Supplement 4: Data Extraction Tables

Table 1. Data Extraction Table for the SCAT 3 (Adult Version only)

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| **ID** | **Author, year, study design,** | **Participants (N, Sex, Age, sport)** | **Exposure/Intervention** | **Outcome** | **Results (including statistical outcomes)** | Risk of Bias | LOE |
| 1 | Black et al, 2012. Retrospective cohort study. | 759 Canadian College Athletes, M&F, mixed sports. | Pre-Post injury comparisons. Epidemiological data. | SCAT Sx only, ImPACT | A total of 81 concussions were reported and diagnosed among 759 athletes. Significantly, more female athletes were concussed than male athletes (13.08%-7.53%, respectively; P = 0.014) with the highest rates in women's rugby [incidence density (ID) = 20.00 concussions per athlete-season], women's ice hockey (ID = 18.67 per athlete-season), and men's basketball (ID = 20.00 per athlete-season). There were no sex differences observed in symptom recovery and cognitive recovery. | L | 3 |
| 2 | Chin, Esther Y.et al., 2016.  Prospective Cohort Study. | 2018 HS, College, M&F, 77% Males; Mixed Sports, 166 Concussed/166 controls. | Baseline normative data. Pre-Post injury comparisons. | SCAT3  BSI-18  WTAR | Sex, level of competition, ADHD, LD) estimated verbal intelligence were  associated with baseline scores on SCAT3 components (small to moderate effect sizes). Female sex, high school, and ADHD were associated with higher baseline symptom ratings (d = 0.25-0.32). Male sex, ADHD, and LD were associated with lower baseline SAC scores (d = 0.28-0.68). Male sex, high school level of competition, ADHD, and LD were associated with poorer baseline BESS (d = 0.14-0.26). Post-injury symptom checklist had largest effect size at 24-hours (d = 1.52), with group differences diminished but statistically significant at day 8 (d = 0.39) and non-significant at day 15. Effect sizes for the SAC and BESS were small to moderate at 24 hours (SAC: d = 20.36; modified BESS: d = 0.46; full BESS: d = 0.51) and became non-significant at day 8 (SAC) and day 15 (BESS). ROC analyses demonstrated a stronger discrimination for symptoms (area under the curve [AUC] = 0.86) than cognitive and balance measures (AUCs = 0.58 and 0.62, respectively), with comparable discrimination of each SCAT3 component using post-injury scores alone versus baseline-adjusted scores (P = .71-.90). Normative conversion tables and RCI criteria were created to facilitate the use of the SCAT3 both with and without baseline test results. | L | 3 |
| 3 | Echlin, P. S., et al., 2012.  Prospective Cohort Study. | 25 male and 20 female Canadian College Ice Hockey athletes | Pre-post season measurements. Physician observed concussions. | SCAT2, ImPACT, MRI | 11 concussions during 55 physician-observed games (20%). Number of concussions per 1000 Athlete Exposures (AE)=10.70 for men and women combined in regular season play, 11.76 for men and women combined across both the regular season and playoff season, 7.50 for men and 14.93 for women in regular season play, and 8.47 for men across both the regular season and playoff season. One male player experienced repeat concussions. No concussions were reported during practice sessions, and 1 concussion was observed and diagnosed in an exhibition game. Neuropsychological testing suggested no preseason/postseason differences between athletes who sustained a physician-diagnosed concussion and athletes who did not sustain a physician-diagnosed concussion on either the ImPACT or SCAT2. The athletes who sustained a physician-diagnosed concussion demonstrated few reliable changes post-injury. | H | 4 |
| 4 | Echlin, P.S., et al. 2010. Prospective Cohort Study. | 67 male, Avg age =18.2, Ice Hockey. | Epidemiologic data. Physician observed concussions | SCAT2, ImPACT | 21 concussions during 52 physician-observed games (incidence 21.5 concussions per 1000 AE. 5 players experienced repeat concussions. No concussions were reported during practice sessions. A concussion was diagnosed by the physician in 19 (36.5%) of the 52 observed games. | H | 4 |
| 5 | Echlin, P.S. et al. 2010 (b).  Prospective Cohort Study. | 67 male, Avg age =18.2, Ice Hockey. | Pre-post season measurements. Physician observed concussions. | SCAT2, ImPACT | Seventeen players sustained a physician-observed or self-reported, physician-diagnosed concussion during a physician-observed ice hockey game. The mean clinical return-to-play duration (in 15 cases) was 12.8 ± 7.02 days (median 10 days, range 7–29 days); the mean number of physician office visits by players who suffered a concussion (15 cases) was 2.1 ± 1.29 (median 1.5 visits). Five of the 17 players who sustained a concussion also suffered a recurrent or second concussion. One of the 5 individuals who suffered a repeat concussion sustained his initial concussion in a regular season game that was not observed by  a physician, and as a result this single case was not included in the total of 21 concussions. This initial concussion of the player was identified during baseline testing 2 days after the injury and was subsequently medically diagnosed and treated. The mean interval between the first and second concussions in these 5 players was 78.6 ± 39.8 days (median 82 days), and the mean time between the return-to-play date of the first and second concussions was 61.8 ± 39.7 days (median 60 days). | H | 4 |
| 6 | Galetta, K. M. et al. 2015.  Prospective Cohort Study | 243 Youth (mean age=11, 16% female) athletes; 89 Collegiate (mean age 20, 26% female). Ice Hockey & Lacrosse | Pre-post injury comparisons. | King-Devick (K-D), SAC, Tandem Gait | Baseline time scores for the K-D test were lower (better) with increasing participant age (p<0.001, linear regression models). Among 12 athletes who sustained concussions K-D scores worsened from baseline by an average of 5.2 seconds; improvement by 6.4 seconds was noted for the non-concussed controls  (n = 14). The vision-based K-D test showed the greatest capacity to distinguish concussed vs control athletes based on changes from pre-season baseline to post-injury (receiver operating characteristic [ROC] curve areas from logistic regression models, accounting for age = 0.92 for K-D, 0.87 for timed tandem gait, and 0.68 for SAC; P = 0.0004 for  comparison of ROC curve areas). | M | 3 |
| 7 | Marinides, Z., et al., 2015.  Retrospective case series. | 217 mixed sport College Athletes, 30 with concussion | Pre-post comparisons. | King-Devick (K-D), SAC, BESS, ImPACT | Among 30 athletes with first concussion during their athletic season (n 5 217 total), differences from baseline to post-injury showed worsening  of K-D time scores in 79%, while SAC showed a 2- point worsening in 52%. Combining K-D and SAC captured abnormalities in 89%; adding the BESS identified 100% of concussions. | H | 4 |
