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# Gender Differences in Symptom Reporting on Baseline Sport Concussion Testing Across the Youth Age Span

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## Abstract

**Background:** Little is known regarding gender differences in concussion symptom reporting developmentally across the age span, specifically in pre-adolescent athletes. The present study asks: Do boys and girls differ in symptom reporting across the pre-adolescent to post-adolescent age span?
**Method:** This retrospective study utilized baseline assessments from 11,695 10–22 year-old athletes assigned to 3 independent groups: Pre-adolescent 10–12 year olds ($n$ = 1,367; 12%), Adolescent 13–17 year olds ($n$ = 2,974; 25%), and Late Adolescent 18–22 year olds ($n$ = 7,354; 63%). Males represented 60% of the sample. Baseline ImPACT composite scores and Post-Concussion Symptom Scale scores (Total, Physical, Cognitive, Emotional, Sleep) were analyzed for the effects of age and gender.
**Results:** Statistically significant main effects were found for age and gender on all ImPACT composites, Total Symptoms, and Symptom factors. Significant interaction effects were noted between age and gender for all ImPACT composites, Total Symptoms, and Symptom factors. Total Symptoms and all Symptom factors were highest in adolescents (ages 13–17) for males and females. In the 10–12 age group, females displayed lower Total Symptoms, Physical, and Sleep factors than males.
**Conclusion:** The notion of females being more likely than males to report symptoms does not appear to apply across the developmental age span, particularly prior to adolescence. Females show greater emotional endorsement across the youth age span (10–22 years). Adolescence (13–17 years) appears to be a time of increased symptomatology that may lessen after the age of 18.

*Keywords:* Baseline testing; Concussion symptoms; Gender differences; Youth concussion

## Introduction

Over the past few decades, the public health issue of concussion has become well recognized both in scientific research and the media (Guskiewicz et al., 2003; Montopoli, 2013; Moser, 2007; Schwarz, 2010). Although attention was initially garnered by male sports, the media spotlight on athletic participation has also unveiled the increasing impact of concussion on women in sports (Keating, 2017). Early work exploring the role of gender differences in concussion (Broshek et al., 2005) highlighted the need to individualize concussion management for each athlete, based on the greater rate of impairment and adverse effects experienced by female athletes, including observations that females appear to be at greater risk for concussion, as well as worse outcomes (Dick, 2009). Increased symptom reporting in females (as compared to males) has been well documented, in soccer players across a wide age span (Colvin et al., 2009), in high school (Covassin, Elbin, Larson, & Kontos, 2012b), and college-aged athletes from a variety of sports (Cottle, Hall, Patel, Barnes, & Ketcham, 2017; Covassin et al., 2006).

A number of hypotheses have been offered to help explain the greater vulnerability of females to concussion. First, it has been suggested that factors such as decreased neck strength (Tierney *et al.* 2005) and neck size differences (Barth, Freeman, Broshek, & Varney, 2001) could account for greater concussion occurrence and symptomatology in females. Such physical differences would explain the greater stability and ability of the male neck to withstand the forces of acceleration, deceleration, and rotation that result in concussion.


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Second, sex differences in neuroanatomy of the brain have been considered. Subtle differences in neurocognitive function and fetal vulnerability to brain dysfunction in males versus females have been linked to morphological differences implicating neuronal densities, the posterior corpus callosum, the hypothalamus, as well as other areas of the cerebral cortex (De Courten-Myers, 1999). Such differences could also explain differences in concussion vulnerability.

Third, decreased symptom reporting in males (relative to females) has also been attributed to decreased awareness of concussion symptoms in males (Covassin *et al.* 2012b) and tendencies to overtly minimize or hide concussion-related symptoms. It has been suggested that males perceive greater pressure to play through the pain and not let down their teammates, consistent with masculine, cultural roles that avoid a focus on admitting weakness.

Fourth, it has also been posited that disruption of endogenous estrogen or progesterone production makes females more vulnerable to the effects of concussion (Bazarian, Blyth, Mookerjee, He, & McDermott, 2010). A meta-analysis and systematic review of 21 (Brown, Elsass, Miller, Reed, & Reneker, 2015) identified eligible studies of the role of sex in symptom reporting of high school and college athletes found that females displayed higher pre- and post-concussion total symptoms but concluded that the results, when statistically corrected, demonstrated no significant clinical difference. Furthermore, at post-concussion only one symptom demonstrated statistical difference. The authors concluded that the observed differences in concussion symptomatology between males and females could be explained by normal hormonal changes related to the menstrual cycle. Thus, these hormonal changes need to be controlled for in our research and clinical investigations and may be the reason that systematic review findings on male and female differences were not consistent, or as the authors stated are “divergent.”

