Peer Review

Kong, Ellie. 2026. “Rethinking Sex Differences in Adolescent Sports Injuries: Distinguishing Injury Distribution from per-Participant Risk.” *Journal of High School Science* 10 (2): 49–70. https://doi.org/10.64336/001c.160408.

1.The content presented is available in the public domain (see references below). Therefore, please remove all content to the contrary, i.e. “…. Despite these known differences, sex-based disparities in sports injury patterns remain underexplored in large-scale, nationally representative studies—particularly during theadolescent and young adult years, when participation in competitive sports peaks anddevelopmental transitions are most pronounced……..” These statements are incorrect. Since there is an abundance of such data in the literature, the manuscript does not significantly contribute to the corpus of knowledge in the field. Therefore, see points 6 and 7. Address point 7 in the manuscript. This will serve as the differentiator for your manuscript to enable contribution to this field.

2.Present multicollinearity heat maps, VIF and R2 values for all the data used to form conclusions.

3.The manuscript must be written in third person, past perfect tense. References must appear sequentially numbered in the text enclosed in curved brackets.

4.you state “….Females were more likely to have injuries involving multiple products…..” In this context, what is a ‘product’? This terminology is not representative of descriptive statistical analysis. