| Authors, Year, Country, Study Design | Participants (n, age, sex); Definition of concussion | Intervention (frequency, duration, operational definition of intervention) | Outcome | Results (including statistical outcomes) | Sign Tool Risk of Bias |
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| **Grool et al, 2016, Canada Prospective Cohort** | n=3063, age (range 5-17.99; mean 11.8±3.4 years), male n=1858 (61%)/female n= 1205 (39%). Definition: 4th CISG Statement. | Questions regarding physical activity (PA) were based on Consensus Statement return-to-play steps; these questions have not been validated. Early PA participation was defined as any level of PA other than no activity at 7 days post-enrolment. | Persistent post-concussive symptoms (PPCS), defined as at least 3 new or worsening individual symptoms compared with the pre-concussion status measured at day 28 according to the validated Post-Concussion Symptom Inventory (PCSI). | PPCS at 28 days occurred in 733 (30.4%). Early PA was associated with lower PPCS risk on propensity score matching (n = 1108 [28.7% for early PA vs 40.1% for no PA]; Absolute risk difference (ARD), 11.4% [95% CI, 5.8%-16.9%]) and on inverse probability of treatment weighting analysis (n = 2099; relative risk [RR], 0.74 [95% CI, 0.65-0.84]; ARD, 9.7% [95% CI, 5.7%-13.7%]). | High Quality |
| **Leddy et al, 2018, USA RCT** | n=54 (BCTT n=27, Control n=27), age (range 14-19; mean 15±1.5 years), male n=37 (69%)/female n= 17 (31%). Definition: 4th CISG Statement. | 1) BCTT group: BCTT on visit #1 and #2. Assessed every minute and the test was stopped if ≥3 point change from that day's pre-treadmill resting overall symptom score or at voluntary exhaustion (RPE≥17). 2) Control group: Underwent usual care and physicians made recovery, return to school/play determinations according to guidelines. | Recovery was defined as normal symptom severity score on Post-Concussion Symptom Scale (PCSS), a normal physical examination (normal oculomotor, vestibular, cervical, and neurological examinations), and normal cognitive performance on ImPACT | Symptom scores for the first 2 time points were examined (visit #1, day after visit #1) using mixed effects linear models. The group variable (BCTT/control) was not significantly associated with the symptom score (F-value = 1.7157, P = 0.1960). This suggests that there is no short term (within 24 hours) acute increase in symptom scores due to use of the BCTT. | High Quality |
| **Leddy et al, 2019, USA RCT** | n=103 (Exercise n=52, Stretching n=51), age (range 13-18; mean 15.4±1.7 years), male n=55 (53%)/female n= 48 (47%). Definition: 5th CISG Statement. | 1) Aerobic Exercise Group: Daily exercise on bike/ treadmill at prescribed target HR. No stretching before or after. HR was 80% of HR achieved at symptom exacerbation on the BCTT at the first visit. 2) Stretching Group: Prescribed stretching routine; gentle, | Time to symptom resolution, confirmed by a normal physical examination (i.e., a normal neurological examination including normal vestibular and oculomotor systems and further confirmed by demonstration of the | Aerobic exercise recovered in a median of 13 days (IQR: 10-18.5), whereas stretching was 17 (IQR: 13-23) p=0.009. Logistic parametric survival model demonstrated aerobic exercise recovered faster than stretching (p=0.005). Incidence of | High Quality |

| | | whole-body, progressive program that would not considerably elevate HR to perform for 20 minutes everyday. | ability to exercise to exhaustion without exacerbation of symptoms on the BCTT. | participants with delayed recovery (>30 days) in stretching group (n=7; median=58, IQR: 36-62) compared to aerobic (n=2; median=50, IQR: 46-54) (p=0.08). No difference in symptom scores across the 30 days. | |
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| **Leddy et al, 2021, USA RCT** | n=118 (Aerobic n=61, Stretching n=57), age (range 13-18 years, mean aerobic 15.5±1.4, mean stretching 15.9±1.4, male n=74 (63%), female n=44 (37%). Definition: 5th CISG Statement. | Aerobic group instructed to exercise at home (ie, walking, jogging, or stationary cycling) at up to 90% of the maximum heart rate achieved on the initial BCCT visit (their target HR) for at least 20 min a day. Stretching group instructed to perform a standardised combination of light progressive stretches and breathing exercises that would not significantly elevate heart rate. | Clinical recovery within the 4-week intervention period (normal exercise tolerance on the BCTT, confirmed by a normal physical examination and a return to the baseline symptom level on the PCSI) and development of persistent post concussive symptoms beyond 28 days after injury. | Aerobic exercise had a significant effect on recovery within the first 4 weeks (HR 0·52 [95% CI 0·28–0·97], log-rank p=0·039) when controlling for sex, site, and mean daily exercise time, corresponding to a 48% reduction in PPCS risk. 13 (21%) participants in the aerobic exercise group versus 18 (32%) participants in the stretching exercise group did not recover by day 29, and were therefore diagnosed with PPCS (relative risk reduced by 34%). | High Quality |
| **Ledoux et al, 2022, Canada RCT** | n=456 (experimental group n=277, Control n=229), age (range 10-17, mean 13.3±2.2 years), male n=255 (56%), female n=201 (44%). Definition: 4th CISG Statement. | The experimental group (EG) were to initiate progressive return-to-PA 72 hours post ED visit even if symptomatic. The control group (CG) were to rest-until- asymptomatic before initiating the progressive return-to-PA protocol. | Total self- reported Health Behaviour Index (HBI) score at 2 weeks post injury. | Intention-to-Treat: The mean difference in HBI total symptom load at 2 weeks was not statistically significant (mean diff=−1.3 (95% CI: −3.6 to 1.1], p=0.30). Per-Protocol Analysis: Of the 166 adherent participants, n=143 (EG=67 and CG=76) had complete primary outcome data. PP analyses indicated the EG reported significantly fewer symptoms than the CG (mean diff=−4.3 (95% CI: −8.4 to −0.2); p=0.038) at 2 weeks post injury. | High Quality |

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| **Lishchynsky et al, 2019, Canada Prospective Cohort** | n=30 (Low activity (LA) group n=15, High activity (HA) group n=15), age (range 12-17; median 14, IQR 14-15 years), male n=25 (83%)/female n=5 (17%). Definition: 5th CISG Statement. | Exposure was defined as the total amount of time (minutes) spent in moderate to vigorous physical activity (MVPA) measured by Actigraph in the initial 3 days (72 h) immediately following concussion diagnosis. The exposure of MVPA was dichotomized by median into high (>148.5 min) and low (≤148.5 min) time in MVPA. | The primary outcome was the time from concussion to full medical clearance by a study sport medicine physician to return to full participation ice hockey. | The median symptom severity score for the LA group was 31 (IQR 14–51)/132 and 14 (IQR 8–29) for the HA group. The HA group took significantly more time to be medically cleared to return to play (chi2=4.18, p=0.041). There were no associations between MVPA and time to: 1) return to baseline symptom scores, 2) first day of initiation of RTP protocol, and 3) first day of unrestricted return to school. | High Quality |
| **Thomas et al, 2015, USA RCT** | n=99 (Usual care (UC) group n=50, Strict rest (SR) group n=49), age (range 11-22, median 14, IQR 12-15), male=65 (66%)/female n=34 (34%). Definition: Centers for Disease Control. | Experimental group were recommended 5 days of strict rest at home (specifically, no school, work, or physical activity). The control group was usual treatment | Self-reported post-concussion symptoms (PCSS), ImPACT scoring, and battery of other cognitive tests Hopkins Verbal Learning Test, Trail Making Test Parts A & B, Symbol Digit Modalities Test, Letter-Number, and Controlled Oral Word Association Test (verbal fluency). | >60% symptom resolution was experienced at the follow-up period; however, it took the strict rest groups three days longer for half of the patients to report symptom resolution compared with the usual care group. No differences were found for the majority of the neurocognitive tests. | High Quality |
| **Brown et al, 2014, USA Prospective Cohort** | n=335, age (range 8-23; mean 15±2.6 years), male n=208 (62%)/female n= 127 (38%). Definition: 4th CISG Statement. | Cognitive activity level was estimated using a scale developed by 2 clinician-researchers experienced in concussion management. Athletes reported their cognitive activity level at each follow-up visit. Cognitive activity-days were then calculated by multiplying the average cognitive activity level reported by the patient by the days between visits. | The duration of post-concussion symptoms (PCSS) was defined as the time between the date of injury and the athlete's last date of symptoms, queried at each clinic visit. Symptom-free was a post-concussion symptom score of 0. | On univariate modelling, patients in the highest quartile of cognitive activity-days took statistically longer to recover than those in first to third quartiles of cognitive activity-days. Multivariate cox proportional hazards modelling, demonstrated that total symptom score at the initial visit and cognitive activity-days were independently associated with duration of symptoms. | Acceptable |

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| **Buckley et al, 2022, USA Prospective cohort** | n=78, age (range 18-23, mean 19.6±1.4 years), sex male n=40 (51%/ female n=38 (49%). Definition: 4th CISG Statement. | The exposure was physical activity (PA) and mental activity (MA) based on Consensus Statement return-to-play steps. | The outcome measures were the number of days until symptom free and days until full RTP | The quadratic regression was significant for both time to symptom free (r2=0.27, P=0.004) and RTP (r2=0.23, P=0.019). Reported early PA was the only significant predictor for symptom-free day (P = 0.002, β = 0.353) and RTP day (P = 0.006, β = 0.332). Reported early MA did not predict time to symptom free (β= −0.160, P=0.155) or RTP (β=−0.152, P=0.188). | Acceptable |
| **Chan et al, 2018, RCT (Phase I-II) Canada** | n=19 (TAU group n=9, Rehab group n=10), age (range 12-18; mean 15.5±1.5 years), male n=5 (26%)/female n=14 (74%). Definition: 4th CISG Statement. | Treatment as usual (TAU) included education on symptom management and RTP, school consultation and physiatrist consultation vs. TAU plus 6 weeks of active rehabilitation (1: submaximal aerobic training; 2: light coordination and sport-specific exercises; 3: visualization, imagery techniques; 4: home exercise) | The primary efficacy outcome was self-reported post-concussion symptoms (PCSS). Secondary outcomes included health-related quality of life, measures of mood, fatigue, balance, and cognitive performance. | The effect for group was significant (Wald's t=2.15, P=.047). Adding a group-by-time interaction term to the model or sex did not achieve improved model fit. Removing group from the original model resulted in a significant degradation of model fit (x2 = 4.83, P = .028), confirming a treatment effect. No interferential statistics for other secondary outcomes. | Acceptable |
| **Chizuk et al, 2022, USA Retrospective Cohort** | n=51 (Adherent group n=31, Non-adherent group n=20), age (range 13-18), male=31 (61%)/female=20 (39%). Definition: 5th CISG Statement. | Prescribed aerobic exercise, updated each week based upon exercise tolerance on the BCTT. Adherence to prescribed exercise was defined as completed >66% of the recommended guidelines each week | Resolution of symptoms to pre-injury level and being able to exercise to 80% of one's predicted HR max without symptom exacerbation | Adherent participants experienced quicker recovery (median days: 12 [IQR: 9-22]) compared to non-adherent participants (22 [IQR: 12-30]). When controlling for sex: higher adherence was associated with a quicker recovery and a lower HRt was associated with greater adherence, while no associated was present between adherence and initial symptom severity. | Acceptable |