| 8 | Miller, JH et al., 2016. Single center retrospective case control study. | 294 pediatric patients presenting at Concussion Clinic. Mixed sports. Mean age 13.7 =/-2.5; 23% female. | Post injury comparisons of presenting symptoms, injury mechanics and recovery. | SCAT2 | No age difference in case and control groups (p = 0.7). On SCAT2, a previous history of concussion (aOR 3.67, 95% CI 1.51–8.95), presenting SCAT2 score < 80 (aOR 5.58, 95% CI 2.61–11.93), and female sex (aOR 3.48, 95% CI 1.43–8.49) were all associated with a higher risk for post-concussive symptoms lasting more than 28 days. For patients without SCAT2 scores, female sex and history of ADHD significantly increased the odds of prolonged recovery (aOR 4.41, 95% CI 1.93–10.07 and aOR 3.87, 95% CI 1.13–13.24, respectively). Concussions resulting from playing a non-helmet sport were also associated with a higher risk for prolonged symptoms in patients with and without SCAT2 scores (OR 2.59, 95% CI 1.28–5.26 and OR 2.17, 95% CI 0.99–7.73, respectively). Amnesia, balance abnormalities, and a history of migraines were not associated with symptoms lasting longer than 28 days. | H | 4 |
| 9 | Putukian, M. et al. 2015. Diagnostic accuracy study. | 263 mixed sport college athletes at baseline, 66.9% male, avg age 20.3 (SD 1.74), 32 athletes with concussion, compared with non-contact and contact control athletes | Baseline normative data. Pre-Post injury comparisons. | SCAT2; symptom checklist, SAC, m-BESS, GAD-7, PHQ-9, modifiers | The total SCAT-2 score and the composite scores of symptoms, symptom severity, and balance were significantly different in concussed groups after injury when compared with baseline. When comparing performance in concussed versus control athletes, all subcomponents of the SCAT-2 were significantly different. No differences in baseline SCAT-2 scores  on self-reported history of concussion. At baseline, anxiety and depression screening scores were associated with higher symptom scores. When compared with baseline, a 3.5-point drop in SCAT-2 score had 96% sensitivity and 81% specificity in detecting concussion. When examined to exclude baseline scores, a cutoff value of 74.5 was associated with 83% sensitivity and 91% specificity in predicting concussion versus control status. | L | 3 |
| 10 | Samadani, U . et al. 2015. Cross sectional study | 75 community trauma patients; age 18-60, 64 controls age 7-76. means for age all groups between 35-40. Control group 47.9% female, non-head injury group 39% female, negative head CT group 44.4% female, positive head CT group 35.9% female | Post injury comparisons of presenting symptoms, eye tracking, and cognitive scores. | eye tracking metrics, SCAT3 | Five out of five measures of horizontal disconjugacy were increased in positive and negative head CT patients relative to non-injured control subjects. Only one of five vertical disconjugacy measures was significantly increased in brain-injured patients relative to controls. Linear regression analysis of all 75 trauma patients demonstrated that three metrics for  horizontal disconjugacy negatively correlated with SCAT3 symptom severity score and positively correlated with total SAC S score. Abnormal eye-tracking metrics improved over time toward baseline in brain-injured subjects observed in follow-up. | M | 4 |
| 11 | Sasaki, et al. 2014. Cross sectional study | Ice hockey, men and women. 39 players scanned at end of 2011-12 season, 5 excluded, 18 male, 16 female. | Post Injury comparisons of concussed and non-concussed athletes on neuroimaging and cognitive data. | DTI, ImPACT, SCAT2 (unclear if all done at same time post season) | Significant increase in FA and AD, and a significant decrease in RD and trace in several brain regions in the Concussed group, compared with the Non-concussed group (p < 0.05). Increased AD was observed in a small area in the left corona radiata. DTI measures neither correlated with the ImPACT nor SCAT2 | M | 4 |
| 12 | Vernau, B.T. et al., 2015. Prospective cohort study. | 108 male hockey players (mean age 12.5,), all BL assessments in 53, NPC in 78, KD in 103, ImPACT in 77. 11 subjects sustained concussion on avg 109 days after injury. | Comparisons of oculomotor and cognitive scores at baseline and post-injury. | Baseline KD, near point of convergence (NPC), ImPACT and SCAT3 or child SCAT3. | No relationship between baseline convergence, ImPACT or K-D times. Worse (higher) K-D times were associated with worse (lower) scores on  the ImPACT visual motor speed and reaction time subtests There was no association between K-D score and SCAT3 memory score. 10 patients who took the K-D test post-injury, eight scored faster and two scored  one second slower than their baseline (range 2– 19 days, M = 8, SD = 5.4) | H | 4 |
| 13 | Shehata, N. et al. 2009.Cross sectional study. | 260 mixed sport college athletes aged 17-32, mean age 20.5. 190 men, 70 women, 167 no prior concussion (NC), 93 previously concussed (PC) | Baseline normative data | Baseline SCAT over 3 seasons, 2005-07 | 41.2% of all athletes had a total post-concussion symptom scale (PCSS) score of 0. Mean baseline PCSS: all participants 4.29; men 3.52; women 6.39; NC=3.75, PC=5.25. Most frequently reported symptoms: fatigue/low energy (37% of subjects), drowsiness (23%), neck pain (20%), difficulty concentrating (18%) and difficulty remembering (18%). Median immediate recall = 5/5. Women median =5/5 on delayed recall, all others = 4/5. Months in reverse successfully completed by 91.6% of sample. | M | 4 |
| 14 | Schneider, K. et al, 2010.  Multi-site Cross sectional study combining data from three prospective cohort studies | 4193 ice hockey players, stratified by prior concussion (PC), age group, gender. 2154 iPee wee (aged 11-12), 33 females, 1971 (bantam) aged 13-14, 14 females, total of 324 female athletes age 9-17. | Baseline normative data | Baseline SCAT2 performed in Edmonton, Quebec city, Montreal (no mBESS data) | 781 players (18.6%) had previous history of concussion. Fatigue, low energy, followed headache most common symptoms The majority of youth players could recite all five words immediately but only three words when delayed. A smaller proportion of the males were able to report the months of the year in reverse order compared with females of a similar age. The median number of digits recited in reverse order was 4. | M | 3 |
| 15 | Snyder, A.R. & Bauer, R.M. 2014. Multi-site cross sectional study | 761, 9-18 yo, M & F,  Mixed sport subjects, excluded if concussion within past 3 months. | Baseline normative data | Baseline SCAT2 performed in 3 settings | Findings indicate a significant age effect on SCAT2. Older adolescents and teenagers produced greater scores than younger children (ages 9 to 11) driven by age differences on SAC, BESS, and PCSS. Females endorsed greater numbers of symptoms at baseline than males. | L | 3 |
