Table 1

*Injury Characteristics of the 92 Sports-Related Concussion Samples Comprising the Meta-Analytic Database from which Samples were drawn for the Current Analyses, arranged by comparison group.*

| Sample [sub-sample] a | Concussed; Controls | |  | Classification criteria | |  | Grade of severity  (% of sample) | | |  | Post-concussion signs and symptoms  (% of sample) | | | | | |  | History of previous concussion  (% of sample) | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample size | Age  (in years) |  | Diagnostic criteria or severity grading scale | LOC |  | 1 | 2 | 3 |  | LOC | RA | AA | H | D | Do |  | *M* (SD) | None | | 1≤ | 2≤ | 3≤ |
| **Pre-injury baseline and independent control group comparison** | | | | | | | | | | | | | | | | | | | | | | | |
| Barr & McCrea ([2001](#_ENREF_3)) | 50; 68 | 17.2; 18.1 |  | AAN; ACRM | <30min |  | N | N | N |  | - | - | - | - | - | - |  | - | | - | - | - | - |
| Cavanaugh et al. ([2005](#_ENREF_13)) | 27; 30 | 19.5; 21.7 |  | CS | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 56 | 22 | 4 | - |
| Collie et al. ([2006](#_ENREF_19)) | 61; 84 | 22.9; 23.4 |  | CISG (2002) | Any alt. |  | N | N | N |  | 25 | - | 36 | 89 | - | - |  | 2.7 (2.4) | | - | - | - | - |
| Echemendia et al. ([2001](#_ENREF_29)) | 29; 20 | *-*; *-* |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Field et al. ([2003](#_ENREF_35))  [high school] | 19; 20 | 15.2; 16.6 |  | CS; AAN | Any alt. |  | - | - | 11 |  | 11 | - | - | - | - | - |  | 0.6 (0.7) | | 47 | 53 | 8 | - |
| Field et al. ([2003](#_ENREF_35)) [college] | 35; 18 | 19.9; 20.1 |  | CS; AAN | Any alt. |  | *-* | *-* | 34 |  | 34 | *-* | - | - | - | - |  | 1.5 (1.3) | | 47 | 53 | 36 | - |
| Guskiewicz et al. ([1996](#_ENREF_38)) | 10; 10 | 17.4; 18.6 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Guskiewicz et al. ([2001](#_ENREF_40)) | 36; 36 | 19.5; 20.0 |  | CS | Any alt. |  | N | N | N |  | 19 | 19 | 31 | 92 | 72 | 58 |  | - | | - | - | - | - |
| Hinton-Bayre et al. ([1997](#_ENREF_42)) | 10; 10 | 22.1; 19.9 |  | CNS; NHMRC | Any alt. |  | N | N | N |  | 0 | *-* | - | - | - | - |  | 2.6 (1.8) | | - | - | - | - |
| Hinton-Bayre et al. ([1999](#_ENREF_41)) | 20; 13 | 21.1; 19.6 |  | CNS; AAN | Any alt. |  | 10 | 70 | 20 |  | 20 | *-* | - | - | - | - |  | 2.4 (2.4) | | 15 | 85 | - | - |
| Iverson et al. ([2003](#_ENREF_45)) | 41; 56 | 16.8; 17.6 |  | AAN | *-* |  | 54 | 22 | 7 |  | 7 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Johnson et al. ([2002](#_ENREF_47)) | 9; 9 | *-*; *-* |  | CoMS | Any alt. |  | *-* | *-* | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Lovell & Collins ([1998](#_ENREF_50)) | 4; 40 | *-*; 19.6 |  | CS; AAN | Any alt. |  | 100 | 0 | 0 |  | 0 | *-* | - | 100 | - | - |  | 1.0 | | - | 100 | - | - |
| Lovell et al. ([2003](#_ENREF_51)) | 64; 24 | *-*; *-* |  | CS | Exc |  | N | N | N |  | 0 | 20 | 30 | - | - | 44 |  | - | | - | - | - | - |
| Macciocchi et al. ([1996](#_ENREF_55)) | 183; 48 | 19.0; 19.0 |  | CS | <2min |  | N | N | N |  | 5 | - | 34 | 71 | 35 | 95 |  | - | | 58 | 20 | 11 | 12 |
| Maddocks & Saling ([1996](#_ENREF_58)) | 10; 10 | *-*; *-* |  | CNS | *-* |  | N | N | N |  | 50 | - | 100 | - | - | - |  | - | | 60 | 40 | 0 | 0 |
| Makdissi ([2001](#_ENREF_59)) | 6; 7 | 20.5; 20.3 |  | CNS | Any alt. |  | N | N | N |  | 17 | *-* | - | 83 | 67 | - |  | - | | - | - | - | - |
| McCrea ([2001](#_ENREF_61)) | 63; 55 | 18.2; 18.2 |  | AAN | Any alt. |  | N | N | N |  | 5 | - | 6 | - | - | - |  | - | | - | - | - | - |
| McCrea et al. ([2003](#_ENREF_62)) | 94; 56 | 20.0; 19.2 |  | CS; [Cantu (2001](#_ENREF_11)) | Any alt. |  | 15 | 70 | 15 |  | 6 | 7 | 19 | 85 | - | - |  | 0.6 (0.8) | | 62 | 21 | 8 | 5 |
| Peterson et al. ([2003](#_ENREF_76)) | 24; 18 | 20.2; 19.3 |  | CS; AAN | Any alt. |  | 13 | 83 | 4 |  | 4 | *-* | - | 74 | - | - |  | 5 | | 79 | 21 | - | - |
| Piland et al. ([2003](#_ENREF_77)) | 17; 16 | 19.8; 19.5 |  | AAN | Any alt. |  | 6 | 94 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Sim et al. ([2008](#_ENREF_82)) | 14; 14 | 15.5; 15.7 |  | ACRM | Any alt. |  | N | N | N |  | 14 | - | 29 | - | - | - |  | - | | 57 | 43 | - | - |
| Sosnoff et al. ([2007](#_ENREF_88)) | 22; 22 | 19.8; *-* |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 41 | 59 | - | - |
| **Independent control group comparison only** | | | | | | | | | | | | | | | | | | | | | | | |
| Bruce & Echemendia ([2003](#_ENREF_8)) | 19; 19 | 20.1; 19.9 |  | AAN | Any alt. |  | N | N | N |  | 21 | 26 | 68 | - | - | - |  | - | | 47 | 37 | 16 | 0 |
| Bruce & Echemendia ([2004](#_ENREF_9))  [>1 previous concussions] | 30; 147 | 20.2; 19.0 |  | AAN | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 0 | 57 | 43 | - |
| Bruce & Echemendia ([2004](#_ENREF_9))  [0 previous concussions] | 27; 286 | 20.2; 18.8 |  | AAN | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Chen et al. ([2007](#_ENREF_15)) | 18; 10 | 28.9; 21.9 |  | CISG (2005); AAN | >1min |  | *-* | *-* | 11 |  | 11 | - | 22 | 45 | 11 | - |  | 3.7 (1.4) | | - | - | - | - |
| Chen et al. ([2008a](#_ENREF_16)) | 16; 16 | 26.0; 20.0 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | 3.4 (1.8) | | - | - | - | - |
| Chen et al. ([2008b](#_ENREF_17)) | 9; 6 | 31.5; 20.0 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | 4.2 (1.4) | | - | - | - | - |
| Cremona-Meteyard & Geffen ([1994](#_ENREF_26)) [Experiment 1] | 9; 12 | 23.0; 22.1 |  | CS | >2min, <20min |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 33 | 11 | 33 | 22 |
| Dupuis et al. ([2000](#_ENREF_28)) | 20; 10 | 21.5; 21.5 |  | AAN | Any alt. |  | *-* | *M,* 2.0 | *-* |  | *-* | *-* | - | - | - | - |  | 2.9 | | 0 | - | - | - |
| Ellemberg et al. ([2007](#_ENREF_30)) | 10; 12 | 22.7; 22.3 |  | AAN | Any alt. |  | 0 | 100 | 0 |  | 0 | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Fazio et al. ([2007](#_ENREF_33)) | 122; 70 | 16.7; 17.3 |  | CS | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 76 | 14 | 7 | 3 |
| Ferguson et al. ([1999](#_ENREF_34)) | 50; 159 | 20.2; 19.6 |  | CS | Any alt. |  | N | N | N |  | *-* | *-* | 56 | 18 | 18 | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Gosselin et al. ([2006](#_ENREF_37)) | 20; 10 | 25.9; 22.0 |  | AAN | Any alt. |  | *-* | *M,* 2.4 | *-* |  | *-* | *-* | - | - | - | - |  | 4.3 (3.6) | | - | - | - | - |
| Gosselin et al. ([2009](#_ENREF_36)) | 10; 11 | 24.3; 22.6 |  | WHO | <30min |  | N | N | N |  | 20 | - | 40 | - | - | - |  | 4.6 (2.1) | | 0 | 0 | 10 | 90 |
| Guskiewicz et al. ([1997](#_ENREF_39)) | 11; 11 | 18.6; 20.2 |  | CNS; CS | <20min |  | N | N | N |  | 55 | 36 | 18 | 91 | 82 | 64 |  | - | | - | - | - | - |
| Killam et al. ([2005](#_ENREF_48)) | 5; 9 | 22.6; 22.0 |  | AAN | Any alt. |  | *-* | *-* | *-* |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Lovell et al. ([2006](#_ENREF_53))  [high school] | 221; 707 | 16.5; *-* |  | CISG (2002) | Any alt. |  | N | N | N |  | *-* | *-* | - | 92 | 61 | - |  | - | | - | - | - | - |
| Lovell et al. ([2006](#_ENREF_53)) [college] | 39; 1039 | *-*; *-* |  | CISG (2002) | Any alt. |  | N | N | N |  | *-* | *-* | - | 92 | 61 | - |  | - | | - | - | - | - |
| Lovell et al. ([2006](#_ENREF_53)) [repeat assessment] | 52; 1746 | *-*; *-* |  | CISG (2002) | Any alt. |  | N | N | N |  | *-* | *-* | - | 92 | 61 | - |  | - | | - | - | - | - |
| Maddocks et al. ([1995](#_ENREF_57)) | 28; 28 | *-*; *-* |  | CS | Any alt. |  | N | N | N |  | 39 | *-* | - | 93 | 64 | - |  | - | | - | - | - | - |
| McCrea et al. ([2002](#_ENREF_63)) | 91; 45 | 17.3; 17.5 |  | AAN; ACRM | <30min |  | 84% no LOC/no AA  9% AA/no LOC  8% LOC & AA | | |  | 8 | - | 17 |  |  | - | - | - | | - | - | - | - |