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| **Chrisman et al, 2019, USA Pilot RCT** | n=30 (Intervention n=19, Control n=11), age (range 12-18; mean 15.5±1.6 years), male n=13 (43%)/female n=17. (57%). Definition: 4th CISG Statement. | Intervention: 6-week daily home aerobic exercise program requiring minimal in-person visits - the Sub-Threshold Exercise Program (STEP). Control: Stretching program (handout) 5-10 mins daily with weekly calls from research assistant. | Feasibility and acceptability. Efficacy: Trajectory of concussive symptoms, measured using the health behavior inventory (HBI). Exploratory outcomes: Health related quality of life, Actigraph measured PA, fear avoidance | There was a significant effect of the intervention on rate of decline of symptoms (HBI, p=0.02), after controlling for age, sex, and prior concussion. Rate of symptom improvement was slower among youth with chronic symptoms compared to those with acute symptoms (<9 weeks) in both groups. | Acceptable |
| **Coslick et al, 2020, USA, Retrospective Cohort** | n=178 (No/Low exercise n=141, moderate/Heavy exercise n=37), age (range 6-17, mean 14.1±2.5, (No/Low), 12.4±2.9 (Mod/Heavy), sex (male n=89, female n=89). Definition: 5th CISG Statement. | Self-reported participation in physical activity based on child and caregiver description at the initial visit. Level 0 (none) to level 5 (full participation in contact competition). The variable was subsequently dichotomized as none or light (0 to 1; 79%) versus moderate to heavy (2 to 5; 21%). | The primary outcome measure was days to recovery from concussion event. This variable was based on clinical documentation of clearance to progress through an RTP protocol through full return to contact play | Mean recovery was 54.1 (SD=35.2) days. The unadjusted difference in recovery was 24 days less among the moderate-to-heavy activity group compared to the none-to-light activity group (59.1 days compared to 35.1 days, $\beta = -24.0$, 95% confidence interval [CI] $-36.3$, $-11.6$, P < .001). After employing the IPEW regression model, the difference in days to recovery was 21 less among the moderate-to-heavy exercise group ($\beta = 21.27$, 95% CI $-27.07$, $-15.48$, P < .001). | Acceptable |
| **Gibson et al, 2013, USA Retrospective Cohort** | n=184 (Rest group n=85), age (range 8-26; mean 15±3 years), male n=132 (72%)/female n=52 (28%). Definition: 3rd CISG Statement. | Recommendation of cognitive rest (n=85) or not (not explicitly defined); Cognitive rest was only considered recommended if it was explicitly mentioned in the medical record. | The duration of post-concussion symptoms was defined as the time interval between the date of injury and the date the athlete last had symptoms (measured 0 on PCSS) | In univariate analyses, mean symptom duration was significantly longer for athletes to whom cognitive rest was recommended (57 vs 29 days; p<0.01). After adjusting for covariates, however, only the initial PCSS score was associated with the duration of concussive symptoms (OR 1.03 (1.01, 1.05)). No association | Acceptable |

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| **Haider et al, 2019, USA Retrospective Cohort** | n=130 (Rest group n=27, Placebo group n=51, Aerobic group n=52), age (range 13-18; mean 15±1.6 years), male n=72 (55%)/female n=58 (45%). Definition: CISG statement (year not specified). | Rest Group (RG): prescribed cognitive and physical rest according to the previous standard of care. Placebo Group (PG): prescribed cognitive rest and instructed to perform a standardized combination of light stretches and breathing exercises that would not elevate HR. Aerobic Group (AG): instructed to perform aerobic exercise at 80% of the HRt achieved on the BCTT for 20 min a day. | Recovery was defined as symptom resolution to baseline, confirmed by a physician performed physical examination, and the ability to exercise to exhaustion without exacerbation of symptoms on the BCTT. | Change in HR significantly correlated with duration of clinical recovery for RG (p= 0.012, R2=0.228) and PG (p=0.011, R2=0.126) but not for AG (p=0.084, R2=0.059). Change in HR values were significantly lower in participants with prolonged recovery (>30 days) in RG (p = 0.01) and PG (p = 0.04). A change in HR of ≤50 bpm on the BCTT is 73% sensitive and 78% specific for predicting prolonged recovery in those prescribed the current standard of care (i.e. cognitive and physical rest) | Acceptable |
| **Hoffman et al, 2020, USA, Prospective Cohort** | n=17, age (range 18-23 years, mean 20.0±1.5 years), male n=9 (53%) female n=8 (47%). Definition: 4th CISG Statement. | Activity measured with an ActiGraphy GT9X Link. Sleep via Pittsburgh Sleep Quality Index and Epworth Sleepiness Scale | Days to symptom recovery on SCAT3 | No significant relationships between recovery and sleep outcomes at 2-3 days post-injury or end of recovery. At mid-point of recovery, a moderate positive relationship existed between wake after sleep onset and recovery (r=0.58, p=0.015), and sleep efficiency (r=-0.51, p=0.035). A moderate positive correlation existed between post-injury PSQI global scores and recovery (rs = 0.63, p = 0.007). | Acceptable |
| **Howell et al, 2016, USA Prospective Cohort** | n=364, age (range 8-27; mean 15.0±2.8 years), male n=222 (61%)/female | Activity was assessed during the initial clinic visit and each follow-up examination. | Symptom duration, defined as the time (days) between the day of injury and the last day of | Neither an initial period of physical inactivity from the time of injury until the first examination | Acceptable |