| 16 | Silverberg, N.D. et al. 2014.Cross sectional study. | 26 community trauma pts with mTBI, age 36.6 SD 12.2, 19 (73.1%) male. 24 w GCS 15, 2 with GCS 14., 33 controls age 42.8 SD 12.2, 17 (51.5%) male. All controls were ankle injuries | Injured vs. control comparisons. | SCAT2 and KD test in ER, MRI within 10 days for mTBI pt | MTBI differed from those without MTBI SCAT2 components: PCSS (Cohen’s d.1.02–1.15, p50.001) and SAC(d.0.81, p.0.004), but not the K-D (d.0.40, p.0.148). In a logistic regression analysis, the K-D Test did not contribute over and above these two measures in predicting group membership (MTBI vs. control), p.0.191. Low K-D Test scores in the MTBI group (<1 SD below controls) were not associated with poor SCAT2 performance, LOC, or abnormalities on MRI suggesting these cases may have been false positives. | M | 3 |
| 17 | Wang, Y. et al, 2015.Case Series. | HS and College Football athletes. 18 concussed athletes (14 college, 4 HS) avg | Pre-post injury comparisons. Injured vs. control comparisons. | CBF maps using ASL MRI. SCAT3, ANAM, ImPACT, WTAR | While the control group did not show any changes in CBF between the two time-points, concussed athletes demonstrated a significant decrease in CBF at 8 days relative to within 24 h. Symptom scores on SCAT3 and cognitive measures (SAC) demonstrated significant impairment (vs. pre-season baseline levels) at 24 h (SCAT, p < 0.0001; SAC, p < 0.01) but returned to baseline levels at 8 days. Two additional computerized neurocognitive tests, the Automated Neuropsychological Assessment Metrics and Immediate Post-Concussion and Cognitive Testing, showed a similar pattern of changes. | L | 3 |
| 18 | Dettwiler, A. et al. 2014. Matched case series. | 15 college mixed sport athletes with SRC, (12 male, 3 female, age 19.8 SD .94) 15 non-contact athlete controls (12 male, 3 female, age 19.8, SD 1.73) | Concussed vs. non-concussed group and individual comparisons | SCAT2, ImPACT paper/pencil tests, fMRI | Compared with age and sex matched normal controls, concussed subjects demonstrated persistent, significantly increased activation for the 2 minus 1 n-back contrast in bilateral dorsolateral prefrontal cortex (DLPFC) in all three sessions and in the inferior parietal lobe in session one and two (alpha < 0.01 corrected). Measures of task performance revealed no significant differences between concussed versus control groups at any of the three time points with respect to any of the three n-back tasks | L | 3 |
| 19 | Wilkins, S. et al. 2014. Retrospective cohort study. | Mixed sport age 0-18, community sample | Comparisons between concussion patients exposed to standardized and on-standardized management protocol | SCAT2 for some | Five hundred eighty-nine patients were identified, including 270 before standardization (2007-2011) and 319 after standardization (2011-2012). Statistically significant differences (p < 0.0001) were observed between the 2 groups for multiple variables: there were more girls, more first-time concussions, fewer initial presentations to the emergency department, more consistent administration of the SCAT2, and more consistent supervision of return to play and return to think after adoption of the protocol. | M | 4 |
| 20 | Hanninen, T., et al. 2015.Cross sectional study. | 304 athletes, male ice hockey players, age 16-40, mean 25.3 | Baseline normative data | baseline SCAT3 | The average number of concussions sustained prior to testing was 1.2 [SD=1.5, interquartile range (IQR)=0-2.0, range=0-12] and the mean time of recovery after the last concussion was 16.7 days (SD=31.3, IQR=7.0-14.0, range=0-308). The means, SDs, medians (md), IQRs and ranges of the SCAT3 components were distributed as follows: (i) Symptom Score (n=205), mean=1.52, SD=2.5, md=1.0, IQR=0-2.0, range=0-21; (ii) Symptom Severity (n=205), mean=2.2, SD=3.8, md=1.0, IQR=0-3.0, range=0-27; (iii) SAC (n=204), mean=26.8, SD=1.7, md=27.0, IQR=26.0-28.0, range=19-30; (iv) Co-ordination Score (n=194), mean=1.0, SD=0.1, md=1.0, IQR=1.0-1.0, range=0- 1.0; (v) M-BESS (n=197), mean=1.9, SD=2.4, md=1.0, IQR=0-3.0, range=0-20.0; (vi) Tandem gait (n=75), mean=10.9, SD=1.8, md=11.0, IQR=9.6-12.3, range=6.7-14.3. The sub-scores of the four SAC components were distributed as follows: (i) Orientation (n=205), mean=4.9, SD=0.4, md=5.0, IQR=5.0-5.0, range=3.0- 5.0; (ii) Immediate memory (n=206), mean=14.5, SD=1.0, md=15.0, IQR=14.0-15.0, range=5.0-15.0; (iii) Concentration (n=206), mean=3.8, SD=0.8, md=4.0, IQR=3.0-4.0, range=2.0- 5.0; and (iv) Delayed recall (n=206), mean=3.7, SD=1.1, md=4.0, IQR=3.0-4.0, range=0-5.0. The most commonly endorsed symptoms on the Symptom Scale were (i) neck pain (n=52, 25.4%), (ii) fatigue (n=48, 23.4%), (iii) trouble falling asleep (n=35, 17.1%) and (iv) drowsiness (n=32, 15.1%). On the SAC, the most difficult components were concentration and delayed recall. Only 43 (20.9%) and 50 (24.3%) performed flawlessly on these components, respectively. Spearman's correlation between the m-BESS and Tandem gait was non-significant (r=0.015, p=0.9). | L | 3 |
| 21 | Jinguji, T., et al., 2016. Cross sectional study | 214 HS participants w mean age 15.71 y (range 13-19), total of 59 females and 155 males. BL SCAT2 analysed as group and stratified based on age, sex and sport. Broken down into ages 13-15, 16-19. | Baseline normative data | baseline SCAT2 | The average SCAT2 score for these high school athletes was 89 of a possible 100 with a SD of 6 units. Athletes reported two or three symptoms at baseline with older students reporting more symptoms than  younger ones. The average balance score was 25.82 (of 30), and all athletes were able to complete the double leg stance. Females scored significantly higher on the balance, immediate memory and concentration scores. Concentration scores in non-concussed high school  athletes were low. Only 67% of high school athletes could recite the months of the year backward and only 41% could correctly sequence 5 digits backward. Only 55% of high school football players could correctly  recite the months of the year backward and 32% could sequence 5 digits. | M | 4 |
| 22 | Zimmer, A. et al., 2015.Cross sectional study | 477 Mixed college athletes, 70% male.18-23 year old | Baseline normative data | Baseline only: SCAT2, SCAT3 | The average number of symptoms endorsed was 1.75.  Average SAC and BESS scores were 27.17 (SD.2.01) and 25.64 (SD.4.07), respectively. Little or no difference was found in total and component scores due to sex, sport type, or concussion history. | M | 4 |