Researchers have shown that females display longer recovery periods than males (Covassin & Elbin, 2011), that high school athletes perform worse on baseline neurocognitive testing than college athletes (Covassin, Elbin, Harris, Parker, & Kontos, 2012a), and that college females performed worse on balance measures than high school females (Covassin *et al.* 2012a). Thus, we are beginning to have some sense of how male versus female athletes differ, how high school versus college age athletes differ, and how female high school versus female college athletes differ. However, the focus has been primarily high school and college youth athletes.

Consensus experts, as part of the Concussion in Sport Group Berlin International Conference (Davis et al., 2017) exposed the lack of research focusing on how different youth age groups should be managed with regard to concussion. A follow-up, systematic review of the literature (Moser, Davis, & Schatz, 2017) further asserted the limited understanding of childhood concussion and the need to address the question of how concussion varies developmentally to help guide diagnosis and management. Importantly, as already noted (Covassin *et al.* 2012a; Moser et al., 2017), youth concussion research has mainly focused on high school to college age groups, with limited focus on pre-adolescence or younger ages. Increased symptom reporting was recently documented (Moser & Schatz, 2017) in pre-high school aged (10–14 years) athletes based on their history of previous concussion, a pattern that had been previously documented in older adolescents (Moser, Schatz, & Jordan, 2005; Schatz, Moser, Covassin, & Karpf, 2011). Overall, publications reveal that self-reported symptoms appeared to be lower in youth athletes (Mean Total Symptom Score=3.1) (Moser & Schatz, 2017) than in high school (Mean=7.3) (Moser et al., 2005; Schatz et al., 2011) or college (Covassin et al., 2006) (Mean=8.6) athletes.

Expanding our research to the younger, pre-adolescent athlete might provide us with a greater understanding of the male versus female difference in symptom reporting. Perhaps in that age group, neck sizes and differences are not as great. Although brain morphology differences may exist, perhaps they are not as influential, as brain development of frontal networks is still occurring in adolescence (Rubia *et al.* 2006). On the one hand, by that time, we might expect that male versus female cultural roles and expectations are substantially incorporated, but hormonal influences may be minimal or still in early stages. Given these physical, cortical, and hormonal differences between the younger and older youth athlete, could one expect differences in male versus female reporting of symptoms?

Given that little is known regarding gender differences in younger athletes and how symptom reporting presents developmentally, the present research study sought to answer the question: Do boys and girls differ in symptom reporting across pre-adolescent and post-adolescent age span?

## Materials and Methods

### *Study Design*

Institutional Review Board approval was obtained for cross-sectional retrospective analysis of de-identified data from a multi-center database. The STROBE statement checklist for reporting of observational, cross-sectional studies was consulted for reporting of results (von Elm et al., 2008).

### Participants

Baseline neurocognitive and symptom data were extracted from large, multi-center samples of athletes who had completed pre-season baseline neurocognitive and symptom assessments between January 2009 and February 2016. All participants were athletes in athletic programs which administered baseline testing as part of pre-participation medical screening. In cases where a participant completed two successive baselines in consecutive or staggered years, only the first baseline was included in the statistical analysis. Prior to compiling the data from this multi-site database, participants were excluded based on the following criteria:

- Evidence of "invalid" baseline scores, flagged as "Baseline ++" within the ImPACT software (Lovell, 2011), representing the cases that fall below predetermined cut-offs that reflect performance below the fifth percentile.
- A previous diagnosis of a learning disorder or attention deficit disorder.
- A history of treatment for headache or migraines.
- Having sustained a concussion within the past six months.
- Excluding participants with self-reports of epilepsy/seizures, brain surgery, meningitis, substance/alcohol use, or psychiatric treatment.

(Because some of the de-identified samples had already excluded participants on the basis of one or more of the above-listed factor, specific numbers and percentages of excluded are not available). The resultant sample included 11,695 athletes, 10–22 years old, 60% male ($N = 7{,}029$) and 40% female ($N = 4{,}666$), from which participants were assigned to one of three independent age groups: Pre-adolescent 10–12 year olds ($n = 1{,}367$; 11.7%), Adolescent 13–17 year olds ($n = 2{,}974$; 25.4%), and Late Adolescent 18–22 year olds ($n = 7{,}354$; 62.9%).

