoint were censored. In cases where a patient was deemed to have recovered from their SRC, but completed the final stages of their return to play progression after their last clinic visit without a discretely documented return to sport date, this date was uniformly estimated by adding 24 hours for each remaining step in the return to play progression after the date of their last clinic visit.

The SE group was defined using a time-varying covariate in the model. Multiple factors felt to have the potential to influence concussion recovery were assessed for inclusion in the model, with the final model controlling for the following covariates: age (as a time-dependent covariate), sex, number of previous concussions, initial Sport Concussion Assessment Tool 3 (SCAT3) total symptom score, history of migraine headache, history of depression and/or anxiety, referral for cervical physical therapy, and referral for vestibular physical therapy. The following covariates were assessed, but were not included in the final model: initial SCAT3 severity score, neck pain, and vestibular symptoms (due to collinearity with SCAT3 symptom scores); history of attention-deficit/hyperactivity disorder (ADHD) and learning disability (due to low counts in the early SE cohort).

Secondary analyses were performed using independent samples *t* tests to compare the number of days from concussion to return to sport and the number of days with symptoms attributed to concussion between the early SE and nonearly SE groups. All statistical analyses were completed using SAS Studio (SAS Institute Inc).

## RESULTS

### Cohort Characteristics

Patients in the early SE cohort presented to clinic sooner than those in the nonearly SE cohort, but the groups were otherwise

similar in demographics, medical history, clinical presentation, and referral to physical therapy (Table 1).

### Safety and Tolerance for Supervised Exercise

No serious adverse events occurred in those completing early SE. All patients in both groups tolerated at least 10 minutes of cardiovascular activity during SE (Table 2).

### Primary Recovery Outcomes

Early SE was associated with earlier clearance for return to sport (Figure 2), as was greater age. Several covariates were associated with later return to sport: initial SCAT3 total symptom score, prior history of depression and/or anxiety, referral to cervical spine physical therapy, and referral to vestibular physical therapy. Full results of the primary analysis are summarized in Table 3.

### Secondary Recovery Outcomes

The early SE group was cleared for return to sport in fewer days (mean  $26.5 \pm 11.2$  days vs  $35.1 \pm 26.5$  days;  $P = 0.020$ ) than the nonearly SE group. There was also a nonsignificant trend toward fewer symptomatic days in the early SE group compared with the nonearly SE group (mean  $16.7 \pm 7.1$  days vs  $22.4 \pm 22.5$  days;  $P = 0.054$ ).

## DISCUSSION

This study suggests that SE in patients who are still acutely symptomatic following SRC is safe, well tolerated, and may improve recovery. This study expands on previous work demonstrating the safety of early exercise following SRC, and to our knowledge is the first to suggest an association between early exercise and earlier return to sport. These results suggest that early SE, in addition to normal daily activities, may be incorporated into the management of acute SRC even in athletes who are still experiencing acute symptoms of concussion.

These findings in patients with acute SRC are similar to previous work demonstrating the safety and efficacy of SE in postconcussion syndrome patients,<sup>8,9</sup> and support expanded use of subsymptom threshold exercise beyond the postconcussion syndrome population.<sup>8,19</sup> A recent randomized clinical trial similarly demonstrated that an early provocative exercise challenge did not worsen symptoms or prolong recovery,<sup>6</sup> but our study expands on that trial by including a broader sample of patients more representative of a typical SRC clinic population (for example, those with pre-existing mood disorder and ADHD) as well as a broader range of SEs. The results of our study are also consistent with previous work in terms of those factors that were found to be associated with a prolonged SRC recovery, including younger age, pre-existing mood disorder, greater initial symptom burden, as well as persistent neck pain and dizziness.<sup>16,20,21</sup>

### Benefits of Supervised Exercise

The use of SE in acute SRC management has several advantages. The clinician can use the level of activity that is tolerated by the patient to provide individualized return to

**TABLE 1. Patient Demographics of Early SE and Nonearly SE Groups**

	Early SE (n = 26)	Nonearly SE (n = 98)
Age	15.3 (10.2-19.4)	15.4 (8.7-19.8)
Sex		
Male	20 (76.9%)	68 (69.4%)
Female	6 (23.1%)	30 (30.6%)
Race		
White	24 (92.3%)	81 (82.7%)
African American	0	6 (6.1%)
Non-white Hispanic	1 (3.9%)	2 (2.0%)
Asian	1 (3.9%)	4 (4.1%)
Other	0	5 (5.1%)
Days to the initial clinic visit	5.4 (1-15)*	10.5 (1-30)*
SCAT3 symptom categories at the initial clinic visit (maximum possible 22)	9.9 (1-22)	9.7 (0-22)
SCAT3 severity score at the initial clinic visit (maximum possible 132)	23.3 (1-87)	24.5 (0-105)
Lifetime number of concussion reported	1.7 (1-4)	1.7 (1-6)
History of migraine	8 (30.8%)	17 (17.3%)
History of depression and/or anxiety	4 (15.4%)	17 (17.3%)
History of ADHD and/or learning disability	2 (7.7%)	14 (14.3%)
Referred to cervical physical therapy	16 (61.5%)	40 (40.8%)
Referred to vestibular physical therapy	7 (26.9%)	29 (29.6%)

\*P value < 0.001.