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| | n=142 (39%). Definition: 4th CISG Statement. | Patients were asked if they had continued regular exercise from the time of injury until the initial examination. During follow-up visits, patients described their average level of PA and cognitive activity since the previous clinic visit using standardized scale (return-to-play protocol). | symptoms. Symptoms were assessed using the PCSS. Symptom free was a PCSS of 0. | (HR 0.794 (95% CI 0.57-1.1)) nor the amount of PA between the time of injury and each clinic visit (HR 1.0 (95% CI 0.1-1.0)) had an independent association with the duration of symptoms. Total PCSS score at the initial clinic visit and female sex were each independently associated with a longer duration of symptoms but nothing else. | |
| **Howell et al, 2021, USA, RCT and Cohort** | n=37 (Exercise Group n=17, Standard Care Group n=30), age (range 14-21, mean 17±2.1 years), male n=20 (54%), female n=17 (46%). Definition: 5th CISG Statement. | Treatment as usual (no systematic exercise recommendation) vs. a specific exercise prescription with individualized target HR, frequency (5 times/wk), and duration (20 minutes at the target HR) to perform over the subsequent 4 weeks. After 4 weeks, target intensity was adjusted for the final 4 weeks based on exercise test performance. | Self-reported post-concussion symptoms assessed with the PCSI at 1 week, 1 month and 2 months after initial visit. Secondary outcomes included measures of exercise volume (average min/wk) during the first 4 weeks and the second 4 weeks of study separately and how many participants in each group were asymptomatic at 4 weeks. | No differences in symptom severity or average weekly exercise volume between groups at either assessment. The group who exercised ≥100 min/wk during month 1 reported lower symptom severity scores. Participants with complete symptom resolution (PCSI score, 0) at 1-month reported more exercise volume than the symptomatic group (mean difference, 168 min/wk; 95% CI, 113-321 min/wk). The ROC analysis identified an optimal cutoff threshold of ≥160 min/wk, with a classification accuracy of 81% (sensitivity, 90%; specificity, 78%). | Acceptable |
| **Howell et al, 2021, USA, Retrospective Cohort** | n=225 (Sleep problems n=82, no sleep problems n=143), age (range 8-18, mean with sleep problems (14.4±2.2 y); those without | Experiencing sleep problems at initial visit: A standardized intake questionnaire whether they were experiencing sleep problems that began since their injury that they did not | Health and Behavior Inventory (HBI). Symptom resolution times were calculated based on the patient HBI score as the time elapsed from injury until the patient no longer | When assessing the presence of symptoms at the second clinic visit, a significantly higher proportion of those without sleep problems at the first clinic visit reported | Acceptable |

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| | sleep problems (14.6±2.23y), male n=82 (36%), female n=143 (64%). Definition: 5th CISG Statement. | regularly experience before the injury. The type included sleeping more than usual, experiencing sleep disruptions (eg, waking up in the night more than usual), trouble falling asleep, or other unspecified sleep problems. | reported the presence of any concussion-related symptoms that began at the time of the injury. | no longer experiencing concussion symptoms (30%) compared to those with initial sleep problems (6%; P < 0.001). Furthermore, those with initial sleep problems took significantly longer to experience symptom resolution than those without initial sleep problems (21 [10-27] vs. 14 [10-20] days, p=0.03). | |
| Kostyun et al, 2015, USA Retrospective Cohort | n=545, age (range 11-18; mean 14 years), male n=301 (55%)/female n=244 (45%). Definition: 4th CISG Statement. | Self-reported quality and duration of sleep. Quality of sleep split into four groups: Trouble falling asleep, sleeping less than normal, sleeping more than normal, no sleep disturbances; within individuals who have a SRC. Duration of sleep split into three groups: Short-duration of sleep (<7 hours), intermediate (7-9 hours), and long (>9 hours). | ImPACT was used where the outcome measures were: Verbal memory, visual memory, visual motor speed, reaction time, and PCSS score | The single-factor ANOVA revealed a significant difference for sleep duration and 3/5 composite scores on ImPACT test 1, a significant difference for sleep duration and 2/5 composite scores on ImPACT test 2, and no differences for sleep duration and composite scores on ImPACT test 3. Patients with disrupted sleep reported a greater number of total concussion symptoms on the PCSS consistently throughout the length of their recovery from a SRC (P < .001). | Acceptable |
| Krainin et al, 2021, USA, Prospective Cohort | n=211 (Early PA n=35, No Early PA n=176), age ( range 5-18, mean early PA: 13.8±2.9, No Early PA: 14.4±2.6 years), male n=110 (52%) female n=101 (48%). Definition: 5th CISG Statement. | Engaging in physical activity after sustaining a concussion but prior to the initial sports medicine clinic visit (early physical activity group) and those who did not (no physical activity group). Cased on response at initial clinic visit: "Since your injury, have you done any physical | PPCS were defined as those having a duration > 28 days after the concussion, which is consistent with previous definitions of persistent symptoms in this age group. Health and Behavior Inventory (HBI). | The early PA group reported significantly lower HBI scores for both the parent and patient report than the no PA group across both time points. A significantly smaller proportion of the early physical activity group (22%) experienced PPCS than the no early physical activity group (44%), and the | Acceptable |