| Moser & Schatz ([2002](#_ENREF_68)) | 14; 21 | 16.4; 16.8 |  | AAN | Any alt. |  | 0 | *-* | *-* |  | *-* | *-* | - | - | - | - |  | - | | 3 | 34 | 49 | 14 |
| Moser et al. ([2005](#_ENREF_69)) | 40; 183 | 15.8; 15.7 |  | AAN | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 20 | 23 | 28 | - |
| Parker et al. ([2005](#_ENREF_71)) | 10; 10 | 20.2; 19.9 |  | AAN | Exc |  | 0 | 100 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Parker et al. ([2006](#_ENREF_72)) | 15; 15 | 20.6; 20.6 |  | AAN | Any alt. |  | 0 | 100 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Parker et al. ([2008](#_ENREF_73)) | 14; 14 | 20.7; 20.6 |  | AAN | Exc |  | 0 | 100 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Pellman et al. ([2006](#_ENREF_74))  [high school] | 37; 125 | 15.8; 15.6 |  | CS | Any alt. |  | N | N | N |  | 35 | 51 | 51 | - | - | 70 |  | 0.9 | | - | - | - | - |
| Pellman et al. ([2006](#_ENREF_74)) [professional] | 48; 68 | 26.3; 24.3 |  | CS | Any alt. |  | N | N | N |  | 23 | 23 | 20 | - | - | 71 |  | 1.2 | | - | - | - | - |
| Riemann & Guskiewicz ([2000](#_ENREF_80)) | 16; 16 | 19.2; 22.5 |  | CS; [Cantu (1998](#_ENREF_10)) | <20min |  | *-* | *-* | 0 |  | 13 | 13 | 25 | 94 | 44 | 38 |  | - | | - | - | - | - |
| Schatz et al. ([2006](#_ENREF_81)) | 72; 66 | 16.5; 17.3 |  | CS | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 0 | 83 | 17 | - |
| Thompson et al. ([2005](#_ENREF_89)) | 12; 12 | 21.0; 21.0 |  | CS | Any alt. |  | *-* | *-* | 0 |  | *-* | *-* | - | - | - | - |  | 1.0 (0) | | 0 | 100 | 0 | 0 |
| **Pre-injury baseline comparison only** | | | | | | | | | | | | | | | | | | | | | | | |
| Broglio et al. ([2007a](#_ENREF_5))  [simple concussion b] | 17 | 19.8 |  | CISG (2005) | Exc |  | 0 | 100 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Broglio et al. ([2007a](#_ENREF_5)) [complex concussion b] | 4 | 19.8 |  | CISG (2005): | >1 min |  | 0 | 0 | 100 |  | 100 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Broglio et al. ([2007b](#_ENREF_6)) | 75 | *-* |  | AAN | Any alt. |  | 25 | 68 | 7 |  | 7 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Broshek et al. ([2005](#_ENREF_7)) [female] | 37 | 17.5 |  | Sideline assessment; AAN [Cantu(2001)] | Any alt. |  | 8 [41] | 82  [27] | 11 [33] |  | 11 | *-* | - | - | - | - |  | - | | 54 | 26 | 11 | 9 |
| Broshek et al. ([2005](#_ENREF_7)) [male] | 94 | 19.2 |  | Sideline assessment; AAN [Cantu(2001)] | Any alt. |  | 11 [48] | 71  [23] | 18 [29] |  | 18 | *-* | - | - | - | - |  | - | | 54 | 26 | 11 | 9 |
| Cavanaugh et al. ([2006](#_ENREF_14)) [steady c] | 16 | *-* |  | MO; Postural instability at 48hrs | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Cavanaugh et al. ([2006](#_ENREF_14)) [unsteady c] | 13 | *-* |  | MO; Postural instability at 48hrs | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Collins et al. ([2003](#_ENREF_20)) [goodd] | 44 | 15.5 |  | CS; AAN | Any alt. |  | 56 | 44 | 19 |  | 12 | 5 | 13 | - | - | 72 |  | - | | 31 | 60 | 20 | - |
| Collins et al. ([2003](#_ENREF_20)) [poord] | 34 | 17.4 |  | CS; AAN | Any alt. |  | 56 | 44 | 19 |  | 21 | 34 | 38 | - | - | 71 |  | - | | 31 | 70 | 20 | - |
| Collins et al. ([2006](#_ENREF_21)) | 136 | 16.1 |  | CS | Any alt. |  | N | N | N |  | 15 | 27 | 25 | 93 | 77 | 68 |  | - | | 72 | 28 | - | - |
| Covassin et al. ([2007](#_ENREF_24)) [female] | 39 | *-* |  | AAN | Any alt. |  | 66 | 34 | 0 |  | 13 e | - | 15 | - | - | - |  | - | | 48 | 20 | 32 | - |
| Covassin et al. ([2007](#_ENREF_24)) [male] | 41 | *-* |  | AAN | Any alt. |  | 59 | 34 | 7 |  | 24 | - | 20 | - | - | - |  | - | | 48 | 20 | 32 | - |
| Covassin et al. ([2008](#_ENREF_25))  [≥2 previous concussions] | 21 | 21.1 |  | AAN | Any alt. |  | 71 | 5 | 24 |  | 24 | - | 29 | - | - | - |  | - | | 0 | 0 | 100 | - |
| Covassin et al. ([2008](#_ENREF_25))  [0 previous concussions] | 36 | 20.6 |  | AAN | Any alt. |  | 81 | 11 | 8 |  | 8 | - | 11 | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Daniel et al. ([2002](#_ENREF_27)) | 21 | *-* |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Erlanger et al. ([2001](#_ENREF_32)) | 26 | 18.6 |  | Cantu (2001) | Any alt. |  | 46 | 23 | 31 |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Erlanger et al. ([2003](#_ENREF_31)) | 47 | 17.6 |  | MO | *-* |  | N | N | N |  | 26 | 13 | - | 94 | 85 | 83 |  | - | | 32 | 26 | 19 | 24 |
| Iverson et al. ([2004](#_ENREF_44))  [≥3 previous concussions] | 19 | 17.8 |  | CS | Any alt. |  | N | N | N |  | 11 | 16 | 37 | - | - | 63 |  | - | | 0 | 0 | 0 | 100 |
| Iverson et al. ([2004](#_ENREF_44))  [0 previous concussions] | 19 | 17.9 |  | CS | Any alt. |  | N | N | N |  | 0 | 16 | 5 | - | - | 26 |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Iverson et al. ([2006](#_ENREF_43)) | 30 | 16.1 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 73 | 13 | 7 | 7 |
| Jantzen et al. ([2004](#_ENREF_46)) | 4 | 20.0 |  | AAN | Any alt. |  | 25 | 75 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Lavoie et al. ([2004](#_ENREF_49)) | 10 | 21.5 |  | AAN | Any alt. |  | 10 | 70 | 20 |  | 20 | *-* | - | - | - | - |  | 3.2 | | 0 | 20 | 20 | 60 |
| Lovell et al. ([2004](#_ENREF_52)) | 43 | 15.6 |  | CS; AAN | Any alt. |  | 100 | 0 | 0 |  | 0 | - | 0 | - | - | 0 |  | - f | | - | - | - | - |
| Macciocchi et al. ([2001](#_ENREF_54)) [after 1st of repeat concussions] | 12 | 19.1 |  | CS; VNIS | Any alt. |  | 100 | 0 | 0 |  | *-* | *-* | - | 42 | 33 | - |  | 1.0 (0) | | 0 | 100 | 0 | 0 |
| McClincy et al. ([2006](#_ENREF_60)) | 104 | 16.1 |  | AAN | Any alt. |  | 75 | 15 | 9 |  | 9 | 18 | 22 | - | - | - |  | - | | 67 | 33 | 13 | - |
| McCrea et al. ([1998](#_ENREF_64)) | 33 | *-* |  | Sideline assessment/ symptom inventory; AAN | Any alt. |  | 100 | 0 | 0 |  | 0 | *-* | - | - | - | - |  | - | | - | - | - | - |
| McCrory et al. ([2000](#_ENREF_65)) | 23 | *-* |  | CNS | Any alt. |  | 26 | 30 | 44 |  | 44 | *-* | - | 100 | 65 | - |  | - | | - | - | - | - |
| Mihalik et al. ([2007](#_ENREF_67))  [high school] | 155 | 15.6 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Mihalik et al. ([2007](#_ENREF_67)) [college] | 26 | 22.1 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Pellman et al. ([2004](#_ENREF_75)) | 95 | 25.4 |  | CS | Any alt. |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | - | - | - | - |
| Register-Mihalik et al. ([2007](#_ENREF_79))  [no preseason headache] | 258 | 16.7 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | - | | 69 | 23 | 8 | 0.3 |
| Register-Mihalik et al. ([2007](#_ENREF_79)) [preseason headache] | 106 | 16.7 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | 72 | - | - |  | - | | 60 | 25 | 9 | 7 |
| Slobounov et al. ([2007](#_ENREF_85)) | 38 | 21.2 |  | CS; Cantu (2006a) | Exc |  | 100 | 0 | 0 |  | 0 | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Slobounov et al. ([2008](#_ENREF_83)) | 12 | 21.2 |  | CS; [Cantu (2006](#_ENREF_12)) | Exc |  | 100 | 0 | 0 |  | 0 | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Slobounov, Slobounov & Newell ([2006](#_ENREF_84)) | 10 | 19.5 |  | MO | *-* |  | N | N | N |  | *-* | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Slobounov, Tutwiler, et al. ([2006](#_ENREF_86)) | 8 | 21.0 |  | Cantu (2001) | Any alt. |  | *-* | *-* | 0 |  | *-* | *-* | - | - | - | - |  | 0 (0) | | 100 | 0 | 0 | 0 |
| Sosnoff et al. ([2008](#_ENREF_87)) | 36 | 21.2 |  | AAN | Any alt. |  | 22 | 67 | 11 |  | 11 | *-* | - | - | - | - |  | - | | - | - | - | - |
| Van Kampen et al. ([2006](#_ENREF_90)) | 122 | 16.6 |  | AAN | Any alt. |  | N | N | N |  | 12 | 54 | 2 | - | - | - |  | - | | 76 | 14 | 8 | 2 |
| Warden et al. ([2001](#_ENREF_91)) | 14 | 19.0 |  | AAN | Exc |  | 43 | 57 | 0 |  | 0 | - | 0 | 79 | 43 | - |  | - | | - | - | - | - |

