Hormonal Contraceptive Influence on Baseline Vestibular/Ocular Symptomatology and Provocation for Concussion

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Background: Hormonal contraceptives (HCs) and the menstrual cycle have been suggested to affect symptom severity and postconcussion recovery. Additionally, hormones have been a suggested rationale for sex differences between female and male athletes on concussion assessment. Researchers have yet to explore the effects of HC use on baseline symptomatology, including symptom reporting and provocation.

Purpose: To examine the influence of HC use on a baseline symptom reporting and vestibular/ocular provocation battery.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 61 college-aged individuals (21 HC-using women, 21 non–HC-using women, 19 men) were administered a baseline symptom battery consisting of the Post-Concussion Symptom Scale (PCSS), Headache Impact Test-6 (HIT-6), Pediatric Vestibular Symptom Questionnaire (PVSQ), and Vestibular/Ocular Motor Screening (VOMS). The main outcome measures consisted of PCSS symptom reporting (total symptoms, symptom severity score, and symptom factors), HIT-6 and PVSQ total scores, and VOMS item (ie, saccades, convergence, or vestibular/ocular reflex) symptom provocation scores.

Results: Significant differences were reported on HIT-6, with the highest headache reporting in the HC group ($P = .026$). On the PVSQ, the HC group also reported greater dizziness and unsteadiness symptoms than the non-HC group ($P = .023$). Similar findings existed on the PCSS, with the HC group reporting greater total symptoms ($P < .001$), symptom severity ($P < .001$), and vestibular-somatic ($P = .024$), cognitive-sensory ($P = .004$), sleep-arousal ($P = .001$), and affective ($P < .001$) factors compared with the non-HC group. Smooth pursuit (ie, following finger smoothly with eyes) was the only VOMS items with differences between groups ($P = .003$), with the HC group having greater provocation compared with non-HC users ($P = .020$).

Conclusion: HC use was associated with overall symptomatology and worse self-reported symptoms on vestibular-related inventories and concussion symptom scales and factors when compared with non-HC users and male controls. Additionally, HC users reported higher VOMS provocation scores on the smooth pursuit item than non-HC users and male controls.

Keywords: head injuries/concussion; Vestibular/Ocular Motor Screening; female athlete

Sport-related concussion remains an area of growing concern among sports medicine clinicians. Assessment of concussion involves a range of clinical domains, including self-reported symptoms, physical signs, behavioral changes, balance, and cognition.[24] Recent impairments of concussion have been categorized into clinical profiles, including vestibular, ocular, migraine, cognitive/fatigue, and anxiety/mood, to better understand specific dysfunction and rehabilitation strategies.[20] Using a multifaceted assessment approach, combined with injury characteristics, medical history, and risk factors, aids in establishing a profile to better manage concussion.[20] Individualized baseline testing and comparisons to normative data may aid in better recognition and clinical decision-making postinjury.[43,44] However, clinicians must be cautious when comparing postinjury performance with normative values in the absence of individualized baseline assessments, as modifying factors may threaten validity if not considered. These factors typically include individuals who may

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underperform or score below average norms, including those with diagnosed attention and learning disorders,[7,10,34] chronic migraines,[30,45] mental and psychological disorders,[18] and physical disability.[28]

Another modifier for concussion assessment is female sex,[8,32] as college female athletes typically endorse more self-reported symptoms at baseline than do male athletes.[8,9] A main hypothesis for sex difference in the literature is due to hormonal changes and fluctuations.[4,9,27] Because of the high rate of female athletes using hormonal contraceptives (HCs) and because they are the most commonly prescribed medication in reproductive-aged women,[23] investigation into the effects of HC use among female athletes has increased. In particular, the use of oral HCs has been associated with a 20% reduction in risk of anterior cruciate ligament injury[16,42,54] and possible improvement in memory and cognition.[52] These results are widely mixed, as the literature suggests that the hormone estrogen has a positive effect on cognition, while progesterone has negative effects.[46] These effects, coupled with estrogen withdrawal, may contribute to menstrual symptoms, especially migraine.[37]