### Measures and Variables

Participants completed the online version of the ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) test, which is a computer-based program that measures neurocognitive functions and concussion symptoms. The test is comprised of six subtests that measure attention, working memory, and processing speed, rendering Verbal Memory, Visual Memory, Motor Processing Speed, Reaction Time and Impulse Control composite scores. (For more detail regarding ImPACT, please see Iverson, Brooks, Lovell, & Collins, 2006). ImPACT includes administration of the Post-Concussion Symptom Scale (PCSS) that renders a Total Symptom Score which is the sum of scores on the 22-item 7-point Likert-type scale. Athletes rate 22 symptoms from (not experiencing) to 6 (severe), including: headache, nausea, vomiting, balance problems, dizziness, fatigue, trouble falling asleep, sleeping more than usual, sleeping less than usual, drowsiness, sensitivity to light, sensitivity to noise, irritability, sadness, nervousness, feeling more emotional, numbness or tingling, feeling slowed down, feeling mentally "foggy," difficulty concentrating, difficulty remembering, and visual problems (see Table 1). Factor analysis research has demonstrated that the symptoms fall into four factors or clusters: physical, cognitive, emotional, and sleep (Kontos et al., 2012; Lau, Collins, & Lovell, 2011).

### Statistical Methods

Two age-by-gender multivariate analyses of variance (MANOVA) were conducted with age (Pre-adolescent, Adolescent, Late Adolescent) and gender (Male, Female) as the independent variables. The dependent measures included ImPACT Composite Index (Verbal Memory, Visual Memory, Visual Motor Speed, and Reaction Time, PCSS Total Symptom Score) in the first MANOVA, and the Physical, Cognitive, Emotional, and Sleep symptom factor scores (derived by summing the symptom scores associated with the particular factor, as shown in Table 1) in the second MANOVA. Analyses were conducted using SPSS, Version 23 (SPSS, 2015). Standard error of the mean (SEM) was calculated using the formula $SEM=SD/\sqrt{N}$, where SD represents the standard deviation, and N represents the sample size. Following Bonferonni correction for inflated Type I Error, statistical significance was set at $p < .001$. Partial-eta squared ($\eta^2$) were calculated as a measure of effect size, with 0.01 constituting a small effect, 0.06 a medium effect and 0.14 a large effect (Cohen, 1988).

## Results

MANOVA revealed a significant main effect of age [$F(10,23370) = 336.8$, $p < .001$, $\eta^2 = .13$] on neurocognitive functioning and total symptom scores, as explained by univariate effects of age on all four ImPACT composite scores and total symptom scores ($p < .001$), with small effect sizes noted for Verbal ($\eta^2 = .02$) and Visual Memory ($\eta^2 = .01$), and large effect

**Table 1.** Symptoms by Physical, Cognitive, Emotional, and Sleep Factors

| Physical | Cognitive | Emotional | Sleep |
|---|---|---|---|
| • Headache | • Feeling mentally "foggy" | • Irritability | • Drowsiness |
| • Nausea | • Feeling slowed down | • Sadness | • Sleeping less than usual |
| • Vomiting | • Difficulty concentrating | • More emotional | • Sleeping more than usual |
| • Balance Problems | • Difficulty remembering | • Nervousness | • Trouble falling asleep |
| • Dizziness | | | |
| • Visual Problems | | | |
| • Fatigue | | | |
| • Sensitivity to light | | | |
| • Sensitivity to noise | | | |
| • Numbness/Tingling | | | |

**Table 2.** Main Effects of Age Group on ImPACT Index and Symptom Factor Scores

| | Age Group | | | | |
|---|---|---|---|---|---|
| Score | 10–12 | 13–17 | 18–22 | $p$ | $\eta^2$ |
| Verbal Memory[a] | 82.80 (9.45/.26) | 84.69 (9.37/.17) | 86.44 (9.65/.11) | .001 | .02 |
| Visual Memory[a] | 71.97 (12.44/.34) | 73.09 (12.65/.23) | 75.59 (12.49/.15) | .001 | .01 |
| Visual Motor Speed[a] | 30.05 (5.69/.15) | 36.97 (6.66/.12) | 40.54 (6.42/.07) | .001 | .21 |
| Reaction Time[b] | .67 (.09/.002) | .59 (.08/.001) | .58 (.08/.001) | .001 | .11 |
| Total Symptom Score[c] | 1.93 (3.35/.10) | 3.09 (4.27/.08) | 2.66 (4.33/.05) | .001 | .01 |
| Physical[d] | .87 (1.96/.05) | 1.02 (1.81/.03) | .86 (1.77/.02) | .001 | .01 |
| Cognitive[c] | .23 (.79/.02) | .43 (1.08/.01) | .34 (1.09/.01) | .001 | .01 |
| Emotional[e] | .42 (1.12/.04) | .64 (1.50/.06) | .61(1.58/.03) | .001 | .01 |
| Sleep[c] | .42 (1.13/.03) | .99 (1.82/.03) | .84 (1.66/.02) | .001 | .01 |

Scores denote: Mean (SD/SEM), SD = Standard Deviation, SEM = Standard Error of the Mean Post-hoc: [a]10–12 < 13–17 < 18–22; [b]18–22 < 13–17 < 10–12; [c]10–12 < 18–22 < 13–17; [d]18–22, 10–12 < 13–17; [e]10–12 < 13–17, 18–22.

sizes for Visual Motor Speed ($\eta^2 = .11$) and Reaction Time ($\eta^2 = .21$); small effect sizes were also noted for Total Symptom Scores and Symptom cluster scores ($\eta^2 = .01$) (Table 2), although between-groups differences extend beyond the SEM. Post-hoc (Scheffé) analyses revealed that individuals in the Late-Adolescent group performed significantly better on ImPACT Composite Scores than individuals in the Adolescent group, who significantly better than the Pre-Adolescent group. However, the Adolescent Group reported significantly more symptoms than did the Late-Adolescent group, who reported significantly more symptoms than the Pre-Adolescent group. MANOVA revealed a significant main effect of gender [$F(5,11685) = 30.4$, $p < .001$, $\eta^2 = .13$] (Table 3) on neurocognitive functioning and total symptom scores, as explained by univariate effects of gender on all 4 ImPACT composite scores and total symptom scores ($p < .001$). Although small effect sizes ($\eta^2 = .01$) are noted on all measures, between-groups differences extend beyond the SEM. A significant age × gender interaction was also noted [$F(10,23370) = 4.8$, $p < .002$, $\eta^2 = .01$], as explained by univariate effects on Visual Motor Speed ($p = .001$), Reaction Time ($p = .002$) and Total Symptom Scores ($p = .001$). See Table 3 for group means, and standard deviations.

A second MANOVA revealed significant main effects of age [$F(8,23372) = 20.3$, $p < .001$, $\eta^2 = .01$] and gender [$F(4,11686) = 19.7$, $p < .001$, $\eta^2 = .01$] on symptom clusters, as well as a significant age × gender interaction [$F(8,23372) = 2.3$, $p < .001$, $\eta^2 = .02$], explained by univariate effects on Physical ($p = .005$), Emotional ($p = .03$) and Sleep ($p = .01$) clusters, with small effect sizes noted ($\eta^2 = .01$) (Table 4, Fig. 1); all between-groups differences extend beyond the SEM. Post-hoc (Scheffé) analyses revealed that, for males, individuals in the Adolescent Group reported significantly more Physical symptoms than individuals in the Late-Adolescent group, significantly more Emotional symptoms than individuals in the Pre-Adolescent group, and significantly more Cognitive Symptoms than individuals in both the Pre- and Late-Adolescent groups; individuals in the Pre-Adolescent group reported significantly fewer Sleep symptoms than individuals in both the Adolescent and Late-Adolescent groups. For females, post-hoc analyses revealed that individuals in the Adolescent Group reported significantly more Physical symptoms than individuals in the Late-Adolescent group, that individuals in the Pre-Adolescent group reported significantly fewer Cognitive, Emotional and Sleep symptoms than individuals in both the Adolescent and Late-Adolescent groups.

## Discussion

Analyses revealed significant effects of age and gender on all ImPACT Index scores, the Total Symptom Score, and Symptom Factors. ImPACT Composite scores improved across the age span, from 10–12 to 13–17 to 18–22 year-old groups.