Abbreviations: ID = Identification number, N = number, LOE = Level of Evidence, M=Male; F=Female; L=low; M=Moderate; H=High; Sx=Symptoms; SCAT=Sport Concussion Assessment Tool; ImPACT = Immediate Post-Concussion Assessment and Cognitive Test, L = Low, M = Moderate, H = High, SAC = Standardized Assessment of Concussion; HS=High School, BSI = Brief Symptom Inventory, ADHD = Attention Deficit Hyperactivity Disorder, LD = Learning Disability, BESS: Balance Error Scoring System, WTAR = Wechsler Test of Adult Reading, ROC= receiver operating characteristic, RCI = Reliable Change Index, MRI = Magnetic Resonance Imaging, Avg = average, K-D = King- Devick, yo = years old, AE = Athlete Exposure, GAD-7 = Generalized Anxiety Disorder – 7 item scale, PHQ – 9 = Patient Health Questionnaire – 9 survey, CT = computerized tomography, DTI = Diffiusion Tensor Imaging, FA = fractional anisotropy, AD = axial diffusiviity, RD = radial diffusivity, BL = baseline, NPC = near point convergence, PCSS = Post-Concussion Symptom Score, ER = emergency room, GCS = Glasgow Coma Scale, pts = patients, mTBI = mild traumatic brain injury, SD = standard deviation, LOC = loss of consciousness, CBF = cerebral blood flow, fMRI = functional magnetic resonance imaging, SRC = sport related concussion

Table 2. Physical/Observable Signs Data Extraction Table

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Article ID#** | **Authors, year, design, duration, country** | **Participants (n, age, sex, sport)** | **Exposure/**  **Intervention (Definition)** | **Outcome (Definition)** | **Results including Statistical outcomes** | **Risk of Bias score** | **Level of evidence** |
|  | Comper & Hutchison 2012.  Seasons 2006-11  Canada.  Abstract only. | National Hockey League.  341 Videos | Retrospective video analysis of confirmed concussions. | Used Heads Up Checklist | The most common clinical signs following concussion included clutching of head/face, obvious disequilibrium following contact, or 'slow to get up'. |  | 5 |
|  | Davis, Makdissi  2016.  Seasons 2012-13,  Australia | Professional Australian Footballers  n=90 (50% concussed)  male 100% | Application of hierarchical flowchart | Determine the highest ranked sign in each case | Concussed- Highest ranked sign “no protective action” (25%). Add “impact seizure”, Motor incoordination”, “blank vacant look” identified 48.9% of concussed players.  Non concussed commonly demonstrates “facial injury”, clutching at head”, slow to get up”. | L | 3 |
|  | Makdissi, Davis 2016.  Seasons 2012-13,  Australia | Professional Australian Footballers  n=102 | Intra- & Inter-rater review of video signs of concussion | Club doctor clinical diagnosis used as confirmation of concussion | Highest sensitivity “slow to get up” (87%). Highest Specificity “blank & vacant look” (100%), “motor incoordination” (95%), “impact seizure” (93%) “rag doll appearance” (91%). “Blank and vacant look” (100%) and “motor incoordination” (81%) had the highest positive predictive value. | L | 3 |
|  | Gardner et al 2015.  Season 2013 Australia | Professional Rugby League, n=19 | Video review of all 20 concussions from 3 NRL teams | Team physician diagnosis of concussion | “LOC” 30%.  Seizure 0%  “body going limp” 45%  “Blank or vacant stare” 53% of those with video available.  “wobbly legs” 12/18.  80% at least one sign. | M | 4 |
|  | Gardner et al 2016.  Season 2014.  Australia | Professional Rugby League, n=122 (162 events) | Inter-rater (IRR) video review of all events recorded under the ‘Concussion Interchange Rule’ (CIR) | Video signs of those removed from field under CIR | IRR  LOC 0.68  Seizure 0.70  Unsteady 0.64  Clutch head 0.50  Loss muscle tone 0.45  Blank vacant stare 0.36  Signs present  LOC 31%  Seizure 2%  Loss muscle tone 54%  Clutch head 70%  Blank vacant stare 66% (where video available)  Balance 66% | M | 4 |
|  | McCrory 1997.  Season 1996.  Australia | Professional Australian Footballers. n=51 | Assessment of tonic posturing in concussed footballers | Video analysis of concussions confirmed by team doctor. | Tonic posturing in 14/51 concussions.  LOC mean Duration in those with tonic posturing 163 secs v non-tonic posturing cases 24 secs (p=0.004) | M | 4 |
|  | McCrory & Berkovic. 2000.  Season 1995-97.  Australia | Professional Australian Footballers.  n=102 videos (selected from 234 concussions). | Assessment of tonic posturing, clonic movements, righting movement, and gait unsteadiness | Video analysis performed by 2 independent observers. Concussions verified by team doctor. | LOC in 75 players, range 10-300 secs.  Tonic posturing in 25 players, 2-30 secs.  Clonic movements in 6 players, <10 secs in 5/6.  Righting movements 40 players.  Gait unsteadiness in 42 players. | M | 4 |
|  | Tenyi et al 2016.  Hungary | 25 concussed. Amateur & Professional Sports; 24% from criminal assault.  Ages 10-30 years. | Videos of concussive convulsions selected from YouTube. | No clear medical data. Relied heavily on Comments posted to YouTube. | 12/25 videos cut before end of convulsions.  Convulsions duration 7-72secs.  Eyes open in 12, closed in 3. Vocalising in 3, non-vocalising in 8.  Fencing response 16 cases – short latency (0-1secs), duration 12±13secs. Bear hug position 5 cases – short latency.  Other tonic phenomena 12 cases – short latency.  Clonus – long latency 6±3 secs. | M | 5 |

Abbreviations: NRL=National Rugby League; LOC=Loss of consciousness; IRR=Inter-rater reliability; CIR=Concussion Interchange Rule; Secs=Seconds.

Table 3. Oculomotor Assessment Data Extraction Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Authors, year, study design** | **Participants (N, Sex, Age, sp*or*t)** | **Exposure/Intervention** | **Outcome (Definition)** | **Results (including Statistical outcomes)** | **Risk of Bias Score** | **LOE** |
| Duenas et al. 2014. Case series. | N=13, male, Median 16.5y ±2, football. | Immediately following a concussion and after the match to identify any unrecognized events. | KD Test, Sideline Concussion Testing | No stats performed. Mean baseline 42.98 s, range 30.8-56.9 s. Concussed individuals took significantly longer time to complete the test, increase of 5-8 s, which returned to baseline 1-2 weeks post-concussion. | 6 | 4 |
| Galetta et al. 2011A. Cross sectional. | N=39, 38 males, 1 female, 24 y (Range=16-53), boxers and MMA fighters. | Boxers: Immediately after the sparring session. MMA fighters: immediately after bout, but 3 participants were delayed 30-60 min due to non-head injuries. | KD Test | Post-fight KD scores were significantly worse for players with head trauma without LOC (59.1±7.4 vs 41.0±6.7 s, p<0.0001), and participants with head trauma with LOC also had worse scores (65.5±2.9 vs 52.7±2.9 s, p<0.0001). Mean increased (worse) time was 11.1 s (p<0.001). Those with no head trauma improved by 2 s. | 10 | 4 |
| Galetta et al. 2011B. Case series. | N=219, 182 male, 37 female, 20.3 y ±1.4, mixed sports. | Immediately | KD Test | Baseline KD scores (best) were 37.9 s (23.4-52.1). Sideline KD scores were significantly higher for those who had a concussion during the game (n=10, 46.9 vs 37.0 s at baseline). There was an average 5.9 s worsening (p=0.009). | 11 | 4 |