| | | activity/exercise?" Specific self-reported type and level of activity was classified to one of the 6 corresponding stages of the graduated RTP strategy | | early physical activity group demonstrated a shorter mean time from the injury to symptom resolution (15.6±12.4 days vs. 27.2±24.2 days) and RTP clearance (24.2±15.7 days vs. 36.7±40.6 days). | |
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| **Kurowski et al, 2017, USA RCT** | n=30 (Exercise n=15, stretching n=15), age (range 12-17; mean 15±1.6 years), male n=13 (43%)/female n=17 (57%). Definition: Mild TBI was defined using the American Congress of Rehabilitation Definition. | 1) Aerobic Exercise Group: Cycling program of 80% the duration that exacerbated symptoms during the initial visit, on a cycling bike; five to six days per week. 2) Stretching Group: program that targeted upper and lower extremity, as well as trunk-musculature, rotated on a two week basis. Received a new group of stretches every two weeks | Post-concussion symptom inventory to assess self- and parent/guardian-rated symptoms. Adolescent version of PCSI has 21 Likert scale (0-6) questions. Parent version has 20 Likert scale questions. | Repeated measures mixed model analysis of self-PCSI ratings from week 1-7 demonstrated a significant group by time interaction, indicating a greater rate of improvement in the sub-symptom aerobic training compared to the full-body stretching group (F-value = 4.11, p-value = .044). The effect size for the trend across time between groups is equivalent to a Cohen's d effect size of ~.81. The effect size at week seven between groups is equivalent to a Cohen's d effect size of ~.51. | Acceptable |
| **Lawrence et al, 2018, Canada Retrospective Cohort** | n=253, age (median 17 IQR 15-20 years), male n=148 (58%)/female n=105 (42%). Definition: 5th CISG Statement. | The primary exposure of interest was the time (days from injury) to the initiation of aerobic exercise following concussion, either self-initiated or physician-prescribed. The time at which aerobic exercise was initiated was captured for all concussion injuries through the use of standardized reporting concussion forms. | Days from injury to full return to 1) sport and 2) school/work (as assessed or cleared by physician) | Initiating aerobic exercise on 3, 5, 7, and 14 days post-injury was associated with a respective 36.5% (HR, 0.63; 95% CI, 0.53–0.76), 59.5% (0.41; 0.28–0.58), 73.2% (0.27; 0.16–0.45), and 88.9% (0.11; 0.06–0.22) reduced probability of faster full RTS compared to initiating aerobic exercise within 1 day post injury (p<0.001), and a respective 45.9% (0.54; 0.44–0.66), 70.5% (0.29; 0.20–0.44), 83.1% (0.17; 0.10–0.30), and | Acceptable |

| | | | | 94.7% (0.05; 0.03–0.11) reduced probability of faster full return to school/work compared to initiating aerobic exercise within 1 day post injury (p<0.001). | |
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| **Leddy et al, 2019, USA RCT (Quasi-experimental)** | n=54 (Exercise group n=24, Rest group n=30), age (range 13-18; mean 15±1.4 years), male n=54 (100%). Definition: 5th CISG Statement. | 1) Exercise Group (EG): After BCTT, instructed to exercise at home or in a gym with supervision each day for 20 minutes on a treadmill or stationary bike at the prescribed HR. 2) Rest Group (RG): Not participating in any sports or any other forms of exercise. Instructed to advance daily cognitive activities according to symptom tolerance. | Symptom recovery was defined as return to a baseline level of symptoms, which was defined as a symptom severity score of 7 or less on the PCSS, for 3 consecutive days. | Recovery time from initial visit was significantly faster for EG than for RG (8.29+/-3.85 days vs 23.93+/-41.73 days, P=0.048). Post hoc analysis revealed that recovery time from initial injury was faster for EG but did not quite reach significance (P=0.052). The average recovery time for the 4 RG participants with delayed recovery was 113.25 (673.6) days. | Acceptable |
| **Majerske et al, 2008, USA Retrospective Cohort** | n=95, age (range 13-18; mean 15.8±1.4 male, 16.3±1.3 female), male n=80 (84%)/female n=15 (16%). Definition: Not reported. | Activity Intensity Scale, ordinal in nature: no school or exercise activity (0), school activity only (1), school activity and light activity at home (e.g., slow jogging, mowing the lawn) (2), school activity and sports practice (3), and school activity and participation in a sports game (4). | IMPACT was used where the outcome measures were: Verbal memory, visual memory, visual motor speed, reaction time, and impulse control composites. Also, PCSS score. | There was a trend between total symptom score and intensity of activity after concussion (P = .08). Evaluation of adjusted means suggests that athletes engaging in the highest activity levels (AIS = 4) over time had the worst visual memory (adjusted mean score = 22.22), scoring below the 2nd percentile. Additionally, reaction times were the worst for the AIS = 4 group (adjusted mean score = 3.51), with performance below the 1st percentile. | Acceptable |
| **Micay et al, 2018, Canada RCT** | n=15 (Exercise group n=8, Usual care group n=7), age (range 14-18; mean 15.7±1.1 years), male n=15 (100%). | Usual Care Group (UCG): directed through 6-stage progression of activity. Exercise (EXG) participants were directed | The efficacy of the intervention was evaluated by symptom status and time to medical clearance (in days) compared with usual | No significant between group difference in mean time to medical clearance, which was 36.1±18.5 days for the EXG and | Acceptable |

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| | Definition: 5th CISG Statement. | through a standardised aerobic exercise intervention beginning on day 6 postinjury while concurrently being directed through 6-stage progression of activity. Session 1 was 10 min and 50% of age-predicted maximal HR. Gradual progression until 70% was reached, then maintained for the final three sessions. Exercised on 2 consecutive days, with 1 day of rest, for a total of 11 days. | care. RTP status was determined by a sports medicine physician who was blinded to the participant's group placement. Assessed at weeks 1, 2, 3 and 4 postinjury on measures of clinical recovery, including RTP status and PCSS symptom severity. | 29.6±15.8 days for the UCG (t(13)=0.03; p=0.87). Multiple linear regression analysis to examine between-group differences in time to medical clearance while controlling for acute symptom severity (ie, symptom severity at day 5 postinjury) overall was not statistically significant (F(2,14)=3.2, p=0.08), R2 =0.35) and the between-group difference was also not found to be significant (p=0.82). | |
| **Moor et al, 2015, USA Prospective Cohort** | n=56, age (range 12-19; mean 15.2±1.7 years), male n=30 (53%) / female n=26 (47%). Definition: 4th CISG Statement. | Self-reported receptivity to each treatment recommendation provided during their care at the sports medicine center and the frequency with which each recommendation was followed. Physical rest, mental rest with restrictions from school, mental rest with restrictions from electronics, recommendations for medication, referral to physical therapy, and referral to another specialist (neurologist, psychologist, or other). | Number of days of treatment. The date when the patient was discharged from sports-medicine and returned to full contact play was recorded. | None of the measures of adherence to the treatment recommendations were significant predictors of the number of days of treatment; however, there was a clear tendency in five of the six rest parameters (physical rest, cognitive rest with restrictions from electronics, and cognitive rest with restrictions from school), where high levels of adherence to rest resulted in an increased average number of days of treatment (slower recovery) and those who reported being less adherent recovered faster. | Acceptable |
| **Popovich et al, 2019, USA Retrospective Cohort** | n=54 (Exercise group n=24, Rest group n=30), age (range 8-20; mean 15±1.4 years), male n=54 (100%). Definition: 5th CISG Statement. | Early supervised exercise (SE) (<16 days) and nonearly SE (>=16 days). Exercise individualized based on each patient's activity tolerance and stage of | Return to sport clearance, symptom resolution on SCAT5 symptom scores | The early SE group was cleared for return to sport in fewer days (mean 26.5 +/- 11.2 days vs 35.1 +/- 26.5 days; P = 0.020) than the nonearly SE group. There was also a nonsignificant trend | Acceptable |