**Table 3.** Main Effects of Gender on ImPACT Index and Symptom Factor Scores

| Score | Male | Female | $p$ | $\eta^2$ |
|---|---|---|---|---|
| Verbal Memory | 84.97 (9.65/.11) | 86.48 (9.54/.14) | .001 | .01 |
| Visual Memory | 74.99 (12.60/.15) | 73.84 (12.57/.18) | .001 | .01 |
| Visual Motor Speed | 37.99 (7.40/.09) | 39.03 (6.96/.10) | .001 | .01 |
| Reaction Time | .595 (.08/.001) | .592 (.08/.001) | .001 | .01 |
| Total Symptom Score | 2.42 (4.06/.05) | 3.07 (4.48/.07) | .001 | .01 |
| Physical | .85 (1.78/.02) | .98 (1.84/.03) | .001 | .01 |
| Cognitive | .33 (1.06/.01) | .36 (1.05/.01) | .001 | .01 |
| Emotional | .45 (1.29/.02) | .81 (1.79/.03) | .006 | .01 |
| Sleep | .78 (1.60/.02) | .92 (1.73/.03) | .001 | .01 |

Scores denote: Mean (SD/SEM), SD = standard deviation, SEM = Standard Error of the Mean.

**Table 4.** Interaction Effects of Age Group by Gender on ImPACT Index and Symptom Factor Scores

| | | Age Group | | | | |
|---|---|---|---|---|---|---|
| Score | | 10–12 | 13–17 | 18–22 | $p$ | $\eta^2$ |
| Verbal Memory | Male | 82.64 (9.74/.34) | 83.93 (9.30/.22) | 85.83 (9.67/.15) | .07 | .01 |
| | Female | 83.06 (8.98/.39) | 85.83 (9.37/.27) | 87.35 (9.56/.18) | | |
| Visual Memory | Male | 72.11 (12.36.55) | 73.59 (12.72.36) | 76.11 (12.46/.23) | .44 | .01 |
| | Female | 71.76 (12.58/.43) | 72.36 (12.50/.30) | 74.82 (12.50/.19) | | |
| Visual Motor Speed | Male | 29.50 (5.58/.19) | 36.33 (6.84/.16) | 40.28 (6.52/.10) | .001 | .01 |
| | Female | 30.92 (5.77/.25) | 37.92 (6.26/.18) | 40.92 (6.26/.12) | | |
| Reaction Time | Male | .678 (.08/.003) | .586 (.08/.002) | .579 (.08/.001) | .001 | .01 |
| | Female | .662 (.09/.003) | .594 (.08/.002) | .592 (.08/.001) | | |
| Total Symptoms | Male | 1.99 (3.68/.13) | 2.79 (4.04/.10) | 2.35 (4.12/.06) | .002 | .01 |
| | Female | 1.85 (3.40/.15) | 3.54 (4.55/.13) | 3.11 (4.58/.08) | | |
| Physical | Male | .94 (2.14/.07) | .97 (1.78/.04)[a] | .79 (1.71/.03) | .005 | .01 |
| | Female | .76 (1.64/.07) | 1.09 (1.86/.05)[a] | .97 (1.86/.03) | | |
| Cognitive | Male | .23 (.80/.03) | .42 (1.08/.03)[c] | .32 (1.11/.02) | .67 | .01 |
| | Female | .23 (.77/.03)[d] | .44 (1.09/.03) | .37 (1.07/.02) | | |
| Emotional | Male | .36 (1.01/.03) | .48 (1.23/.02)[b] | .46 (1.37/.02) | .03 | .01 |
| | Female | .51 (1.25/.05)[d] | .89 (1.81/.05) | .82 (1.84/.03) | | |
| Sleep | Male | .46 (1.20/.04)[d] | .91 (1.75/.04) | .78 (1.60/.02) | .01 | .01 |
| | Female | .35 (1.00/.04)[d] | 1.11 (1.92/.06) | .92 (1.73/.03) | | |

Scores denote: Mean (SD/SEM), SD = standard deviation, SEM=Standard Error of the Mean Post-hoc: [a]13–17 > 18–22; [b]13–17 > 10–12; [c]13–17 > 10–12,18–22; [d]10–12 < 13–17, 18–22.

Interestingly, for the Total Symptom Score and the four factor scores (Physical, Cognitive, Emotional, Sleep), the trend was one of increased symptoms in the 13–17 year-old adolescent group with a decline by age 18–22 years, although usually not back to the lowest level of symptomatology that was generally seen in the 10–12 year-old group. This peak suggests an overall vulnerability in the adolescent years, which is understandable given the considerable changes in physical body, emotional development, brain development, and hormonal influences (Blakemore, Burnett, & Dahl, 2010). It is during adolescence that we observe significant fine tuning of cortical function (Casey, Tottenham, Liston, & Durston, 2005) and the most substantial morphological, neurochemical and neurobehavioral changes (Arain et al., 2013), with extensive development of the frontostriatal, frontotemporal, and frontoparietal networks that are associated with increased cognitive control (Rubia et al., 2006).