| Galetta et al. 2013. Case series. | N=27, all male, 28±5y, professional ice hockey. | Immediately | KD Test | No stats. Median baseline scores were 36.1 s (range 23.4-52.1). The two players with concussions scored 4.2 s and 6.4 s longer on sideline KD test. | 11 | 4 |
| Galetta et al. 2015. Case series | Youth N=243, 204 male, 39 female, 11±3y, ice hockey.  College N=89, 66 male, 23 female, 20±1y, lacrosse. | Immediately | KD Test | Among concussed athletes, KD worsened from baseline by an average of 5.2 s vs. improvement by 6.4 s for non-concussed control athletes (p=0.002). | 12 | 4 |
| King et al. 2012. Case series. | N=50, all male, 19.3±4 y, amateur rugby | Immediately, within 30 min of the injury, post-match & 3,7,14, and 21 days post injury | KD Test | Pre-competition baseline was 48.2 s (34.6-62.0). Three payers with witnessed events scored significantly lower than baseline (5-7.1 s, p=0.025). 2 players had greater than 5 s increases post-match but this was not significant. | 10 | 4 |
| King et al. 2013. Case series. | N=37, all male 22±4y, amateur rugby. | Immediately, within 30 min of the injury, post-match & 3,7,14, and 21 days post injury | KD Test | Authors found that both witnessed and unwitnessed concussions had significantly longer KD test times and that witnessed concussions took longer than non-witnessed concussions on the date of injury (but report a p value of 0.063, which is not significant). There was more variability in the witnessed concussion cohort. | 10 | 4 |
| King et al. 2015A. Case series. | N=104, all male, 23.7±5 y, amateur rugby. | 15 min rest period after injury then KD test | KD Test | Baseline median KD scores were 45.1s (IQ range: 41.1-50.6). Witnessed concussion KD score increased by 6.2 s (IQ range: 4-8.8) p=0.012 and unwitnessed concussion increased by 4.6 s (IQ range: 3.6-6) p<0.001). Average increase in KD scores for concussion was 4.6 s (p<0.001). | 10 | 4 |
| King et al. 2015B. Case series. | N=19, 14 male, 5 female, 10.4±0.9 y, junior rugby. | Immediately | KD Test | Baseline KD test score was 62.0±9.8 s, post-match average test score was 58.8±10 s, and players with “unwitnessed concussions” had an increase of 7.4±7 s post-match (p=0.018) | 10 | 4 |
| Leong et al. 2014. Cross sectional. | N=34, 29 male, 5 female, 25.8±8.5 y, boxing. | Immediately and post-fight | KD Test | Six players witnessed to have overt head trauma as decided by the physician but only 1 scored significantly worse on the KD test and only one was diagnosed with a concussion by the physician after other measurements. Average baseline KD test was 41±8.4 s, which improved to 39.3±9.1 s. The concussed athlete went from 45.1 to 48.3 s (+3.2 s). | 10 | 4 |
| Leong et al. 2015. Cross sectional. | N=127, 119 male, 8 female, 19.6±1.2 y, mixed sports. | Immediately post injury for football players only (no basketball concussions) | KD Test | Baseline KD test was 35.9 s (26-54.5), which improved to 34.5 s (p<0.05) for footballers post- season and to 31.8 s (p<0.05) for basketballers post-workout. The KD score for concussed footballers post-injury increased by 4.4 s (-0.9 - 15.6), p<0.005. | 10 | 4 |
| Marinides et al. 2015. Case series. | N=221, 150 male, 71 female, university aged, mixed sports. | 23/28 athletes tested day of injury, 5/28 reported it a few days later. KD test was done a median of 87 min after injury. | KD Test | Baseline KD score was 42.4 s (range 26.5-66.5). KD score for those who had a concussion went from 44.0 s (26.5-65.1) to 51.2 s (30.4-170.6). Change was 4.4 s (-4.9 to 130.7), p=0.0001 | 9 | 4 |
| Pearson et al. 2007. Cross sectional. | N=12, all male, university aged, boxing. | Post-fight | Saccadometer | In 6 boxers the median latency was significantly increased (p<0.05) post-match. The 4 with the greatest increase seemed to have more head insults assessed by blow tallies. The one with the second highest increase (34ms, p<0.01) was diagnosed with a concussion. | 7 | 4 |
| Seidman et al. 2015. Case series. | Non concussed: 328, 15.4±1.3y, all male | Immediately post-injury | KD Test | Baseline for players without concussion improved from 47.4±9.7 s to 46.8±11.8 s post- game (p=0.73). KD score in players with concussion went from baseline 47.1 s (33.3-67.5) to 66.2 s (51-72.1), p=0.003 | 12 | 4 |

Abbreviations: Y=years; KD=King-Devick; S=seconds; MMA=Mixed Martial Arts; LOC=Loss of consciousness

Table 4. Sideline Assessment Data Extraction Table

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Author, year** | **Participants (n, age, sex, sport)** | **Exposure/Intervention (Definition)** | **Outcome (Definition)** | **Domain** | **Results (Including statistical Outcomes)** | **Risk of Bias** | **Study Type/Level of Evidence** |
| Zimmer, A.; Piecora, K.; Schuster, D.; Webbe, F.; 2013. | N=437 (males=273, females=164,19.61+1.64yrs, NCAA DII student-athletes) | Concussion Resolution Index (CRI), SAC,and BESS compared at baseline between sports, teams, and sex | Determine effect of premorbid factors of concussion baseline measures | neurocog (CRI)/SAC/BESS - sport differences | No sport, team, or sex differences on SAC (p>.05); Men's basketball scored worse on BESS (p=.002) and CRI (p<.001) | 11 | Cross-sectional -3 |
| Onate, J. A.; Beck, B. C.; Van Lunen, B. L.. 2007. | N=21 (20.1+1.4yrs, collegiate baseball) | BESS test in two environments (controlled locker room and uncontrolled sideline) | Determine if testing envrionment affects BESS | Balance (BESS) | Worse BESS scores during uncontrolled sideline environment (7.33+/-2.11) vs controlled clinical environment (5.19+/-2.16) | 12 | Experimental, randomized, repeated measures - 2 |
| Rahn, C.; Munkasy, B. A.; Barry Joyner, A.; Buckley, T. A. 2015. | N=38 (females, 20.1+1.1yrs, NCAA D1 soccer (N=17), volleyball (N=13), softball N=8); controls N=38 (females, 20.8+1.1yrs, recreationally active female college students) | BESS test in different environments (baseline clinical, live football setting, and live basketball setting) | Examine sideline environment on BESS performance | balance (BESS) | Worse BESS scores by student athletes at football (12.2+/-6.4) setting, compared to baseline clinical setting (10.6+/-5.1) | 12 | Prospective longitudinal cohort - 2 |
| Register-Mihalik, J.; Guskiewicz, K. M.; Mann, J. D.; Shields, E. W. 2007. | N=247; high school and collegiate athletes (baskeball, football, lacrosse, and soccer); randomly selected; 16.65+1.87yrs; | GSC, ANAM, SAC, BESS assessed in 3 different headache groups (no baseline headache, baseline headache, and post-traumatic headache at day-1 postinj) | Examine effects of preseason baseline headache and posttraumatic headache on overall symptoms, neurocognitive function, and balance | sx and ANAM/BESS | Elevated symptom severity scores at day 1 postinjury in both headache groups; and headache groups had deficits in select neurocognitive tests (p<.05); no post-injury BESS or SAC group differences were found (p>.05) | 14 | Retrospective repeated measures - 3 |