Many of the same symptoms associated with hormonal fluctuation and changes, such as headache, nausea, dizziness, difficulty concentrating, irritability, sadness, and emotional changes, are also common symptoms after concussion.[11,49] Furthermore, HCs, while primarily used to prevent pregnancy, are also commonly used to reduce the severity of symptoms associated with menses, including migraines, fatigue, and depression.[56] Mihalik et al[26] reported that eumenorrheic females reported more total symptoms and severity scores than oral HC users on baseline testing, despite no differences on cognition. However, it is unclear which specific symptoms (eg, headache, dizziness, irritability, and feeling more emotional) and factors (eg, vestibular-somatic and affective) were endorsed. Similar results were noted after concussion in collegiate female athletes, with non-HC users reporting higher symptom severity scores than HC users.[12] However, that study did not control for a history of concussion, depression, anxiety, ADHD, or headaches, which are all previously established modifying factors on concussion assessment. Recent data from the National Collegiate Athletic Association (NCAA)—Department of Defense (DoD) Concussion Assessment, Research and Education (CARE) Consortium indicated that HC use was not associated with differences in recovery time, postconcussion symptoms, or neurocognitive performance 24 to 48 hours postinjury.[17] Moran et al[31] also noted a lack of neurocognitive and oculomotor reaction time differences between HC users and nonusers, but at baseline. Wunderle et al[55] reported that 1 month postconcussion, adult women who were injured during the luteal phase, the last stage of menstruation and when progesterone concentration is high, had lower quality of life (QoL) scores using the EuroQoL questionnaire compared with those who were injured in the follicular phase or taking HC. No differences were reported between phases on the Rivermead Post-Concussion Symptom Questionnaire, a self-report symptom scale describing factors of somatic, cognitive, and emotional symptoms.

The combined findings of the previous literature may provide further clarification into the protective mechanism of estrogen and HCs on the body, while progesterone may negatively contribute to concussion assessment measures. However, researchers have yet to further explore the different symptom factors at baseline between HC and non-HC users, as well as results on screening tools, such as the Vestibular/Ocular Motor Screening (VOMS), which aims to provoke symptoms beyond rested symptom reporting to determine vestibular and ocular impairments. Given the clinical emphasis placed on symptom reporting and the recent implementation of the VOMS into the Sport Concussion Office Assessment Tool 6[38] for sport-related concussion assessment 72 hours after injury, it is imperative to explore the modifying potential of HC use on such measures. Therefore, the primary aim of this study was to examine the influence of HC use on a baseline symptom reporting and provocation battery. This battery consisted of baseline symptoms and factors, headache, vestibular symptom QoL questionnaires, and the VOMS, between HC-using and non–HC-using female athletes and a male control group. Furthermore, this study aimed to implement a more well-controlled design to exclude known modifying factors.

METHODS

Participants

A total of 61 healthy, nonconcussed college-aged individuals (20.43 ± 1.3 years of age), consisting of 42 female athletes and 19 male athletes, participated in this study. Participants were healthy, recreationally active college students and were recruited via fliers, university newsletters, and word of mouth. Participants were screened via

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email regarding their use of HCs and additional inclusion and exclusion criteria, and all participants read and acknowledged the informed consent document. One individual who participated was later excluded from the analyses because of her use of a Nexplanon etonogestrel implant, resulting in a final sample size of 61 participants. Of the female athletes in the sample, 21 were categorized into the HC-using group, indicated by their daily use of oral HCs, and 21 were categorized into the non–HC-using using group, indicated by their not taking HCs. The 19 male athletes in the study served as a control group. Exclusionary criteria for the study included a history of previous concussion, attention or learning disability (eg, attention-deficit/hyperactivity disorder and dyslexia), diagnosed migraines, mental or psychological disorder (eg, depression), and vestibular or visual impairments. Additionally, female participants were excluded from the study if they used other methods besides oral contraceptives (eg, Depo-Provera shot, intrauterine device, or diaphragm/cervical cap), previously or currently were undergoing hormone therapy, were currently menstruating or experiencing premenstrual syndrome effects, or used HCs for <1 year, despite evidence suggesting that hormone and side effect relation balances out after 3 to 5 months.[13] HC users self-reported their specific HC (eg, Ortho Tri-Cyclen and Yaz) by entering it under the medications item of the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT). Institutional review board approval was granted and informed consent was obtained before testing. All participants were compensated monetarily for their participation in the study.