One could argue that the younger 10–12 year-old group may not yet be sophisticated enough to identify, express, endorse, or describe the types of symptoms on the PCSS, and so it would expected that the adolescent group would be better able to endorse more symptoms, resulting in what might appear to be greater symptomatology in the adolescent group. However, such an explanation falls short as it does not explain why there is a trend toward decreasing symptom endorsement by the 18–22 year-old group. It may well be that by the end of puberty, with the stabilization of brain development and hormonal swings, there is a diminution of symptoms.

With respect to gender, females generally showed better performance on Verbal Memory and Visual Motor Speed. These findings are somewhat surprising in that previous studies have shown college-aged males to be stronger on Visual Memory. Perhaps including the younger 10–12 year-old group, which has typically been missing from the research in this area, helps to level the playing field in a sense. As for symptoms, gender was a significant factor for differences between males and

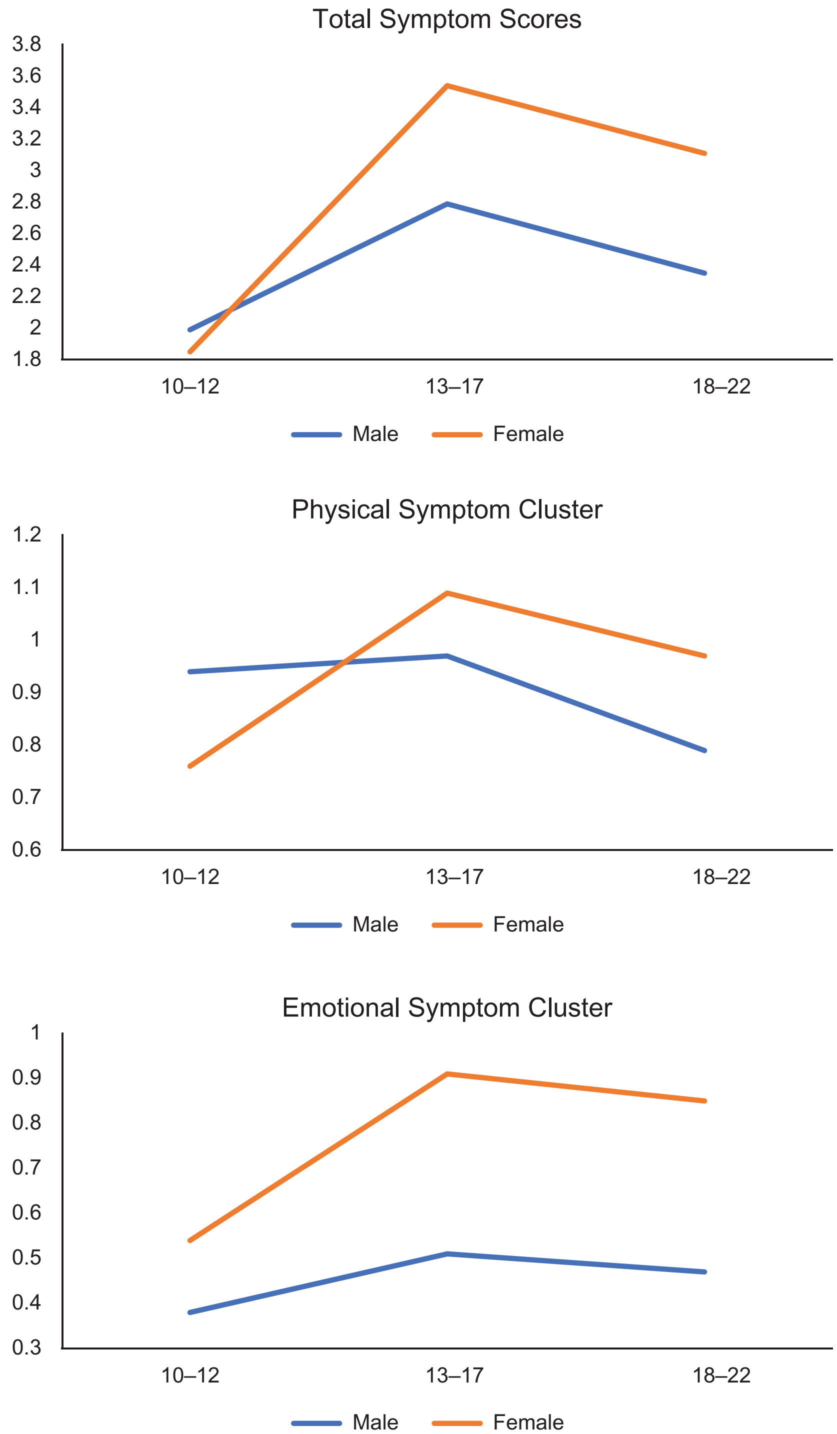