| Sabin, M. J.; Van Boxtel, B. A.; Nohren, M. W.; Broglio, S. P. 2011. | N=105 (total football players); 16 identified with headaches & 16 controls (matched for gender, age, height, weight, and position). | GSC (Graded Symptom Checklist), SAC & BESS compared between athletes with headached and those without headache | Relationship between nonconcussion headache and concussion assesment measures | sx/SAC/BESS in non-concussed | Symptom severity increased (8.06+/-2.22 to 16.06+/-3.82) in the headache group and decreased in the nonheadache group (6.81+/-1.85 to 3.00+/-1.08); Worse BESS scores in both groups at postgame/postpractice (13.31+/-1.68 to 18.13+/-1.69; No group differences for SAC; Presence of headache was significantly correlated with symptom reports, but not SAC or BESS | 14 | Prospective cohort - repeated measures - 2 |
| Caccese, J. B.; Kaminski, T. W. 2016. | N=111 (48% male, 19+2yrs, men’s and women’s soccer, women’s field hockey and volleyball, and American football) | BESS test while standing on the Tekscan MobileMat | Level of agreement between raters and Mat vs rater | balance | Between raters (ICCs= .53-1.0); Mat vs raters (ICCs= .44-1.0) | 7 | Correlational: 3 |
| Chang, Jasper O.; Levy, Susan S.; Seay, Seth W.; Goble, Daniel J. 2014. | N=30 (50% male, 24.4+3.9yrs, not active in organized sports) | BESS test while standing on the Wii Balance Board (WBB) and Force Platform | Concurrent validity and reliability | balance - reliability | WBB vs Force Platform (r's = .99); BESS vs Force Platform (r=.08-.60) | 7 | Correlational: 3 |
| Eckner, James T.; Richardson, James K.; Kim, Hogene; Joshi, Monica S.; Youkeun K, O. H.; Ashton-Miller, James A. 2015. | N=46 (52% male, 16.3+5.0yrs, football, American football, ice hockey, martial arts, wrestling, lacrosse) | Clinical reation time test and Axon CCAT simple and complex reaction time | reliability and criterion validity of Clinical Reaction Time | reaction time | Reliability (ICCs= .70-.79); validity (r's=.33-.54 | 9 | Correlational: 3 |
| Reddy, S.; Eckner, J. T.; Kutcher, J. S. 2014. | N=42 (50%male, Exercise group 19.6+1.1yrs; controls 20.1+1.7yrs; American football, soccer, gymnastics, basketball, volleyball) | exercise | Clinical reaction time pre- and post-intervention | reaction time | No group or exercise effect (p's>0.05) | 16 | Experimental RCT: 2 |
| Mansell, J. L.; Tierney, R. T.; Higgins, M.; McDevitt, J.; Toone, N.; Glutting, J. 2010. | N=201 (84%male, 19.7+ 1.5 yrs, American football, soccer) | Concussion related signs and symptoms following head impact in those with and without concussion history | concussion signs and symptoms | symptoms | Greater percent athletes with concussion history (80% vs 59%) report signs and symptoms following head impact (p=0.005) | 11 | Quasi-experimental: 3 |
| Hayter, C.; Meares, S.; Shores, E. A. 2016. | N=127 (100% male, 24.9+5.8yrs, Austrailian rules football) | Austrailian rules football participation without concussion | Abbreviated Westmead Post-traumatic Amnesia Scale (WPTAS), Maddocks Questions, PCSS | sx and orientation (Maddock's ??) | WPTAS (98.4% pass), Maddocks (81.9% pass), PCSS (13.4% reported no symptoms) | 7 | Observational-Cohort: 3 |

Abbreviations: CRI = Concussion Resolution Index; SAC - Standardized Assessment of Concussion; BESS - Balance Error Scoring System; GSC - Graded Symptom Checklist; ANAM - Automated Neuropsychological Assessment Metrics; WBB - Wii Balance Board; Axon CCAT - Axon Computerized Cognitive Assessment Tool; WPTAS - Abbreviated Westmead Post-traumatic Amnesia Scale; PCSS - Post concussion symptom scale.

Table 5. Child SCAT Data Extraction

| **Authors, study year, study design, country** | **Participants (n, age, sex, sport)** | **Exposure/**  **Intervention (Definition)** | **Outcome (Definition)** | **Results including Statistical outcomes** | **Risk of Bias Score** | **Level of evidence** |
| --- | --- | --- | --- | --- | --- | --- |
| Bohm A et al  ABSTRACT ONLY Neurology 2015 | N= 342 college and HS athletes | Cross sectional assessment of King Devick, SAC, tandem gait | Time to completion of KD | KD correlated with SAC and balance assessments | Low risk of bias | 4 |
| Brooks A, et al ABSTRACT ONLY  CJSM 2015 | N= 476 athletes, 5-13yo | Cross sectional assessment of Child SCAT 3 | Scores on Child SCAT 3 | Age gender were significantly associated with score > 1/3 don’t tell date <5% can state 4 digits backward | Low risk of bias | 4 |
| Dhanota ASet al  2015  CJSM | N=180,  6-18yo ice hockey players | Cross sectional observation study | BESS and timed gait performance vs. clinical test of sensory intergration and balance | Single leg and tandem stance may be more useful than double leg and timed gait | Low risk of bias | 4 |
| Furman et al,  2013  AJSM | N=70 HS athletes, 43 w concussion/27 controls | Case-control study | Comparing BESS to balance accelerometer measure (BAM) | BESS score >20 distinguisghed concussed from control, BAM could not | Moderate risk of bias | 3 |
| Galetta KM et al.  2015  J Neuro-ophthalmology | N=243 5-17yo youth hockey players (also 89 college students) | Prospective cohort study | SAC, King-Devick, tandem gait,  Baseline and post injury for cases and controls | King Devick best distinguished between cases and controls | Low risk of bias | 4 |
| Glaviano NR, et al.  2015  CJSM | N=361 middle and high school students, single school | Cross sectional study baseline SCAT 2 measures, mBESS, | Scores by age | 12 yo demonstrated lower scores on concentration sub measures  Recommend Child SCAT 3  Did not correct for multiple comparisons | Moderate risk of bias | 3 |
| Gorman M et al.  2016  Applied Neuropsychology: Child | Youth soccer players | Case-control assessment of SCAT 3  SCAT 3 during competition | Between head injured, injured non-head injured, and uninjured players | HI differed from controls only in Sx reporting, not on SAC | Moderate risk of bias | 3 |
| Grubenoff JA, et al.  2010  Pediatrics | N=348 ED pts  6-18yo | Cross sectional case-control  SAC and GSC | Between head injured, injured non-head in ED | GSC differed between HI and non-HI, SAC did not differ significantly | Moderate risk of bias | 3 |
| Hansen C, et al.  2016  CJSM | N=373 healthy children  5-14yo | Inter-rater reliability assessment of Balance Error System Score | Intraclass Correlations and minimum detectable changes in scores | BESS had excellent intra and inter-rater reliability | Low risk of bias | 4 |
| Howell DR et al.  2016  JPO B | N=398  8-18yo | Cross sectional study  Normative pediatric data | mBESS and forceplate/videography | Normative data provided  Girls had better postural stability | Moderate risk of bias | 4 |