Measures

Post-Concussion Symptom Scale. The Post-Concussion Symptom Scale (PCSS) is a 22-item symptom questionnaire from ImPACT[25] where the participant self-rates severity from 0 (none) to 6 (severe). PCSS symptoms were scored as the total number of symptoms (of 22), symptom severity score (sum of symptoms; of 132), and sum of individual symptom factors. PCSS baseline symptom factors, as described by Kontos et al,[19] consisted of 5 vestibular-somatic (headache, nausea, vomiting, balance problems, and dizziness); 7 cognitive-sensory (sensitivity to light and noise, feelings slowed down, mentally foggy, difficulty concentrating and remembering, and vision problems); 5 sleep-arousal (fatigue, trouble falling asleep, sleeping more or less than usual, and drowsiness); and 4 affective (irritability, sadness, nervousness, and feeling more emotional) symptoms. Numbness was included on the PCSS total number and symptom severity score but not included as a symptom factor given its low factor loading.[19]

Headache Impact Test-6. The Headache Impact Test-6 (HIT-6) is a brief 6-question tool used to assess the impact of headache in both clinical research and practice.[21] The HIT-6 queries about health-related QoL domains of pain, social, role, cognitive functioning, vitality, and psychological distress. Each of the 6 questions is answered and scored on a 5-point Likert scale (6 = never, 8 = rarely, 10 = sometimes, 11 = very often, 13 = always) with a total score ranging between 36 (minimum) and 78 (maximum), with higher scores indicating greater impact of headaches on life. Scores ≥50 indicate that headaches are disrupting the person's life and warrant a visit to their doctor. For this study, the HIT-6 was scored as the total score and binarily as 50 + or below.

Pediatric Vestibular Symptom Questionnaire. The Pediatric Vestibular Symptom Questionnaire (PVSQ) is a brief 10-question tool used to assess the vestibular symptoms of dizziness and unsteadiness in clinical research and practice.[39] The PVSQ queries about sensations of vestibular symptoms such as feeling like things are spinning, pressure in the ears, headaches, nausea, balance problems, and fogginess. Each of the 10 questions is answered and scored on a 4-point Likert scale (0 = never, 1 = almost never, 2 = sometimes, 3 = most of the time), with a total score ranging from 0 (minimum) to 30 (maximum). For this study, the PVSQ was scored as the total score. While the questionnaire is geared toward a population aged 17 years and younger, no validated vestibular questionnaires exist in the literature for adult populations. However, the queries in the PVSQ about daily vestibular symptoms are still applicable to adults. Therefore, the purpose of using the PVSQ is to better understand overall vestibular symptom reporting, regardless of age.

Vestibular/Ocular Motor Screening. The VOMS is a brief vestibular and ocular motor screening tool used to assess symptom provocation after concussion.[36] The VOMS consists of 7 vestibular and oculomotor items that are used to provoke 4 vestibular-related symptoms of headache, dizziness, nausea, and fogginess, including (1) smooth pursuits (ie, following finger smoothly with eyes), (2) horizontal saccades, (3) vertical saccades, (4) convergence, (5) horizontal vestibular ocular reflex (VOR), (6) vertical VOR, and (7) visual motion sensitivity (VMS). Before completing the VOMS, participants indicate their current self-reported rating of the 4 symptoms from 0 (none) to 10 (severe). After each VOMS item, participants report their symptoms on the same scale, noting the change from pretest levels,[29,33,51] to provide a symptom provocation score, for each item. Near point of convergence distance was not included in the analysis because it is an objective measurement of ocular convergence, rather than a symptom report.

Procedures

Participants completed a 1-time baseline symptom battery consisting of the PCSS, HIT-6, PVSQ, and VOMS. All testing was completed individually with the principal investigator (R.N.M.) in a standardized fashion. All symptom reporting questionnaires were completed before the VOMS, so that symptom provocation did not elicit additional symptom reporting on baseline symptoms, with the order of administration as HIT-6, PVSQ, and PCSS.