**Fig. 1.** Age-by-gender interaction effects on total symptom scores and symptom clusters.

females, irrespective of age, for Total Symptom Score and all the Symptom factors. The latter finding replicates previous research reports (Covassin et al., 2006; Kontos et al., 2012).

Importantly, an interaction effect for age and gender was observed for all variables. For Visual Motor Speed and Reaction Time, it appears that age and gender together have the greatest effect in the younger years. Interestingly, the 10–12 year-old female group revealed lower Total Symptom, Physical Factor, and Sleep Factor scores than the 10–12 year-old males.

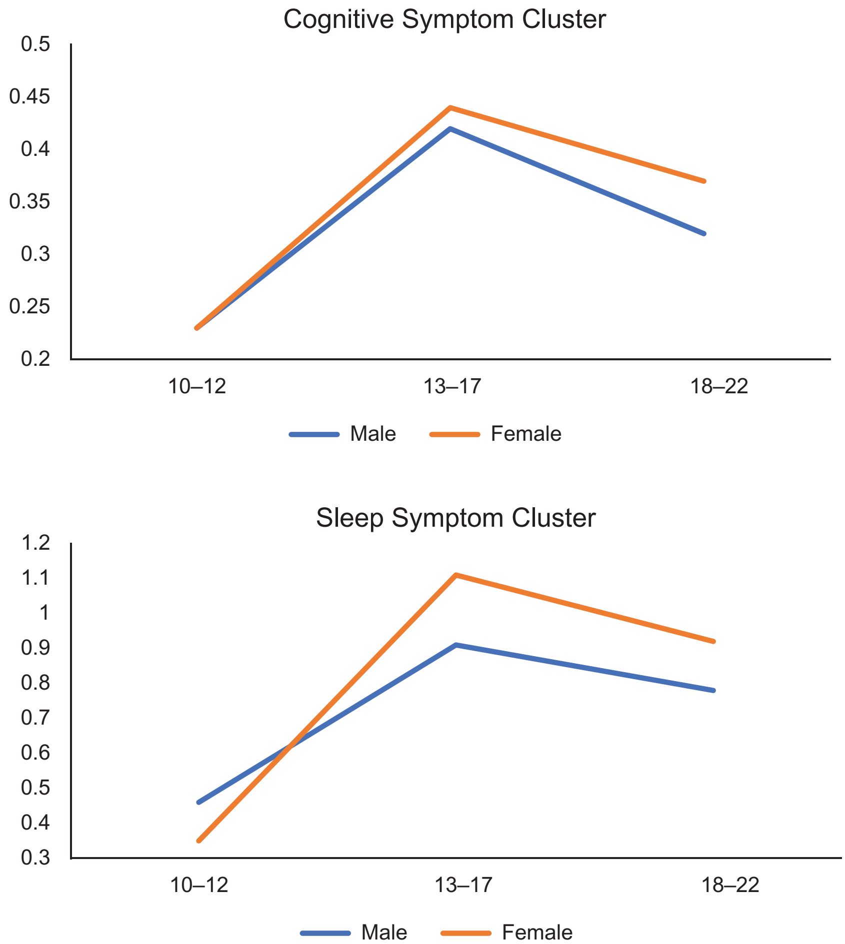


**Fig. 1.** *Continued*

However, this trend was reversed for the two older groups where females exhibited a greater endorsement of symptoms. Such an observation may challenge the theory that females are generally more likely to report symptoms than males are, because such is not the case in the younger group of females. On the other hand, this observation lends further credence to the influence of female hormonal factors on symptoms beginning in the adolescent years (Bazarian et al., 2010). Nevertheless, across all three age categories, females reported more emotional symptoms than males.