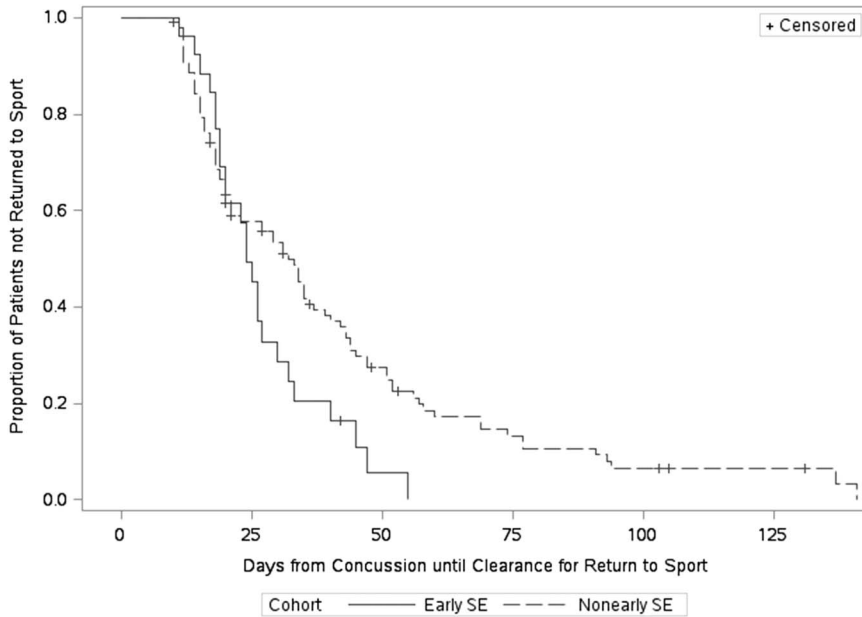
activity guidance. In this study, all patients were able to tolerate at least 10 minutes of SE and 32% of those in the early SE group tolerated over 40 minutes. When serial neurologic examinations are performed during exertion, some abnormalities that are not otherwise present at rest can be observed. Patients who otherwise would underreport symptoms (creating risk of recurrent injury due to overactivity) or overreport symptoms (subsequently avoiding activity) can be identified. This allows the physician to recognize any disconnect between reported symptom severity and actual performance to prompt evaluation for other complicating factors contributing to a lack of recovery, including psychological complications associated with concussion, deconditioning, and inactivity.<sup>22</sup> Furthermore, exercise has been associated with reduction in psychiatric symptoms.<sup>23</sup> Although not directly investigated in

this work, our clinical experience suggests that returning to exercise soon after SRC can help athletes reduce postinjury anxiety and depression. Finally, SE provides information to guide additional treatments, such as cervical and vestibular physical therapies, based on the symptoms provoked by exercise.

As the sample characteristics show, both early and nonearly groups reported similar symptom burden. The early group achieved similar maximum heart rates and duration of exercise despite undergoing high-intensity exercise more acutely in the course of injury. The fact that this group less frequently reported symptom worsening during exercise and had no instances of premature stoppage of exercise in this sample indicates that high levels of exercise may be tolerated in concussion patients while acutely symptomatic, and it may

**TABLE 2. Breakdown of the Intensity and Length of Exercise Duration for Patients in Early SE, Nonearly SE, and SE Once Asymptomatic Groups**

	Early SE (n = 26)	Nonearly SE (n = 30)	SE While Asymptomatic (n = 29)
Days to SE	11.7 (8-16)	29.4 (17-103)	20.2 (8-51)
Average maximum heart rate	177 ± 22	175 ± 24	194 ± 8
Duration of SE			
11-20 min	4 (15.4%)	4 (13.3%)	0
21-30 min	10 (38.5%)	15 (50.0%)	14 (48.3%)
31-40 min	4 (15.4%)	9 (30.0%)	11 (37.9%)
41-50 min	8 (30.8%)	2 (6.7%)	3 (10.3%)
51-60 min	0	0	1 (3.5%)
Symptom(s) worsened ≥ 3 points	9 (34.6%)	19 (63.3%)	0
SE stopped prematurely	0	2 (6.7%)	0



**Figure 2.** Primary analysis survival plot of the early SE and nonearly SE cohorts.

be suggested that delayed initiation of such activity may lead to greater intolerance to exercise.