Statistical Analysis

Descriptive statistics including frequency counts and percentages for categorical variables and means ± standard

TABLE 1
Breakdown of Progestin Hormone in the HC group[a]

	HC Users (n = 21)
Age, y	20.95 ± 1.3
Norethindrone acetate	10 (47.6)
Norgestimate	6 (28.6)
Desogestrel	2 (9.5)
Drospirenone	2 (9.5)
Levonorgestrel	1 (4.8)

[a]Data are presented as n (%). All HC users' estrogen hormone was ethinylestradiol. Progestin hormones were only present in HC users. HC, hormonal contraceptive.

deviations were used to characterize characteristics such as age, sex, and medication. Means and medians were calculated for symptom reporting and for symptom provocation on the VOMS. A 1-way analysis of variance with a Tukey post hoc test was conducted between groups on HIT-6 symptoms. Because of the nonnormalcy of the PVSQ, PCSS, and VOMS data, a series of Kruskal-Wallis H tests were conducted on the pairwise permutations (HC vs non-HC vs male participants) with follow-up Mann-Whitney U tests. To limit the effects of multiple comparisons, separate tests were performed for each battery item and the VOMS was analyzed separately as ocular and vestibular tasks. Effect sizes for the HIT-6 were interpreted using partial eta squared, with $\eta^2 = 0.001$ (small), 0.06 (medium), and 0.14 (large). Epsilon squared (ϵ^2) was used for effect size for the H tests on PVSQ, PCSS, and VOMS with the same interpretation. A 2 × 3 chi-square test for association was conducted between groups and HIT-6 scores ≤50 or ≥50.

RESULTS

Participant Data

A total of 61 healthy individuals aged 18 to 23 years participated in the study, with 21 female participants in the HC group (mean age, 20.95 ± 1.3), 21 female participants in the non-HC group (mean age, 20.00 ± 1.2), and 19 male participants in the control group (mean age, 20.32 ± 1.3). Of the 21 oral pill users, all had ethinylestradiol as the estrogen hormone. A breakdown of progestin hormone in the HC group is provided in Table 1.

Symptom Reporting

Significant group differences were observed between groups on the HIT-6 ($F = 3.891$; $P = .026$), with the HC group reporting higher headache inventory scores than male participants ($P = .035$). No association was noted between groups and likelihood of scores ≤50 or ≥50 ($\chi^2 = 2.662$; $P = .264$). No differences existed between non-HC and both HC ($P = .076$) and male control ($P = .919$) groups. On the PVSQ, no group differences ($H = 5.64$; $P = .060$) occurred, but individual differences were observed between the HC and non-HC groups, with higher symptom scores in HC users ($U = 131.0$; $P = .023$). Large effect sizes were noted for HIT-6 scores ($\eta^2 = 0.12$) and a medium effect size for PVSQ total score ($\epsilon^2 = 0.07$).

PCSS symptom reporting between groups revealed group differences for total symptoms ($H = 14.06$; $P < .001$) and symptom severity ($H = 14.86$; $P = .001$) scores. Specifically, the HC group reported higher total symptom scores than the non-HC ($U = 81.5$; $P < .001$) and male ($U = 113.5$; $P = .019$) groups, along with higher severity scores than the non-HC ($U = 75.5$; $P < .001$) and male ($U = 122.0$; $P = .035$) groups. The non-HC group self-reported a lower symptom severity than the male group ($U = 129.0$; $P = .050$) but not on total symptom scores ($U = 140.5$; $P = .100$). All symptom reporting scores are provided in Table 2. Regarding symptom factors, group differences were observed for all baseline factors: vestibular-somatic ($H = 10.47$; $P = .005$), cognitive-sensory ($H = 8.64$; $P = .013$), sleep-arousal ($H = 10.18$; $P = .006$), and affective ($H = 17.97$; $P < .001$). The HC group reported greater factor scores compared with the non-HC group on vestibular-somatic ($U = 151.0$; $P = .024$), cognitive-sensory ($U = 116.0$; $P = .004$), sleep-arousal ($U = 95.0$; $P = .001$), and affective ($U = 81.0$; $P < .001$). Higher scores were also noted compared with male controls for the vestibular-somatic ($U = 122.5$; $P = .006$) and affective ($U = 83.5$; $P < .001$) factors. Symptom severity ($U = 129.0$; $P = .050$) and cognitive-sensory ($U = 129.0$; $P = .028$) factor scores were higher in the male control group compared with the non-HC group. Large effect sizes were noted on PCSS total symptoms ($\epsilon^2 = 0.16$) and severity ($\epsilon^2 = 0.15$).