*Note*. AA = anterograde amnesia; AAN = Quality Standards Subcommittee of the American Academy of Neurology ([1997](#_ENREF_78)); ACRM = American Congress of Rehabilitation Medicine ([1993](#_ENREF_1)); Any alt. = any alteration in level of consciousness; C = post-concussion confusion; CISG = Concussion in Sport Group ([Aubry et al., 2002](#_ENREF_2); [McCrory et al., 2005](#_ENREF_66)); CNS = Congress of Neurological Surgeons ([Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons, 1966](#_ENREF_23)); CoMS = Colorado Medical Society, Sports Medicine Committee ([1991](#_ENREF_22)); CS = clinical signs; D = post-concussion dizziness;Do = post-concussion disorientation; Exc = concussion with LOC or Grade 3 AAN (1997) injuries excluded; H = post-concussion headache; LOC = loss of consciousness; MO = diagnosed by medical officer; N = a system of grading injury severity was not used; NHMRC = National Health and Medical Research Council ([1994](#_ENREF_70)); RA = retrograde amnesia; VNIS = Virginia Neurologic Institute Standards ([Macciocchi, Barth, & Littlefield, 2000](#_ENREF_56)); WHO = World Health Organisation Collaborating Centre Task Force on mild traumatic brain injury ([Borg et al., 2004](#_ENREF_4)).