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| | | recovery from modified BCTT. | | toward fewer symptomatic days in the early SE group compared with the nonearly SE group (mean 16.7 +/- 7.1 days vs 22.4 +/- 22.5 days; P = 0.054). | |
| **Seehusen et al, 2021, USA, Prospective Cohort** | n=32, age (range 12-18, mean RTP≥28 days 14.9±1.9, RTP<28 days 15.4±1.5 years), male n=18 (56%), female n=14 (44%). Definition: 5th CISG Statement. | Fitbit Charge 3 worn to track PA from the first full day after the initial assessment until they received RTP clearance. First two weeks of data analysed. | RTP clearance as assessed by the Sports Medicine Physician (Grouped RTP < 28 days vs. ≥28 days). Post-Concussion Symptom Inventory (PCSI) was measured at their initial and RTP assessments but not primary outcome. | The ≥28 days group reported significantly greater symptom severity at initial assessment. The RTP ≥28 days group took fewer steps/day (8158±651 vs. 11,147±4013; p = 0.02), exercised fewer days/week (2.9±2.4 vs. 5.0±1.9; p = 0.01), and fewer total minutes/week (117±122 vs. 261±219; p = 0.03). Optimal cutpoints to distinguish between groups were ≥10,251 average steps/day, ≥4 exercise sessions/week, and exercising ≥134 total minutes/week. | Acceptable |
| **Sufrinko et al, 2018, USA, Prospective Cohort** | n=19, age (range 12-19, mean 15.4±2.0), male n=11 (58%), female n=8 (42%). Definition: 4th CISG Statement. | Actigraphy derived sleep and activity metrics: total daily physical activity, average physical activity, physical activity intensity/max vector magnitude, variation in total daily physical activity, time in bed, total sleep time, sleep efficiency, and variation in total sleep time. | Neurocognitive (ImPACT) and vestibular ocular motor screening (VOMS) scores. | Positive linear relationship was found between activity intensity and visual memory scores with no impact on verbal memory or reaction time. Positive relationships were also found between physical activity levels and the vast majority of the VOMS measures. Participants with lowered sleep efficiency and variation in total sleep time experienced a slower reaction time. | Acceptable |
| **Trobvich et al, 2021, USA, Prospective Cohort** | n=17, age (range 12-19, mean 15.4±2.1 years), male n=9 (53%) female n=8 | Actigraph-measured Total Sleep time (TST) and Sleep Efficiency (SE%). TST was defined as the | Ecological momentary assessment (EMA) of post-concussion symptoms (three | SE% was negatively associated with total symptoms the following day (IRR .98, | Acceptable |

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| | (47%). Definition: not reported, physician diagnosed. | total time the participant spent asleep, and sleep efficiency as the ratio of TST to the total time between in-bed and out-of bed times and reported as percentage. | surveys per day on mobile application) based on a modified Post-concussion Symptom Scale (PCSS). | 95%CI: .97, .996, P = .01), but TST was not. Both SE% (IRR .97, 95%CI: .95, .99 P = .009) and TST (IRR .91, 95%CI: .84, .999, P = .047) were negatively associated with night symptoms the following day but not morning or afternoon symptoms. TST had significant negative associations of a small magnitude with all symptoms (r=.10-.28) except light sensitivity and numbness. | |
| **Willer et al, 2019, USA Quasi-experimental** | n=151 (Exercise group n=52, Stretching group n=51, Rest group n=48), age (range 13-18; mean 15.4±1.6 years), male n=91 (60%), female n=60 (40%). Definition: 5th CISG Statement. | Exercise group: subthreshold aerobic exercise prescription using BCTT. Aerobic exercise at home or in a gym under supervision each day for 20 minutes on a treadmill or stationary bike at the prescribed HR. Stretching group: Progressive stretching program that would not significantly elevate HR. Rest group: Participants were prescribed relative rest according to the previous standard of care. | Days to recovery: defined as symptom resolution to baseline (symptom severity scores </=7 on the PCSS for 3 consecutive days), confirmed by a normal physical examination (normal neurologic examination including normal vestibular and oculomotor systems), and further confirmed by ability to exercise to exhaustion without exacerbation of symptoms on the BCTT. | The rest group recovered in 16 days (IQR, 9-23), which was significantly delayed (p=.020) compared with exercise group (13d; IQR, 10-18). The stretching group recovered in 17 days (IQR, 13-23d). 4% of the exercise group, 14% of the stretching group, and 13% of the rest group had delayed recovery (p=.190). Regarding Kaplan-Meier estimates of time to recovery, significant difference (p=.039) was found on log-rank test between treatment groups. Proportional hazards assumption was met for Cox regressions, which showed a significant difference with treatment (p=.015). | Acceptable |
| **Wilson et al, 2020, USA, Retrospective Cohort** | n=575 (Early PA n=69, No Early PA n=506), age (range 8-18 years, median 14.8 years), male | Early PA group: Those who reported participation in PA since their injury but before the initial evaluation, and No | Health and Behaviour Inventory (HBI) symptom frequency questionnaire. | On univariable analysis, the no PA group had significantly longer median symptom resolution times (16 | Acceptable |

| Study | Sample | Exposure/Intervention | Outcome | Results | Rating |
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| | n=378 (66%), female n=197 (34%). Definition: 4th and 5th CISG Statements. | PA group: those who reported that they had not. Intake questionnaire that included the question, "Are you currently doing any activity/exercise?" and asked to describe their PA level. | | days [IQR=8, 24] vs. 10.5 days [IQR=4, 17]; P=0.02). After adjusting for headache history and time from injury to clinical evaluation, early PA was associated with a shorter symptom recovery time. | |
| **Yang et al, 2021, USA, Prospective Cohort** | n=83, age (range 11-17, mean 14.2±1.9 years), male n=54 (65%), female n=29 (35%). "Physician-confirmed diagnosis of concussion". | Exposure to physical activity was measured using the ActiGraph. Exposure to cognitive activity was measured using the Narrative Clip (outside of school) and school attendance time (defined as high-intensity). | Days from injury to symptom resolution, based on daily ratings by youth on the Post-Concussive Symptom Scale. | Every 2000-step increase across week 1 associated with a 17% increase in likelihood of early symptom resolution (HR = 1.17; 95% CI, 1.02-1.34). No longer significant after adjusting for covariates, (aHR = 1.08; 95% CI, 0.91-1.28). Cognitive activity: every 60-min increase in school attendance time across week 1 associated with earlier symptom resolution, in both the unadjusted (HR = 1.17; 95% CI, 1.05-1.30) and adjusted (AHR = 1.14; 95% CI, 1.02-1.27) analyses. | Acceptable |
| **Bailey et al, 2019, USA, RCT** | n=15, age (range 14-18, mean 15.8±1.4 years), male n=7 (47%), female n=8 (53%). Definition: 5th CISG Statement. | Intervention: Daily monitored exercise at 80% of one's heart rate threshold three times per week. Control: Five stretching activities daily for 3 weeks, followed by 20-minutes daily walking. | Post-concussive scale revised (PCS-R), computerized and paper/pencil measures, and postural stability testing. | When controlled for the rates of depression, participants in the intervention group demonstrated greater improvements (PCS-R Percent Change: Mean ± SD = −63.3±17.4) improving more than those in the control group (PCS-R Percent Change: Mean ± SD = −56.8±27.8). | Inadmissible |
| **Bramley et al, 2017, USA, Retrospective Cohort** | n=417, age (range 13-18, mean 15.3±1.4 years), male n=254 (61%), female n=163 (39%). | Self-reported difficulty falling asleep and staying asleep. | Time to recovery (not operationally defined). | Self-reported presence of sleep disturbance protracted recovery time (29 days [IQR 14-84]) vs. 111 days | Inadmissible |

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| | Definition: Not reported. | | | [IQR 27-311]). Participants who were prescribed melatonin took longer to recover (153 days) compared to those not prescribed (95 days). | |
| **Buckley et al, 2016, USA, Prospective Cohort** | n=50 (Rest group n=25, Non-rest group n=25), age (range not reported, mean 19.6±1.3 years), male n=31 (62%), female n=19 (38%). Definition: 4th CISG Statement. | Rest group: The treating clinical/member of research team documented a self-reported day of complete cognitive and physical rest. Non-rest group: No recommendations or monitoring of cognitive or physical rest accommodations. | Number of days until baseline participants scored comparable to baseline on: graded symptom checklist (GSC), computerized neuropsychological test (CNT), the Balance Error Scoring System (BESS), and Standard Assessment of Concussion (SAC). | The rest group was symptomatic longer (5.2±2.9 days) than the no-rest group (3.9±1.9 days); however, no differences were noted between groups for CNT, BESS, SAC, or time to clinical recovery. | Inadmissible |
| **Chung et al, 2019, USA, Retrospective Cohort** | n=517 (Good sleep quality group n=376, Poor sleep quality group n=141), age (range 6-18, median years), male n=277 (54%), female n=240 (46%). Definition: Not Reported. | Good sleep quality: Global composite score of ≤5. Poor sleep quality: Global composite score of >6. Sleep quality assessed using Pittsburgh Sleep Quality Index (PSQI). | Time to symptom resolution once symptoms resolved on Concussion Symptom Log and the time to return to play. Generalized Anxiety Disorder Scale (GAD-7), and Patient Health Questionnaire (PHQ-8). | Participants reporting poorer sleep quality reported higher total symptom scores, GAD-7 total score, and PHQ-8 total score. Those in the poor sleep quality also took longer to experience symptom resolution, which was especially pronounced in the pediatric participants. | Inadmissible |
| **Clausen et al, 2016, USA, Pre-Experimental and Cross-Sectional** | n=22 (Post-Concussion Syndrome n=9, controls n=13), age (range not reported, 23±6 years), female=22 (100%). Definition: World health organization criteria for post-concussion syndrome (PCS). | Exercise group: subthreshold aerobic exercise prescription using BCTT. Aerobic exercise at home or in a gym under supervision each day for 20 minutes on a treadmill or stationary bike at the prescribed HR. Reference group: healthy, age-matched, aerobically trained athletes | Symptom resolution using the post-concussion symptom scale. Resolution of post-concussion syndrome was defined as the ability to exercise to exhaustion without symptom exacerbation. | Participants experiencing PCS experienced lower minute ventilation (18%) and an elevated partial pressure of end-tidal carbon dioxide (5%) and cerebral blood velocity (14%). Following the exercise intervention, participants experiencing PCS were able to exercise to exhaustion without symptom resolution. | Inadmissible |
| **Gauvin-Lepage et al, 2018, Canada,** | n=49 (Control n=13, Experimental n=36), age (range | Control: Rest or light symptom-limited activities, including limited participation | Child and parent self-reported levels of post-concussion symptom inventory | No group differences were found for PCSI symptom levels, but an effect of time was | Inadmissible |