Symptom Provocation

Symptom provocation on the VOMS yielded group differences on smooth pursuits ($H = 11.49$; $P = .003$), with female participants in the HC group reporting higher smooth pursuit provocation scores than both the non-HC ($U = 157.5$; $P = .020$) and male ($U = 133.0$; $P = .006$) groups. Despite a lack of group differences, individual comparisons revealed nearly significantly higher VMS scores in the HC group compared with the male group ($U = 142.5$; $P = .056$) and higher horizontal VOR scores in the non-HC group compared with the male group ($U = 129.0$; $P = .026$). No other differences were observed in VOMS provocation scores between the HC and non-HC groups (P value range, .306 [smooth pursuit] to .999 [convergence]), HC and male groups (P value range, .173 [vertical VOR] to .477 [convergence]), and non-HC and male groups (P value range, .105 [VMS] to .509 [horizontal saccades]). On VOMS, a large effect size was noted for smooth pursuits only ($\epsilon^2 = 0.16$), with small effect sizes on all other items (ϵ^2 range, –0.02 to 0.04). VOMS item symptom provocation scores are provided in Table 3.

DISCUSSION

This study is believed to be the first to examine the influence of HC use on both baseline symptom reporting and

TABLE 2
PCSS, HIT-6, and PVSQ Symptom Reporting Between Groups[a]

	HC Female Group		Non-HC Female Group		Male Control Group			
Symptom Reporting Item	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	ϵ^2/η^2	*P*
PCSS								
Total symptoms[b,c]	6.38 ± 4.2	7	2.29 ± 3.4	0	3.53 ± 3.3	3	0.160	<.001
Symptom severity[b,c,d]	10.90 ± 10.3	9	2.95 ± 4.3	0	5.47 ± 5.4	4	0.156	<.001
Vestibular-somatic[b,c]	1.00 ± 1.7	0	0.24 ± 0.7	0	0.05 ± 0.2	0	0.088	.005
Cognitive-sensory[b,d]	1.76 ± 2.1	1	0.67 ± 1.6	0	1.58 ± 2.2	1	0.024	.013
Sleep-arousal[b]	4.76 ± 4.0	4	1.52 ± 1.9	0	2.95 ± 2.6	4	0.143	.006
Affective[b,c]	3.38 ± 3.3	3	0.57 ± 1.2	0	0.84 ± 1.8	0	0.216	<.001
HIT-6								
Total score[c]	48.67 ± 8.4	46	44.00 ± 6.3	44	43.16 ± 5.1	42	0.118	.026
PVSQ								
Total score[b]	5.71 ± 3.9	6	3.10 ± 2.9	2	3.79 ± 2.8	3	0.078	.060

[a]PCSS and PVSQ were analyzed via the *H*-test and HIT-6 was analyzed via analysis of variance. HC, hormonal contraceptive; HIT-6, Headache Impact Test; PCSS, Post-Concussion Symptom Scale; PVSQ, Pediatric Vestibular Symptom Questionnaire.
[b]Different between HC and non-HC groups.
[c]Different between HC and male control groups.
[d]Different between non-HC and male control groups.

TABLE 3
VOMS Symptom Provocation Scores Between Groups[a]

VOMS Item	HC Female Group	Non-HC Female Group	Male Control Group	ϵ^2	*P*
Smooth pursuits[b,c]	0.33 ± 0.4	0.05 ± 0.2	0.00 ± 0.0	0.164	.003
Horizontal saccades	0.38 ± 0.6	0.43 ± 0.9	0.21 ± 0.5	–0.019	.637
Vertical saccades	0.48 ± 0.8	0.38 ± 0.7	0.21 ± 0.5	–0.010	.569
Convergence	0.05 ± 0.2	0.05 ± 0.2	0.16 ± 0.5	–0.010	.684
Horizontal VOR[d]	0.62 ± 1.1	0.95 ± 1.4	0.21 ± 0.4	0.040	.081
Vertical VOR	0.57 ± 1.1	0.48 ± 0.8	0.16 ± 0.3	0.006	.376
VMS	0.86 ± 1.1	0.81 ± 1.3	0.26 ± 0.7	0.024	.143