a For full reference see asterisked (\*) citations in References section below. b Simple concussion = no loss of consciousness, symptom resolution <10 days; Complex concussion = loss of consciousness, symptom resolution >10 days. c Steady = postural stability at 48 hours post-injury; Unsteady = postural instability at 48 hours post-injury. d Good post-injury presentation = no change in neuropsychological function pre- to post-injury, asymptomatic; Poor post-injury presentation = 10≤ point decline in memory score, 10≤ point increase in symptom severity from pre- to post-injury. e Inconsistency between AAN grading and incidence of LOC as per published paper. f Reported no significant difference in baseline scores between those with and without previous concussions.

Table 2

*Effect Size Presented as a Function of Injury Characteristics and Athlete Age Group: measures of speed of information processing administered at first post-injury assessments conducted 1-10 days following concussion.*

| Injury characteristics | | Sample size | |  | All athletes | | | |  | Adolescent athletes (≤18 years) | | | |  | Adult athletes (≥19 years) | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |
| Concussed | Controls |  | TSI | *d* | *k* | *Q* |  | TSI | *d* | *k* | *Q* |  | TSI | *d* | *k* | *Q* |
| **All comparison groups** | | | | | | | | | | | | | | | | | | |
| Severity Grading Criteria a | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 127 | 10 |  | 2.2 | -0.17 \* | 5 | 7.51 |  | 1.4 | -0.37 \*\* | 1 | - |  | 2.6 | -0.03 | 3 | 3.03 |
|  | All Grades (including LOC) | 1139 | 514 |  | 2.0 | -0.55 \*\*\* | 24 | 99.16 \*\*\* |  | 2.6 | -0.59 \*\*\* | 4 | 2.68 |  | 2.8 | -0.46 \*\*\* | 9 | 15.95 \* |
| Severity Grading Criteria (AAN only) | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 0 | 0 |  | - | - | - | - |  |  |  |  |  |  |  |  |  |  |
|  | Grade 3 (LOC) | 525 | 90 |  | 2.2 | -0.56 \*\*\* | 12 | 67.26 \*\*\* |  |  |  |  |  |  |  |  |  |  |
| **Pre-injury baseline comparisons** | | | | | | | | | | | | | | | | | | |
| Severity Grading Criteria a | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 117 | 0 |  | 2.4 | -0.15 \* | 4 | 5.47 |  | 1.4 | -0.37 \*\* | 1 | - |  | 3.1 | 0.00 | 2 | 0.00 |
|  | All Grades (including LOC) | 804 | 0 |  | 2.0 | -0.57 \*\*\* | 15 | 84.29 \*\*\* |  | 2.2 | -0.61 \*\*\* | 1 | - |  | 1.5 | -0.63 \*\*\* | 5 | 9.14 |
| Severity Grading Criteria (AAN only) | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 0 | 0 |  | - | - | - | - |  |  |  |  |  |  |  |  |  |  |
|  | Grade 3 (LOC) | 450 | 0 |  | 2.1 | -0.54 \*\*\* | 9 | 64.8 \*\*\* |  |  |  |  |  |  |  |  |  |  |
| **Independent control group comparisons** | | | | | | | | | | | | | | | | | | |
| Severity Grading Criteria a | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 10 | 10 |  | 1.5 | -0.83 | 1 | - |  | - | - | - | - |  | 1.5 | -0.83 | 1 | - |
|  | All Grades (including LOC) | 335 | 514 |  | 2.2 | -0.41 \*\*\* | 9 | 10.94 |  | 2.7 | -0.53 \*\* | 3 | 2.47 |  | 2.1 | -0.25 \* | 4 | 1.09 |
| Severity Grading Criteria (AAN only) | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | Grade 1 or 2 only (no LOC) | 0 | 0 |  | - | - | - | - |  |  |  |  |  |  |  |  |  |  |
|  | Grade 3 (LOC) | 75 | 90 |  | 2.4 | -0.75 \*\*\* | 3 | 0.87 |  |  |  |  |  |  |  |  |  |  |

*Note.* AAN = Quality Standards Subcommittee of the American Academy of Neurology (1997); *d* = weighted mean effect size. *k* = number of independent sample effect sizes; LOC = loss of consciousness; *Q* = test of homogeneity of effect size variance; TSI = average time elapsed since injury (in days).

a Reported injury severity reclassified according to AAN (1997) criteria on the basis of the presence or absence of LOC within the concussed sample. Any sample included in ‘Grade 1 or 2 only’ was not included in ‘All Grades’.