There are several reasons why a patient in this study may not have undergone SE. Although the delay in initiation of the SE program is multifactorial and varied on a patient-by-patient basis, it may be attributed to provider conservatism in initiating SE in patients with high symptom burden, which could include vestibular abnormalities, catastrophizing behaviors, or somatization. In this study, it was more common that delayed initiation of SE was associated with routine challenges encountered in a clinical environment, such as scheduling challenges and lack of provider or patient availability. In some cases, SE was initiated greater than 1 month following injury, at which point the patient was already experiencing a prolonged recovery. This was often due to a delayed initial presentation to clinic, highlighting the value of prompt evaluation by a provider with expertise managing SRC as compared to delayed specialist referral only after failure to recover in an anticipated timeframe.

In addition, it is worth noting that our heterogeneous patient population represents the diversity of clinical presentations typically encountered in a concussion clinic. Our patients had many comorbidities commonly encountered by concussion providers, including mood disorders, migraine headaches, and vestibular–ocular or cervical spine dysfunction. In addition, patients also presented with various neurological examination abnormalities, most commonly including positive vestibular–ocular motor screening examination and convergence insufficiency. On this basis, we feel our results are applicable to real-world SCR care in a concussion clinic.

**Limitations**

This study does have several noteworthy limitations. First, causality cannot be inferred from these results given the retrospective study design. Furthermore, this study is also subject to all common biases associated with analysis of medical records data. For example, the later initial clinic presentation in the

<b>Table 3. Hazard Ratio Analysis on Factors That Influence SRC Recovery</b>		
<b>Variable</b>	<b>Hazard Ratio (95% CI)</b>	<b>P</b>
SE (within 16 days of concussion)	2.35 (1.09-5.07)	0.03
SE (all)	0.69 (0.35-1.38)	0.296
Age	1.26 (1.05-1.51)	0.013
Age × days to return to sport clearance	1.00 (0.99-1.00)	0.037
Gender	0.87 (0.54-1.39)	0.552
Total concussions	0.80 (0.63-1.03)	0.079
SCAT3 total symptom score at the initial clinic visit	0.95 (0.92-0.99)	0.015
History of migraine	0.82 (0.49-1.35)	0.43
History of depression and/or anxiety	0.48 (0.27-0.88)	0.018
Referred for cervical physical therapy	0.57 (0.37-0.89)	0.013
Referred for vestibular physical therapy	0.38 (0.20-0.69)	0.002

nonerly SE cohort likely results in a form of lead-time bias favoring improved outcomes in the early SE cohort who generally had earlier access to treatments, including SE and physical therapy. There were a smaller number of patients in the early SE group compared with the nonerly SE group, which also potentially introduced bias when comparing the samples.

Although our study population does represent the type of patients typically encountered in our medical practice, it was a predominantly white and pediatric-aged sample, so external validity may be lower in other demographic groups. Symptom reporting was used to track recovery from concussion, both in determining the timing of return to play, as well as a direct outcome measure in the number of days symptomatic from concussion. It should be noted that symptoms reported during concussion are not exclusive to concussion, and can be attributed to other causes such as neck strain, vestibular dysfunction, and mood disorders.<sup>24,25</sup> Furthermore, symptom underreporting is a known pitfall in tracking recovery from concussion.<sup>26</sup> We believe that limitations associated with variance in symptom reporting are considered a random error equally affecting patients in both groups, and may not represent a systematic bias favoring one group; therefore, it is unlikely that it influenced the outcomes of the study. Although the patients in both groups were provided recommendations regarding their activities, it is unclear whether these recommendations were implemented consistently between patients in both groups. Although unlikely, it is possible that the activities performed at home contributed to some of the observed differences between groups. Future studies may consider tracking activities at home by using continuous activity monitoring. Cognitive activity may influence recovery<sup>3</sup> but was not directly accounted for in this study. This said, we have no reason to suspect that cognitive activity systematically differed between early and nonerly SE groups.

This study demonstrates the positive clinical outcomes of the SE approach examined in this study. Although quantification of the effects of SE on health care utilization and cost in the current sample would have been meaningful, this was not the aim of the current study. A future direction for this line of work will be a cost analysis. Finally, this study was limited to an athlete-only population. Future works should study the role of SE in non-SRC as well.

## CONCLUSIONS

This study is novel both in terms of the acute postinjury time frame during which SE was administered, as well as the degree of direct physician and athletic trainer supervision during SE. These results address the existing knowledge gap in regard to the appropriate timing, type, and intensity of exercise following SRC. This study using data collected in a real-world setting demonstrates that symptomatic acute SRC patients can tolerate and may benefit from early supervised subsymptom threshold exercise. This study represents a step toward the establishment of evidenced-based practices for exercise in the management of SRC. Additional prospective clinical trials are needed to further clarify the role of early SE in recovery following SRC.

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