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| **Quasi-Experimental** | 8-17, 23±6 years), male=23 (47%), female=26 (53%). Definition: World health organization criteria for post-concussion syndrome (PCS). | in vigorous sport/physical activity. Experimental: Standard care plus active rehabilitation containing five subcomponents: 1) 15-mins aerobic exercise at 50-60% HRmax, 2) 10-mins sport-specific activities, 3) 5-mins motor mental imagery of a favorite activity, 4) education on recovery and coping strategies, and 5) a home program. | (PCSI). Measures of mood/anxiety, energy level/fatigue, quality of life, balance and coordination, parental anxiety, cognitive function, physical activity participation, and satisfaction with intervention. | present indicating recovery. However, youth in the experimental group reported higher quality of life, lower anger scoring, more energy levels, and faster tandem gait speeds. | |
| **Hoffmann et al, 2017, USA, Prospective Cohort** | n=151 (Shorter sleep group n=35, No shorter sleep group n=35, Longer sleep group n=81), age (range not reported, 19.3±1.2 years), male=85 (56%), female=66 (44%). Definition: Not reported. | Self-reported hours of sleep on the SCAT3. A sleep change score was calculated as the difference between baseline and 24-48-hours post-injury. This was categorized into three categories: 1) shorter relative sleep (reduction 1+ hours), 2) no sleep change (within 1-hour of baseline), and 3) longer relative sleep (increase 1+ hours). | Duration to clinical recovery (number of days to asymptomatic), Standardized Assessment of Concussion (SAC), Balance Error Scoring System (BESS), and Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) composite scores. | Days to asymptomatic were not different between all three groups; however, symptoms severity scores were elevated for the shorter relative sleep group at both 24-48-hours and 2-4-days post-concussion. At 24-48-hours and the asymptomatic time points, ImPACT reaction time was slower for those in the shorter relative sleep group. | Inadmissible |
| **Howell et al, 2020, USA, Prospective Cohort** | n=72 (Exercise group n=39, No exercise group n=33), age (range not reported, 20.2±1.3 years), male=39 (54%), female=33 (46%). Definition: 5th CISG Statement. | Those who reported engaging in exercise between time of injury and symptom resolution. Exercise bouts included 10-15 mins of stationary biking or light jogging. | Duration to symptom resolution defined as the number of days to return to a zero on the post-concussion symptom score. | Between groups there were no difference between groups for initial symptom severity, symptom resolution time, or time until medical clearance between the exercise and no exercise groups. When adjusting for time to evaluation from injury, lower PCSS were found within the exercise group and less severe cognitive, fatigue, | Inadmissible |

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| **Leddy et al, 2013, USA, Quasi-Experimental** | n=12 (Exercise group n=4, Stretching group n-4, Control n=4), age (range 17-33, 23.4±5.8 years), male=4 (33%), female=8 (67%). Definition: World health organization criteria for post-concussion syndrome (PCS). | Exercise group: Progressive aerobic exercise at 80% of heart rate attained on BCTT, 6-days per week for 20-minutes. Stretching group: Low impact stretching and breathing program for 12-weeks, 6-days per week for 20-mins. Control group: Participants instructed to not exceed a heart rate maximum of 40-50%. | Functional MRI math task modelled from the Automated Neuropsychological Assessment Metrics (ANAM). For all participants, accuracy (percent correct) and speed (mean reaction time) were recorded. | No differences were noted for accuracy or reaction time during the test between groups; however, at time one controls had elevated activation within the cerebellum, lingual gyrus, and posterior cingulate gyrus. At the second time point the stretching group displayed less activation compared to the controls within the thalamus, cingulate gyrus, and the cerebellum. | Inadmissible |
| **Maerlender et al, 2015, USA, RCT** | n=28 (Control n=15, Exertion n=13), age (range not reported), male=8 (29%), female=20 (71%). Definition: Not reported. | Exertion group: A daily exertion protocol on a stationary bicycle at a perceived exertion of mild-to-moderate. Control group: No exertion greater than that required for normal daily activities. | Test scores, balance, and symptoms being comparable to baseline levels. | Days to recovery was not different between groups. During light, moderate, and strenuous rides, a symptom increase of 1.8, 0.5, and 7.0 occurred, respectively. The amount of daily vigorous activity was associated with an increasing recovery duration. | Inadmissible |
| **Stumph et al, 2019, USA, Prospective Cohort** | n=187 (Early exercise group n=112, Comparison group n=75), age (range 10-17), male=103 (55%), female=84 (45%). Definition: 4th CISG Statement. | Early exercise group: Subsymptom exercise without any possible head contact/injury. Exercise intensity was not standardized, but participants were advised to stop exercise if they experienced a worsening of symptoms. Comparison group: Participants who did not engage in exercise. | Days from injury and initial visit to symptom resolution. | Males in the early exercise group had a longer time to symptom resolution; however, females did not differ compared to the comparison group. Generalized linear models displayed prolonged recovery for the early exercise group when controlling for sex, age, concussion history, symptom score at injury, and days to initial visit. | Inadmissible |
| **Walton et al, 2021, USA,** | n=40 (Concussed n=20, Controls | Comparing mood, psychological, and | Self-reported symptomology via | No differences were found between | Inadmissible |

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| **Prospective Cohort** | n=20), age (range 18-29, 9.3±1.1 years), male=18 (45%), female=22 (55%). Definition: 4th and 5th CISG Statements. | behavior factors during recovery from concussion compared to healthy matched controls. | the head injury scale (HIS-r), healthy, Health-Related Quality of Life (HRQOL), TBI-Quality of Life (TBI-QOL), and Crude Appetite Score. | concussed athletes and controls for anxiety, resilience, and fatigue scores; however, concussed athletes greater sleep disturbances and stigma reportings. Over time, fatigue scores increased for those with a concussion. | |