\* p < .05, \*\* p < .01, \*\*\* p < .001

Table 3

Meta-Regression of Injury Severity Markers*: neuropsychological outcome measures administered at first post-injury assessments conducted 1-10 days following concussion.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Injury Characteristics | Sample size | | |  | Sample Incidence | |  | Regression results | | | | |
| *k* | Concussed | Controls |  | *M* (%) | Range (%) |  | Intercept | Slope | 95% CI  Lower; Upper | Q*M* | *QR* |
| **All comparison groups** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness a | 29 | 1204 | 531 |  | 15.5 | 0-100 |  | -0.394 \*\*\* | -0.013 \*\*\* | -0.019, -0.006 | 13.79 \*\*\* | 139.11 \*\*\* |
| Retrograde amnesia | 12 | 765 | 343 |  | 23.7 | 5-54 |  | -0.454 \*\*\* | -0.006 \*\* | -0.011, -0.002 | 7.38 \*\* | 88.02 \*\*\* |
| Anterograde amnesia | 18 | 976 | 441 |  | 22.2 | 0-51 |  | -0.472 \*\*\* | -0.005 \* | -0.011, -0.0003 | 4.25 \* | 107.76 \*\*\* |
| a Adolescent samples | 5 | 294 | 163 |  | 12.8 | 0-35 |  | -0.453 \*\*\* | -0.013 \*\*\* | -0.025, -0.002 | 5.18 \* | 9.63 \* |
| a Adult samples | 14 | 439 | 242 |  | 18.6 | 0-100 |  | -0.205 \* | -0.011 \* | -0.021, -0.001 | 4.39 \* | 24.63 \* |
| **Pre-injury baseline comparisons** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness b | 17 | 683 | 0 |  | 17.1 | 0-100 |  | -0.304 \*\*\* | -0.22 \*\*\* | -0.031, -0.014 | 28.20 \*\*\* | 104.50 \*\*\* |
| Retrograde amnesia | 7 | 403 | 0 |  | 18.4 | 5-27 |  | 0.096 | -0.039 \*\*\* | -0.051, -0.026 | 36.23 \*\*\* | 50.39 \*\*\* |
| Anterograde amnesia | 11 | 536 | 0 |  | 19.5 | 0-37 |  | -0.146 | -0.025 \*\*\* | -0.033, -0.016 | 32.02 \*\*\* | 95.30 \*\*\* |
| b Adolescent samples | 2 | 179 | 0 |  | 7.4 | 0-15 |  | - | - | - | - | - |
| b Adult samples | 7 | 196 | 0 |  | 24.2 | 0-100 |  | -0.241 \* | -0.019 \*\* | -0.031, -0.006 | 9.02 \*\* | 13.07 \* |
| **Independent control group comparisons** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness c | 12 | 521 | 531 |  | 13.3 | 0-35 |  | -0.596 \*\*\* | 0.005 | -0.007, 0.017 | 0.77 | 18.70 \* |
| Retrograde amnesia | 5 | 362 | 343 |  | 31.0 | 7-54 |  | -0.233 | -0.008 \* | -0.015, -0.001 | 5.25 \* | 1.53 |
| Anterograde amnesia | 7 | 440 | 441 |  | 26.7 | 2-51 |  | -0.617 \*\*\* | 0.007 | -0.000, 0.013 | 3.82 | 11.58 \* |
| c Adolescent samples | 3 | 115 | 163 |  | 16.4 | 0-35 |  | -0.683 \*\* | 0.002 | -0.015, 0.019 | 0.07 | 0.15 |
| c Adult samples | 7 | 243 | 242 |  | 13.0 | 0-25 |  | -0.238 | 0.000 | -0.019, 0.020 | 0.00 | 4.06 |

\* *p* < .05, \*\* *p* < .01, \*\*\* *p* < .001

Table 4

Meta-Regression of Injury Severity Markers*: measures of speed of information processing administered at first post-injury assessments conducted 1-10 days following concussion.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Injury Characteristics | Sample size | | |  | Sample Incidence | |  | Regression results | | | | |
| *k* | Concussed | Controls |  | *M* (%) | Range (%) |  | Intercept | Slope | 95% CI  Lower; Upper | Q*M* | *QR* |
| **All comparison groups** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness a | 27 | 1,136 | 503 |  | 16.7 | 0-100 |  | -0.358 \*\*\* | -0.011 \*\* | -0.018, -0.004 | 10.57 \*\* | 119.64 \*\*\* |
| Retrograde amnesia | 11 | 701 | 319 |  | 24.0 | 5-54 |  | -0.482 \*\*\* | -0.002 | -0.006, 0.002 | 1.46 | 73.03 \*\*\* |
| Anterograde amnesia | 17 | 912 | 417 |  | 21.9 | 0-51 |  | -0.467 \*\*\* | -0.003 | -0.008, 0.002 | 1.35 | 73.97 \*\*\* |
| a Adolescent samples | 4 | 230 | 139 |  | 16.0 | 0-35 |  | -0.380 \*\* | 0.003 | -0.009, 0.014 | 0.19 | 4.34 |
| a Adult samples | 13 | 435 | 238 |  | 20.0 | 0-100 |  | -0.153 | -0.012 \* | -0.022, -0.003 | 6.33 \* | 24.45 \* |
| **Pre-injury baseline comparisons** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness b | 17 | 683 | 0 |  | 17.1 | 0-100 |  | -0.256 \*\*\* | -0.021 \*\*\* | -0.029, -0.013 | 26.40 \*\*\* | 90.82 \*\*\* |
| Retrograde amnesia | 7 | 403 | 0 |  | 18.4 | 5-27 |  | -0.099 | -0.024 \*\*\* | -0.035, -0.013 | 19.20 \*\*\* | 50.03 \*\*\* |
| Anterograde amnesia | 11 | 536 | 0 |  | 19.5 | 0-37 |  | -0.228 \* | -0.016 \*\*\* | -0.024, -0.008 | 13.69 \*\*\* | 51.35 \*\*\* |
| b Adolescent samples | 2 | 179 | 0 |  | 7.4 | 0-15 |  | - | - | - | - | - |
| b Adult samples | 7 | 196 | 0 |  | 24.2 | 0-100 |  | -0.118 | -0.021 \*\*\* | -0.032, -0.009 | 12.33 \*\*\* | 15.91 \*\* |
| **Independent control group comparisons** | | | | | | | | | | | | |
| Post-concussion signs |  |  |  |  |  |  |  |  |  |  |  |  |
| Loss of consciousness c | 10 | 453 | 503 |  | 15.9 | 0-35 |  | -0.670 \*\*\* | 0.012 | -0.001, 0.025 | 3.55 | 9.31 |
| Retrograde amnesia | 4 | 298 | 319 |  | 33.8 | 7-54 |  | -0.252 | -0.005 | -0.012, 0.002 | 2.05 | 0.60 |
| Anterograde amnesia | 6 | 376 | 417 |  | 26.2 | 2-51 |  | -0.533 \*\*\* | 0.006 | -0.000, 0.012 | 3.29 | 5.19 |
| c Adolescent samples | 2 | 51 | 139 |  | 24.7 | 14.3-35 |  | - | - | - | - | - |
| c Adult samples | 6 | 239 | 238 |  | 15.1 | 0-25 |  | -0.453 \* | 0.009 | -0.012, 0.031 | 0.71 | 1.82 |

\* *p* < .05, \*\* *p* < .01, \*\*\* *p* < .001

**References**

### References marked with an asterisk (\*) indicate studies included in the meta-analytic database.

American Congress of Rehabilitation Medicine. (1993). Report of the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group: Definition of mild traumatic brain injury. *Journal of Head Trauma Rehabilitation, 8*(3), 86-87.

Aubry, M., Cantu, R. C., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J. P., . . . Schamasch, P. (2002). Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001. *British Journal of Sports Medicine, 36*(1), 6-10.

\*Barr, W. B., & McCrea, M. (2001). Sensitivity and specificity of standardized neurocognitive testing immediately following sports concussion. *Journal of the International Neuropsychological Society, 7*(6), 693-702.

Borg, J., Holm, L., Cassidy, J. D., Peloso, P. M., Carroll, L. J., von Holst, H., & Ericson, K. (2004). Diagnostic procedures in mild traumatic brain injury: Results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine, 36*(S43), 61-75.

\*Broglio, S. P., Macciocchi, S. N., & Ferrara, M. S. (2007a). Neurocognitive performance of concussed athletes when symptom free. *Journal of Athletic Training, 42*(4), 504-508.

\*Broglio, S. P., Macciocchi, S. N., & Ferrara, M. S. (2007b). Sensitivity of the concussion assessment battery. *Neurosurgery, 60*(6), 1050-1058.

\*Broshek, D. K., Kaushik, T., Freeman, J., Erlanger, D., Webbe, F., & Barth, J. T. (2005). Sex differences in outcome following sports-related concussion. *Journal of Neurosurgery, 102*(5), 856-863.

\*Bruce, J. M., & Echemendia, R. J. (2003). Delayed-onset deficits in verbal encoding strategies among patients with mild traumatic brain injury. *Neuropsychology, 17*(4), 622-629.

\*Bruce, J. M., & Echemendia, R. J. (2004). Concussion history predicts self-reported symptoms before and following a concussive event. *Neurology, 63*(8), 1516-1518.

Cantu, R. C. (1998). Return to play guidelines after a head injury. *Clinics in Sports Medicine, 17*(1), 45-60.

Cantu, R. C. (2001). Posttraumatic (retrograde and anterograde) amnesia: Pathophysiology and implications in grading and safe return to play. *Journal of Athletic Training, 36*(3), 244-248.

Cantu, R. C. (2006). Concussion classification: Ongoing controversy. In S. M. Slobounov & W. J. Sebastianelli (Eds.), *Foundations of sport-related brain injuries*. New York, NY: Springer.

\*Cavanaugh, J. T., Guskiewicz, K. M., Giuliani, C., Marshall, S., Mercer, V., & Stergiou, N. (2005). Detecting altered postural control after cerebral concussion in athletes with normal postural stability. *British Journal of Sports Medicine, 39*(11), 805-811.

\*Cavanaugh, J. T., Guskiewicz, K. M., Giuliani, C., Marshall, S., Mercer, V. S., & Stergiou, N. (2006). Recovery of postural control after cerebral concussion: New insights using approximate entropy. *Journal of Athletic Training, 41*(3), 305-313.

\*Chen, J. K., Johnston, K. M., Collie, A., McCrory, P. R., & Ptito, A. (2007). A validation of the post concussion symptom scale in the assessment of complex concussion using cognitive testing and functional MRI. *Journal of Neurology, Neurosurgery & Psychiatry, 78*(11), 1231-1238.

\*Chen, J. K., Johnston, K. M., Petrides, M., & Ptito, A. (2008a). Neural substrates of symptoms of depression following concussion in male athletes with persisting post-concussion symptoms. *Archives of General Psychiatry, 65*(1), 81-89.

\*Chen, J. K., Johnston, K. M., Petrides, M., & Ptito, A. (2008b). Recovery from mild head injury in sports: Evidence from serial functional magnetic resonance imaging studies in male athletes. *Clinical Journal of Sport Medicine, 18*(3), 241-247.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

\*Collie, A., Makdissi, M., Maruff, P., Bennell, K., & McCrory, P. R. (2006). Cognition in the days following concussion: Comparison of symptomatic versus asymptomatic athletes. *Journal of Neurology, Neurosurgery and Psychiatry, 77*(2), 241-245.

\*Collins, M. W., Iverson, G. L., Lovell, M. R., McKeag, D. B., Norwig, J., & Maroon, J. (2003). On-field predictors of neuropsychological and symptom deficit following sports-related concussion. *Clinical Journal of Sport Medicine, 13*(4), 222-229.

\*Collins, M. W., Lovell, M. R., Iverson, G. L., Ide, T., & Maroon, J. (2006). Examining concussion rates and return to play in high school football players wearing newer helmet technology: A three-year prospective cohort study. *Neurosurgery, 58*(2), 275-286.

Colorado Medical Society. (1991). *Report of the Sports Medicine Committee: Guidelines for the management of concussion in sports (revised)*. Denver, Colorado: Colorado Medical Society.

Committee on Head Injury Nomenclature of the Congress of Neurological Surgeons. (1966). Glossary of head injury, including some definitions of injury to the cervical spine. *Clinical Neurosurgery, 12*, 386-394.

\*Covassin, T., Schatz, P., & Swanik, C. B. (2007). Sex differences in neuropsychological function and post-concussion symptoms of concussed collegiate athletes. *Neurosurgery, 61*(2), 345-351.

\*Covassin, T., Stearne, D., & Elbin, R. (2008). Concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes. *Journal of Athletic Training, 43*(2), 119-124.

\*Cremona-Meteyard, S. L., & Geffen, G. M. (1994). Persistent visuospatial attention deficits following mild head injury in Australian rules football players. *Neuropsychologia, 32*(6), 649-662.

\*Daniel, C., Nassiri, J. D., Wilckens, J., & Land, B. C. (2002). The implementation and use of the Standardized Assessment of Concussion at the U.S. Naval Academy. *Military Medicine, 167*(10), 873-876.

\*Dupuis, F., Johnston, K. M., Lavoie, M., Lepore, F., & Lassonde, M. (2000). Concussions in athletes produce brain dysfunction as revealed by event-related potentials. *Neuroreport: For Rapid Communication of Neuroscience Research, 11*(18), 4087-4092.

\*Echemendia, R. J., Putukian, M., Mackin, R. S., Julian, L., & Shoss, N. (2001). Neuropsychological test performance prior to and following sports-related mild traumatic brain injury. *Clinical Journal of Sport Medicine, 11*(1), 23-31.

\*Ellemberg, D., Leclerc, S., Couture, S., & Daigle, C. (2007). Prolonged neuropsychological impairments following a first concussion in female university soccer athletes. *Clinical Journal of Sport Medicine, 17*(5), 369-374.

\*Erlanger, D., Kaushik, T., Cantu, R. C., Barth, J. T., Broshek, D. K., Freeman, J. R., & Webbe, F. M. (2003). Symptom-based assessment of the severity of a concussion. *Journal of Neurosurgery, 98*(3), 477-484.