| Howell DR, et al.  2016  Physician and Sportsmedicine | N=393  8-18yo |  | 1) Correlation between mBESS and forceplate/videography  2) Effect of prior concussion | moderately high correlation single-leg stance  low correlation tandem stance | Moderate risk of bias | 4 |
|  |  |  |  |  |  |  |
| Hugentobler, Jason A.; Gupta, Resmi; Slater, Robert; Paterno, Mark V.; Riley, Michael A.; Quatman-Yates, Catherine  2016  Prospective cohort study  USA | n=71  mean age= 14.14±2.44 yrs  male 59% | Concussed Children & adolescents from outpatient concussion clinics.  Symptoms – PCSS  Balance –  BESS  Postural sway – AccuSway+ force plate. | Effects of age, sex, ADHD, Concussion Hx on postural control in children post concussion. | Age was significantly correlated with postural sway. None of the other factors were found to significantly affect postural sway. | Moderate risk of bias | 4 |
| Jennings, David; Sells, Pat; Allison, Jenni; Boyd, Kasey; Frommert, Dave; Kessler, Chelsea; Merryman, Lindsey; Muchmore, Joe; Odom, T. J.; Salmon, Ryan; Robinson, Kevin  2015  USA | Youth football (contact group) n=29    Baseball (non-contact group) n=13  Mean age 10 years  Male 100% | ChildSCAT3  Preseason and Postseason  Excluded if concussion during season.  Only included SAC, Balance & Coordination in study.  Many tested at preseason did not return for follow-up post season | Change pre-season vs post season and between groups  (assumption that contact group = subconcussive injury) | No significant difference between groups over time.  Both groups demonstrated improvement over time. (Probable learning &/or development effect).  Small numbers. Large number lost to follow-up.  Follow-up: Contact group 113 days. Non-contact group 70 days. | Moderate risk of bias | 4 |
| Khanna, N.; Baumgartner, K.; LaBella, C.  2013  ABSTRACT ONLY | N=95  (61 males)  10-13 yrs=64  14-17 yrs=31 | 10-17 years, from pediatric ortho and sports med clinics.  No ortho, neuro, or concussion PHx.  PCSS (20 item) | “Healthy children” – Normative data. | Mean PCSS scores:  Female=2.8  Male=5.6  Age  10-13 yrs=5.1  14-17 yrs=3.5 | Moderate risk of bias | 4 |
| Khanna, N.; Baumgartner, K.; LaBella, C.  2013  ABSTRACT ONLY | N=100  10-13 yrs=68  14-17 yrs =32 | 10-17 years, from pediatric ortho and sports med clinics.  No ortho, neuro, or concussion PHx.  BESS protocol | “Healthy children” – Normative data. | Mean BESS score  10-13 yrs =17.8  14-17 yrs = 17.3  These scores are higher than those reported for healthy adults age 20-39. | Moderate risk of bias |  |
| Khanna, Neil K.; Baumgartner, Katherine; LaBella, Cynthia R.  2015  USA | N=100.  10-17 years  65% male | 10-17 years, from pediatric ortho and sports med clinics.  No ortho, neuro, or concussion PHx.  BESS protocol | “Healthy children” – Normative data. | No difference in Total BESS, firm surface or foam surface by age or gender. Scores were normally distributed. | Moderate risk of bias | 4 |
| Ko, P. T.; Lockhart, C. T.; Lockhart, J. H.; Lynn, F. B.; Chen, M. L.  2015  Retrospective cohort study. March-Nov 2014.  ABSTRACT ONLY | N=84  Mean age 14 yrs  50% male | Physician confirmed sports concussion.  Sleep questionnaire & modified pediatric Epworth sleepiness scale (ESS) | Characterise sleep disturbance in children post concussion | Mean symptom score 12.3.  Mean ESS worse post concussion (p<0.001).  Symptom scores correlated with increases of ESS (p=0.005) | Moderate risk of bias | 4 |
| Mailer, Brandy J.; Valovich-McLeod, Tamara C.; Bay, R. Curtis  2008  Cohort Study  USA | n=126  middle school students.  Mean age 13.1 ±0.8 yrs | Graded symptom scale (16 symptoms) administered twice, 45 days apart. | Test-retest reliability and baseline symptom rates. | High internal consistency (0.86). Excellent reliability (ICC 0.88-0.93)  Base-rate symptoms ≥1 in 92%.  Headache most common symptom. | Moderate risk of bias | 4 |
| Morganroth, J.; Galetta, S.; Balcer, L.  2014  ABSTRACT ONLY | N=99  Mean age 10.8 yrs  Range 6-17 yrs. | Youth Ice Hockey | Compare King-Devick v SAC v tandem gait(balance) | All 3 tests showed improved results with older age groups. | Moderate risk of bias | 5 |
| Mucha, Anne; Collins, Michael W.; Elbin, R. J.; Furman, Joseph M.; Troutman-Enseki, Cara; DeWolf, Ryan M.; Marchetti, Greg; Kontos, Anthony P.  2014  Cross-sectional design.  USA | Concussed  n=64  age 13.9 (9-18) yrs  (36 male)  Control  N=78  Age 12.9 (10-17) yrs  (57 male) | Concussed within 21 days vs Healthy athletes ≤18 yrs | VOMS and PCSS | High internal consistency VOMS and near point convergence  VOR highest symptom provocation in concussed.  NPC distance greater in concussed.  Age was a significant covariate with each VOMS item in association with concussion. | Moderate risk of bias | 3 |
| Nelson, Lindsay D.; Loman, Michelle M.; LaRoche, Ashley A.; Furger, Robyn E.; McCrea, Michael A.  2016  Cross sectional study  Oct 2013-Jun 2015  USA | N=155  5-13 yr soccer and American football players  Age  5-7 n=25  8-9 n=24  10-11 n=45  12-13 n=60  male= 64.5% | ChildSCAT3 –administered to all ages  (in 57, repeated 14-208 days (mean 64))  +SCAT3 symptoms – only in 10-13 yrs  Adult BESS (mBESS-A) also administered to all.  Peabody Picture Vocabulary Test-4 (PPVT-4) in all.  Order of tests balanced, and some tested pre-practice, others during practice. | Primary aim : Baseline performance, reliability of scores.  Secondary aim :  Comparability of symptom ratings through different means. | ChildSCAT Symptoms –  Younger self report more than older. Parents report more in older than younger.  Lower vocabulary skills (PPVT-4)associated with more symptoms.  Adult SCAT symptoms – older females report more than younger females.  SAC-C:  Older performed better on all tasks.  Higher PPVT-4: better performance.  BESS – females better than males & older better than younger. Tandem gait better in older.  Internal consistency good (self) excellent (parent). Test-Retest reliability good (self), modest (SAC, tandem gait), poor (mBESS) | Low risk of bias | 4 |
| Pearce, Kelly L.; Sufrinko, Alicia; Lau, Brian C.; Henry, Luke; Collins, Michael W.; Kontos, Anthony P.  2015  Prospective cohort study  Fall 2014  USA | N=78  Mean age 14.3 range 9-24 years.  Male =45 | SRC within 30 days seen at concussion clinic.  NPC, ImPACT, PCSS | NPC v PCSS and cognitive impairment | NPC high internal consistency.  NPC impairment associated with neurocognitive impairment and symptoms (effect sizes small to medium). Abnormal NPC associated greater PCSS. Age was a significant covariate. | Moderate risk of bias | 3 |
| Quatman-Yates, Catherine C.; Bonnette, Scott; Hugentobler, Jason A.; Mede, Butovens; Kiefer, Adam W.; Kurowski, Brad G.; Riley, Michael A  2015  USA | Concussed n=20  Controls n=20  Mean age 13.23 yrs range 10-16 yrs. | Concussed = under care of physician for concussion symptoms and referred to physical therapy.  Mean days since injury 48±65. | BESS v COP (centre of pressure using force plate technology) | No difference in BESS between concussed and controls.  Differences in COP between concussed and control were significant, especially path length. | Moderate risk of bias | 3 |