[a]Data are presented as n (%) or mean ± SD unless otherwise indicated. All medians of VOMS items for all groups were 0.00; VOMS was analyzed using *H* tests. HC, hormonal contraceptive; VMS, visual motion sensitivity; VOMS, Vestibular/Ocular Motor Screening; VOR, vestibular ocular reflex.
[b]Different between HC and non-HC groups.
[c]Different between HC and male control groups.
[d]Different between non-HC and male control groups.

VOMS symptom provocation. The key findings indicated that female athletes using HCs reported higher symptom inventory scores on the HIT-6 than male athletes and higher PVSQ scores compared with non–HC-using female athletes at baseline. Female athletes using HCs also reported greater total symptoms and symptom severity scores, along with vestibular-somatic and affective symptom factors, than non–HC-using female athletes and male athletes. On the VOMS, HC users had greater smooth pursuit provocation than nonusers. After experiencing trauma, resulting symptoms arise from a combination of inputs involving the peripheral nervous system, as well as from central perceptual-cognitive processes.[50] Therefore, a large number of variables, in addition to the physiological disturbance, can contribute to a person's perception of symptom severity.

Synthetic sex hormones have been available since the 1960s and are used by >100 million women worldwide.[6] It has been hypothesized that hormones lead to sex differences on concussion assessment measures, specifically symptom reporting.[8,9,27] However, very few studies have considered HC influence on these measures to date.[26] Endogenous sex hormones have well-documented effects on the brain, yet the effects of synthetic sex hormones have been less explored,[6] but still may have a significant neural impact.[5] Pletzer et al[40] found structural changes related to HC use, specifically an increase in volume of gray matter in the cerebellum, parahippocampus, and fusiform gyri. Pletzer and Kerschbaum[41] later found that HC may also induce changes in the neurochemistry and cognitive function. Mordecai et al[35] showed enhanced verbal memory in HC users compared with nonusers. Previous

studies on psychological performance in HC users have shown mixed results. Moran et al[31] reported no effect of HC use on common objective measures of concussion, including ImPACT memory, reaction time, processing speed, and impulse control and King-Devick reading time. Wharton et al[53] noted that mental rotation performance improved with HC use, specifically the androgenicity of the progestin component. Previous studies have also looked at the effects of HC on emotions with inconsistent results. Elevated estradiol levels may have antidepressive effects due to its serotonin-enhancing property.[3] However, progesterone may be associated with positive mood changes at low concentrations and negative mood changes at high concentrations.[2] These findings suggest a role for HC to influence concussion assessment and management.

Our findings are different from those of Mihalik et al,[26] who noted higher total symptoms and symptom severity scores in eumenorrheic women compared with women using oral contraceptive pills. Our findings more closely align with commonly reported symptoms caused by hormone changes and fluctuations, which occur with HC use.[11,49] Our findings also provide clarity into which symptom factors may be influenced compared with non-HC users and men. Our findings regarding symptom factors are not comparable to those of Wunderle et al[55] as they utilized a different symptom inventory as opposed to the PCSS, which is a more commonly used tool in the sport-related concussion literature and research.[9,19] While data from the NCAA-DoD CARE Consortium noted a lack of differences postconcussion in symptoms and neurocognitive performance between HC- and non–HC-using collegiate female athletes,[17] our findings may be due to the nature of postinjury data compared with baseline and preinjury data, in addition to the use of advanced symptomatology inventories and factors. As migraine history has been identified as a modifier for VOMS provocation, including headache and dizziness symptoms, this relationship of exacerbated symptoms from HC use may have an overlap with migraine headaches.[30] This increase in migraine headaches may be further attributed to estrogen withdrawal[37] and contraceptive headaches,[22] reiterating the findings of Mihalik et al,[26] and may align with medical practices in which contraceptives are used to treat chronic migraine headaches.[1]