\*Erlanger, D., Saliba, E., Barth, J., Almquist, J., Webright, W., & Freeman, J. (2001). Monitoring resolution of postconcussion symptoms in athletes: Preliminary results of a web-based neuropsychological test protocol. *Journal of Athletic Training, 36*(3), 280-287.

\*Fazio, V. C., Lovell, M. R., Pardini, J. E., & Collins, M. W. (2007). The relation between post concussion symptoms and neurocognitive performance in concussed athletes. *NeuroRehabilitation. Special Issue: Sports and concussion, 22*(3), 207-216.

\*Ferguson, R. J., Mittenberg, W., Barone, D. F., & Schneider, B. (1999). Postconcussion syndrome following sports-related head injury: Expectation as etiology. *Neuropsychology, 13*(4), 582-589.

\*Field, M., Collins, M. W., Lovell, M. R., & Maroon, J. (2003). Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *The Journal of Pediatrics, 142*(5), 546-553.

\*Gosselin, N., Lassonde, M., Petit, D., Leclerc, S., Mongrain, V., Collie, A., & Montplaisir, J. (2009). Sleep following sport-related concussions. *Sleep Medicine, 10*(1), 35-46.

\*Gosselin, N., Theriault, M., Leclerc, S., Montplaisir, J., & Lassonde, M. (2006). Neurophysiological anomalies in symptomatic and asymptomatic concussed athletes. *Neurosurgery, 58*(6), 1151-1161.

\*Guskiewicz, K. M., Perrin, D. H., & Gansneder, B. M. (1996). Effect of mild head injury on postural stability in athletes. *Journal of Athletic Training, 31*(4), 300-306.

\*Guskiewicz, K. M., Riemann, B. L., Perrin, D. H., & Nashner, L. M. (1997). Alternative approaches to the assessment of mild head injury in athletes. *Medicine & Science in Sports & Exercise, 29*(Suppl. 7), S213-S221.

\*Guskiewicz, K. M., Ross, S. E., & Marshall, S. W. (2001). Postural stability and neuropsychological deficits following concussion in collegiate athletes. *Journal of Athletic Training, 36*(3), 263-273.

\*Hinton-Bayre, A. D., Geffen, G. M., Geffen, L. B., McFarland, K. A., & Frijs, P. (1999). Concussion in contact sports: Reliable change indices of impairment and recovery. *Journal of Clinical and Experimental Neuropsychology, 21*(1), 70-86.

\*Hinton-Bayre, A. D., Geffen, G. M., & McFarland, K. A. (1997). Mild head injury and speed of information processing: A prospective study of professional Rugby League players. *Journal of Clinical and Experimental Neuropsychology, 19*(2), 275-289.

\*Iverson, G. L., Brooks, B. L., Collins, M. W., & Lovell, M. R. (2006). Tracking neuropsychological recovery following concussion in sport. *Brain Injury, 20*(3), 245-252.

\*Iverson, G. L., Gaetz, M., Lovell, M. R., & Collins, M. W. (2004). Cumulative effects of concussion in amateur athletics. *Brain Injury, 18*(5), 433-443.

\*Iverson, G. L., Lovell, M. R., & Collins, M. W. (2003). Interpreting change on ImPACT following sport concussion. *The Clinical Neuropsychologist, 17*(4), 460-467.

\*Jantzen, K. J., Anderson, B., Steinberg, F. L., & Kelso, J. A. S. (2004). A prospective functional MR imaging study of mild traumatic brain injury in college football players. *American Journal of Neuroradiology, 25*(5), 738-745.

\*Johnson, P. D., Hertel, J., Olmsted, L. C., Denegar, C. R., & Putukian, M. (2002). Effect of mild brain injury on an instrumented agility task. *Clinical Journal of Sport Medicine, 12*(1), 12-17.

\*Killam, C., Cautin, R. L., & Santucci, A. C. (2005). Assessing the enduring residual neuropsychological effects of head trauma in college athletes who participate in contact sports. *Archives of Clinical Neuropsychology, 20*(5), 599-611.

\*Lavoie, M. E., Dupuis, F., Johnston, K. M., Leclerc, S., & Lassonde, M. (2004). Visual P300 effects beyond symptoms in concussed college athletes. *Journal of Clinical and Experimental Neuropsychology, 26*(1), 55-73.

\*Lovell, M. R., & Collins, M. W. (1998). Neuropsychological assessment of the college football player. *Journal of Head Trauma Rehabilitation, 13*(2), 9-26.

\*Lovell, M. R., Collins, M. W., Iverson, G. L., Field, M., Maroon, J. C., Cantu, R. C., . . . Fu, F. H. (2003). Recovery from mild concussion in high school athletes. *Journal of Neurosurgery, 98*(2), 296-301.

\*Lovell, M. R., Collins, M. W., Iverson, G. L., Johnston, K. M., & Bradley, J. P. (2004). Grade 1 or 'ding' concussions in high school athletes. *The American Journal of Sports Medicine, 32*(1), 47-54.

\*Lovell, M. R., Iverson, G. L., Collins, M. W., Podell, K., Johnston, K. M., Pardini, D., . . . Maroon, J. C. (2006). Measurement of symptoms following sports-related concussion: Reliability and normative data for the post-concussion scale. *Applied Neuropsychology, 13*(3), 166-174.

\*Macciocchi, S. N., Barth, J., Littlefield, L., & Cantu, R. C. (2001). Multiple concussions and neuropsychological functioning in collegiate football players. *Journal of Athletic Training, 36*(3), 303-306.

\*Macciocchi, S. N., Barth, J. T., Alves, W., Rimel, R. W., & Jane, J. A. (1996). Neuropsychological functioning and recovery after mild head injury in collegiate athletes. *Neurosurgery, 39*(3), 510-514.

Macciocchi, S. N., Barth, J. T., & Littlefield, L. M. (2000). Outcome after sports concussion. In R. C. Cantu (Ed.), *Neurologic athletic head and spine injuries* (pp. 101-107). New York: W.B. Saunders Company.

\*Maddocks, D. L., Dicker, G. D., & Saling, M. M. (1995). The assessment of orientation following concussion in athletes. *Clinical Journal of Sport Medicine, 5*(1), 32-35.

\*Maddocks, D. L., & Saling, M. M. (1996). Neuropsychological deficits following concussion. *Brain Injury, 10*(2), 99-103.

\*Makdissi, M., Collie, A., Maruff, P., Darby, D. G., Bush, A., McCrory, P. R., & Bennell, K. (2001). Computerised cognitive assessment of concussed Australian Rules footballers. *British Journal of Sports Medicine, 35*(5), 354-360.

\*McClincy, M. P., Lovell, M. R., Pardini, J. E., Collins, M. W., & Spore, M. K. (2006). Recovery from sports concussion in high school and collegiate athletes. *Brain Injury, 20*(1), 33-39.

\*McCrea, M. (2001). Standardized mental status testing on the sideline after sport-related concussion. *Journal of Athletic Training, 36*(3), 274-279.