| Quatman-Yates, Catherine; Hugentobler, Jason; Ammon, Robin; Mwase, Najima; Kurowski, Brad; Myer, Gregory D.  2014  Aug2010-June2013  USA | Stage 1  Retrospective review  N=42  Mean age 14 yrs range 9-18  Male=64%  Stage 2  Prospective study  Concussed n=20  Control n=20  Mean age 13 range 10-16 yrs.  Male=65% | Assessed in outpatients within 14 days of injury.  ImPACT  PCSS  BESS | Stage 1  Retrospective analysis of records.  Stage 2  Prospective comparison of BESS performances | Stage 1  Age sig. correlated with single-leg stance (firm and foam), tandem firm stance, and Total BESS score.  Stage 2  Mean days since injury 7.45  Sig difference between concussed and controls in single-leg stance (firm and foam), tandem firm stance, and Total BESS score. | Moderate risk of bias | 3 |
| Sady, Maegan D.; Vaughan, Christopher G.; Gioia, Gerard A.  2014  USA | Concussion n=633  Age 5-7=91  8-12=315  13-18=227  male=67%  Control  n=1273  Age  5-7=198  8-12=690  13-18=385  male=71% | Psychometric analysis of Post Concussion Symptom Inventory (PCSI)  4 versions:  SR5:5-7yrs  SR8:8-12yrs  SR13:13-18yrs  P:parent report | PCSI completed on computer as part of ImPACT | Differences by age in days since injury and mechanism of injury.  Analysis suggested removing certain items from each version. Symptoms classified physical, cognitive, emotional & sleep.  Identified fewer items for younger children.  Presents psychometric data on each. | Moderate risk of bias | 3 |
| Schneider, J.; Gioia, G.  2005  USA  ABSTRACT ONLY | n=180  5-7yrs=57  8-12=153 | PCSI psychometrics in healthy children  For 5-7 yrs  and  8-12 yrs  Mean Test-re-test interval= 9.48 days  range=5-48 | Test-re-test and internal consistency reliabilities for the two sessions | PCSI test-re-test reliability  5-7 yrs  alpha=0.62  8-12 yrs alpha=0.84  and acceptable internal consistency across age groups.  Symptom scores in healthy children  5-7yrs=14.6  8-12=2.3 | Low risk of bias | 4 |
| Schneider, Kathryn J.; Emery, Carolyn A.; Kang, Jian; Schneider, Geoff M.; Meeuwisse, Willem H.  2010  Secondary data analysis of pooled data from three prospective cohort studies. 2007-09  Canada | Male  11-12 yrs  n=2049  13-14 yrs  n=1831  Female  9-17 yrs  n=313 | Youth Hockey players who completed SCAT at baseline. | Normative data on SCAT | Variable symptom scores by age and history of concussion, especially in females.  Immediate word recall=5 in all groups. Delayed word recall median=3, but significant variability.  Months reverse order worse in males and younger females.  Digits backwards similar across age and gender groups. | Low risk of bias | 4 |
| Schneider, Kathryn J.; Meeuwisse, Willem H.; Kang, Jian; Schneider, Geoff M.; Emery, Carolyn A.  2013  Secondary data analysis of pooled data from 2 prospective cohort studies.  Canada | n=3832 Pee Wee and Bantam Ice hockey players.  male 100%  age 11-14 yrs | SCAT for assessment of Baseline levels of headache, dizziness, neck pain. | Incidence of Concussion if baseline headache, dizziness or neck pain on SCAT. | 175 concussions occurred.  Headache and neck pain were risk factors for concussion. Dizziness was only a risk factor in 11-12yrs in league with no body checking. | Low risk of bias | 4 |
| Snyder, Aliyah R.; Bauer, Russell M.; Health, Impacts for Florida Network  2014  USA | n=761  9-18 yrs  male 86.2% | SCAT2 baseline in student athletes across Florida Network. | Normative data for SCAT2 in children and adolescents. | Younger age associated with poorer scores on SCAT2, especially 9-10 yrs (p<0.001). Differences in total and component scores (cognition & balance).  Younger age was associated with higher symptom endorsement at baseline.  Gender was found to be associated with no significant differences on SCAT2 scores. | Low risk of bias | 4 |
| Valovich McLeod, Tamara C.; Barr, William B.; McCrea, Michael; Guskiewicz, Kevin M.  2006  Quasi-experimental, repeated-measures design.  USA | n=50  (although only 49 in table 1 in paper)  9-11 yrs  n=21  male=57%  12-14 yrs  n=28  male=39% | Test-re-test over 60 days of cognitive and balance tests in youth (9-14 yrs) sport population. | SAC  BESS  Neuropsychological tests (Buschke Selective Reminding Test (SRT), Trail Making Test B (Trails B), and the Symbol Search and Coding subsets of the WISC-III) | Test-retest indices for each of the 6 scores were poor to good, ranging from r=0.46 to 0.83. Good reliability was found for the Coding and Symbol Search tests. Weak rela- tionship (r=0.36) between the SAC and each of the neuropsychological assessments.  12-14 yrs performed better on BESS than 9-11 yrs.  Slight practice effects were observed on most of the tests | Moderate risk of bias | 4 |
| Valovich McLeod, Tamara C.; Perrin, David H.; Guskiewicz, Kevin M.; Shultz, Sandra J.; Diamond, Robert; Gansneder, Bruce M.  2004  USA | n=50  (1 excluded)  24 Control  age =12.34 ± 1.55  male=70%  25 Practice  age = 11.77 ± 1.82  male=28% | BESS and SAC administered 60 days apart. | Practice group also tested days 3,5 & 7. | BESS- Significant practice effect (p<0.0001)  SAC-  No significant practice effect.  Intratester reliability – High ICC (0.87-0.98) | Moderate risk of bias | 3 |
| Vernau, Brian T.; Grady, Matthew F.; Goodman, Arlene; Wiebe, Douglas J.; Basta, Luke; Park, Yong; Arbogast, Kristy B.; Master, Christina L.  2015  USA | n=108 youth ice hockey  mean age=12.5 y  range 6-18  Male 100% | King-Devick (KD) - all  ImPACT (≥11 yrs)  SCAT3(>12yrs)  ChildSCAT3(≤12yrs)  Near Point Convergence (NPC)  Tests at baseline and post concussion | Aimed to correlate KD with ImPACT, SCAT3 and NPC at Baseline and post concussion. | 53 completed all baseline tests.  NPC (78 athletes) mean=4.2cm (1.5-10.5). Abnormal (≥6cm) in 11.5%  KD (103 athletes) mean=55.9s (31-103)  ImPACT (77 athletes)  Baseline – no relationship between NPC, KD or ImPACT, nor KD and SCAT3.  Concussion (n=11). 1/11 abnormal NPC.  8/10 improved KD post concussion.  5/6 Improved ImPACT post injury.  (?developmental gains or learning effects) | Moderate risk of bias | 4 |

Abbreviations: Yrs=years; BESS=Balance Error Scoring System; mBESS=modified BESS; HS=High School; SAC=Standardized Assessment of Concussion; KD=King-Devick; SCAT=Sport Concussion Assessment Tool; Yo=years old; BAM=Balance accelerometer measure; GSC=Graded Symptom Checklist; ADHD= Attention Deficit Hyperactivity Disorder; Hx=History; PHx=Past Hx; PCSS=Post Concussion Symptom Scale; VOMS=Vestibular/Ocular-Motor Screening; VOR=Vestibular Ocular-Motor Reflex; SRC=Sports-related Concussion; NPC=Near Point Convergence; ImPACT=Immediate Post-Concussion Assessment and Cognitive Test.