Altogether, these results provide some insights, and but also many questions. As noted earlier, hypotheses regarding neck strength/size, cortical/morphological differences, sex/cultural role expectations, and hormonal changes have been some of the explanations that have been posited to account for male versus female differences in symptom reporting. Adding the 10–12 year-old pre-adolescent age group to an examination of male versus female differences across the youth age span has revealed that this younger group indeed presents differently in pattern of symptom presentation than the older youth age groups (adolescent and late adolescence).

The Tanner scales of sexual maturity document the fact that males physically develop somewhat later than females in general (WHO, 2010). Thus, it could be suggested that neck strength and size differences between males and females during the ages 10–12 are not as pronounced as in later years when hormonal/growth changes are in process. Likewise, one could argue the same is true for brain development which manifests significant changes occurring during adolescence as noted earlier. Similarly, the influence of female hormonal changes is more pronounced in the adolescent group.

As for sex role perceptions and expectations, development of and identification with a sex role begins early in life, with a rigid sense of gender identity prior to age 5 and more flexible perceptions after the age of 5 (Ruble et al. 2007). Given all the above, it would seem most likely that physical and sexual development mediated by hormonal changes would explain the results observed here. Furthermore, the hypothesis of a pre-disposition of males to report symptoms less frequently than females due to sex role expectations is challenged here as this was not the case in the pre-adolescent group. It just may be that females do indeed experience more valid, real symptoms than males, and that may well be due to physical/hormonal differences. Physical/hormonal changes would also explain the peak in symptomatology in the adolescent 13–17 year-age range as a whole, when hormones are an issue for both sexes.

These findings support the notions that concussion may not render the same presentation across different youth age groups and that maturation and hormonal changes mediate symptomatology. As researchers we will need to develop frameworks on how to address concussion in different youth age groups, knowing that one size does not fit all. The development of age-specific guidelines for clinical use will need to consider the greater vulnerability of the middle adolescent group, and understand the reasons for differences in male versus female reporting of symptoms as not just attributed to sex role expectations.

### *Limitations and Recommendations*

There are numerous limitations to the present study. Importantly, it was retrospective and cross-sectional in nature. A prospective, longitudinal study that followed a cohort could produce different and more robust findings. In addition, the age cut-offs for the three age categories are not evidence-based and are derived from an arbitrary chronological perspective rather than pubertal/physical development. A future study that can assign participants based on pubertal stages could provide more accurate findings. Furthermore, cluster analyses of trends and shifts in symptom reporting across the youth chronological years may also help provide evidence-based age cut-offs that make more sense.

The present study did not take into account other modifiers/variables that could provide a greater understanding of these results. For example, consideration of history of concussions and other demographic and cultural variables could provide clarification to the present results. Similarly, the present research employed the PCSS 4 factor model for both men and women. Preliminary research presented elsewhere suggests that females may exhibit additional or different factors, such as a Fatigue or a Nausea factor (Murray, Moser, Cabry, & Schatz, 2016). Further research is recommended to more accurately identify female factor model that can be utilized.

Data for the present study was gleaned from a database that included ImPACT and the PCSS. However, younger athletes such as 10 and 11 year olds are now advised to access pediatric versions of baseline neurocognitive testing and symptom reporting. Employing these pediatric versions could potentially alter the interpretation of the findings of this present study. Thus, future research would do well to include pediatric tools as well as venture forth to younger age groups to better assess the developmental spectrum. Such is the research that is needed in order to create age-specific concussion guidelines, as called for by the 2016 Berlin International Conference on Concussion in Sport (Davis et al., 2017).

## Conclusion

The present study is the first of its kind to examine gender differences in baseline neurocognition and symptom reporting across the youth age span extending down to the 10–12 year-old pre-adolescent age group. General results, based on youth ages 10 through 22 years, revealed gender and age to be significant for differences in all ImPACT Composite scores, Total Symptom Score and the symptom factors, with significant interaction effects noted. Total Symptom score and all Symptom Factors peaked in adolescence for both males and females, suggesting a period of adolescent vulnerability. In the 10–12 age group, females displayed lower Total Symptoms, Physical Factor and Sleep Factor scores than males challenging the notion of females generally being more likely than males to report their symptoms as that does not seem to be the case prior to adolescence. Unsurprisingly, greater emotional symptom endorsement for females across the youth age span (10–22 years) is supported. The adolescent years of 13–17 years appear to be a time of increased symptomatology that may lessen after the age of 18 years. The role of hormonal influence and physical, pubertal development may help explain these findings and should be further explored.

## Conflict of Interest

None declared.

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