\*McCrea, M., Guskiewicz, K. M., Marshall, S. W., Barr, W., Randolph, C., Cantu, R. C., . . . Kelly, J. P. (2003). Acute effects and recovery time following concussion in collegiate football players: The NCAA Concussion Study. *Journal of the American Medical Association, 290*(19), 2556-2563.

\*McCrea, M., Kelly, J. P., Randolph, C., Cisler, R., & Berger, L. (2002). Immediate neurocognitive effects of concussion. *Neurosurgery, 50*(5), 1032-1040.

\*McCrea, M., Kelly, J. P., Randolph, C., Kluge, J., Bartolic, E., Finn, G., & Baxter, B. (1998). Standardized Assessment of Concussion (SAC): On-site mental status evaluation of the athlete. *Journal of Head Trauma Rehabilitation, 13*(2), 27-35.

\*McCrory, P. R., Ariens, M., & Berkovic, S. F. (2000). The nature and duration of acute concussive symptoms in Australian football. *Clinical Journal of Sport Medicine, 10*(4), 235-238.

McCrory, P. R., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R. C., Dvorak, J., . . . Schamasch, P. (2005). Summary and agreement statement of the second International Conference on Concussion in Sport, Prague 2004. *Clinical Journal of Sport Medicine, 15*(2), 48-55.

\*Mihalik, J. P., McCaffrey, M. A., Rivera, E. M., Pardini, J. E., Guskiewicz, K. M., Collins, M. W., & Lovell, M. R. (2007). Effectiveness of mouthguards in reducing neurocognitive deficits following sports-related cerebral concussion. *Dental Traumatology, 23*(1), 14-20.

\*Moser, R. S., & Schatz, P. (2002). Enduring effects of concussion in youth athletes. *Archives of Clinical Neuropsychology, 17*(1), 91-100.

\*Moser, R. S., Schatz, P., & Jordan, B. D. (2005). Prolonged effects of concussion in high school athletes. *Neurosurgery, 57*(2), 300-306.

National Health and Medical Research Council (NHMRC). (1994). *Football injuries of the head and neck*. Canberra: Australian Government.

\*Parker, T. M., Osternig, L. R., Lee, H. J., Donkelaar, P., & Chou, L. S. (2005). The effect of divided attention on gait stability following concussion. *Clinical Biomechanics, 20*(4), 389-395.

\*Parker, T. M., Osternig, L. R., Van Donkelaar, P., & Chou, L.-S. (2006). Gait stability following concussion. *Medicine and Science in Sport and Exercise, 38*(6), 1032-1040.

\*Parker, T. M., Osternig, L. R., van Donkelaar, P., & Chou, L. S. (2008). Balance control during gait in athletes and non-athletes following concussion. *Medical Engineering & Physics, 30*(8), 959-967.

\*Pellman, E. J., Lovell, M. R., Viano, D. C., & Casson, I. R. (2006). Concussion in professional football: Recovery of NFL and high school athletes assessed by computerized neuropsychological testing - Part 12. *Neurosurgery, 58*(2), 263-274.

\*Pellman, E. J., Lovell, M. R., Viano, D. C., Casson, I. R., & Tucker, A. M. (2004). Concussion in professional football: Neuropyschological testing - Part 6. *Neurosurgery, 55*(6), 1290-1303.

\*Peterson, C. L., Ferrara, M. S., Mrazik, M., Piland, S., & Elliott, R. (2003). Evaluation of neuropsychological domain scores and postural stability following cerebral concussion in sports. *Clinical Journal of Sport Medicine, 13*(4), 230-237.

\*Piland, S. G., Motl, R. W., Ferrara, M. S., & Peterson, C. L. (2003). Evidence for the factorial and construct validity of a self-report concussion symptoms scale. *Journal of Athletic Training, 38*(2), 104-112.

Quality Standards Subcommittee of the American Academy of Neurology (AAN). (1997). Practice Parameter. The management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology, 48*(3), 581-585.

\*Register-Mihalik, J., Guskiewicz, K. M., Mann, J. D., & Shields, E. W. (2007). The effects of headache on clinical measures of neurocognitive function. *Clinical Journal of Sport Medicine, 17*(4), 282-288.

\*Riemann, B. L., & Guskiewicz, K. M. (2000). Effects of mild head injury on postural stability as measured through clinical balance testing. *Journal of Athletic Training, 35*(1), 19-25.

\*Schatz, P., Pardini, J. E., Lovell, M. R., Collins, M. W., & Podell, K. (2006). Sensitivity and specificity of the ImPACT test battery for concussion in athletes. *Archives of Clinical Neuropsychology, 21*(1), 91-99.

\*Sim, A., Terryberry-Spohr, L., & Wilson, K. R. (2008). Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes. *Journal of Neurosurgery, 108*(3), 511-516.

\*Slobounov, S., Cao, C., Sebastianelli, W., Slobounov, E., & Newell, K. (2008). Residual deficits from concussion as revealed by virtual time-to-contact measures of postural stability. *Clinical Neurophysiology, 119*(2), 281-289.

\*Slobounov, S., Slobounov, E., & Newell, K. (2006). Application of virtual reality graphics in assessment of concussion. *CyberPsychology & Behavior. Special Issue: Virtual and physical toys: Open-ended features for non-formal learning, 9*(2), 188-191.

\*Slobounov, S., Slobounov, E., Sebastianelli, W., Cao, C., & Newell, K. (2007). Differential rate of recovery in athletes after first and second concussion episodes. *Neurosurgery, 61*(2), 338-344.

\*Slobounov, S., Tutwiler, R., Sebastianelli, W., & Slobounov, E. (2006). Alteration of postural responses to visual field motion in mild traumatic brain injury. *Neurosurgery, 59*(1), 134-139.

\*Sosnoff, J. J., Broglio, S. P., & Ferrara, M. S. (2008). Cognitive and motor function are associated following mild traumatic brain injury. *Experimental Brain Research, 187*(4), 563-571.

\*Sosnoff, J. J., Broglio, S. P., Hillman, C. H., & Ferrara, M. S. (2007). Concussion does not impact intraindividual response time variability. *Neuropsychology, 21*(6), 796-802.

\*Thompson, J., Sebastianelli, W., & Slobounov, S. (2005). EEG and postural correlates of mild traumatic brain injury in athletes. *Neuroscience Letters, 377*(3), 158-163.

\*Van Kampen, D. A., Lovell, M. R., Pardini, J. E., Collins, M. W., & Fu, F. H. (2006). The 'value added' of neurocognitive testing after sports-related concussion. *The American Journal of Sports Medicine, 34*(10), 1630-1635.

\*Warden, D. L., Bleiberg, J., Cameron, K. L., Ecklund, J., Walter, J., Sparling, M. B., . . . Arciero, R. (2001). Persistent prolongation of simple reaction time in sports concussion. *Neurology, 57*(3), 524-526.