We believe that our study is the first to examine the effect of HC use on the VOMS concussion screening tool. Female HC users reported higher smooth pursuit symptom provocation than non–HC-using women and greater VMS symptom provocation compared with men. One possible explanation for HC differences in smooth pursuits is that HC use has been linked to dry eye in a nationwide sample of individuals aged 15 to 45 years.[15] Smooth pursuits consist of vertical, horizontal, and angular eye movements and tracking,[36] which is performed by having the patient follow the clinician's finger with his or her eyes on the VOMS as they make 2 "H" patterns, moving approximately 1.5 feet in all directions. Patients often do not blink when completing the smooth pursuits item on the VOMS, which may dry out their eyes and provoke further symptoms potentially exacerbated from current HC use. Additionally, gonadal steroid hormones can decrease motion perception, which makes it harder to perceive movement of an object.[14] This may force the eye to work harder to perform the same action that others do not have any issues with. Previous research on the VOMS and modifying factors has identified attention disorders,[34] migraine history,[30] and socioeconomic status[51] as negative influences of performance. However, sex, while explored as a potential modifier, has not been reported to date to affect VOMS performance at baseline[29] and postconcussion.[48] The findings of this current study differ in that sex differences between non–HC-using female participants and male controls were apparent on the horizontal VOR item, with worse symptom provocation by non–HC-using females. Because no group differences existed between male controls and HC users, it can be hypothesized that these findings may be attributed to the sample itself, with a smaller sample size, or we would expect to see similar findings between the male control group and both female groups. Interestingly, studies by Moran et al[29] and Sufrinko et al[48] consisted of participants younger than 18 years of age, with mean ages between 11 and 14 years, who likely would not be on HCs and may not have begun menstruation, and thus hormone changes and levels may not be present.[23]

This study not only helps to emphasize the potential role of HC use on concussion symptoms in female athletes but also further clarifies specific factors for differences beyond just biological sex. These findings may potentially lay the groundwork for future studies and advocacy for women's health in concussion and sports medicine, given that women remain underrepresented in sports science and sports medicine research,[47] despite increasing participation in and popularity of women's sports.

Limitations

This study was not without limitations. First, the results of this study are only applicable to college-aged individuals, and not younger populations including high school and youth ages, as menses and the menstrual cycle may not have begun in younger groups. Despite using strict inclusion criteria, and all female participants free of menstruating or premenstrual syndrome, our study did not consider the menstrual phase (ie, follicular, ovulation, or luteal), which may influence symptom provocation. Our study attempted to be the first to examine HC use via oral administration; it is unclear how other forms of HC may influence symptomatology. While our study did inquire about the specific medication, and therefore the progestin hormone in each HC-using participant, we did not inquire about the dosage of each HC as well as the timing and frequency of use. Roughly 75% of HC-using participants' progestin hormone consisted of norethindrone acetate or norgestimate. It may be beneficial to understand if other progestin hormones may influence outcomes, such as desogestrel and etonogestrel, which accounted for <10% of our sample. While this study had strict inclusion criteria, to limit confounding modifying factors of performance, future

research should inquire about the possible effects of a history of previous or multiple concussions, coupled with HCs. Future studies should also seek to determine if our findings are consistent postconcussion and how HC influences clinical recovery. Last, future authors should consider blood tests to measure a variety of sex hormones that may affect measures.

CONCLUSION

College-aged female athletes who use oral HCs self-reported higher baseline concussion symptoms and factors compared with non–HC-using female athletes and male controls. HC users also reported higher symptoms on headache and dizziness inventories than non–HC-using female athletes, potentially highlighting oral HCs and contraceptive use in general as a modifier of baseline concussion assessment. Beyond subjective symptom reporting, differences were noted between smooth pursuits on the VOMS, with higher provocation scores in female HC users than in nonusers, and on the VMS item of the VOMS, with higher provocation scores in HC users compared with male athletes. When analyzing and interpreting self-reported symptoms and, more recently, symptom provocation on the VOMS for baseline assessment and postinjury comparisons on the Sport Concussion Office Assessment Tool 6, sports medicine professionals should inquire about current medication, specifically HCs, that may influence performance and main outcome measures.

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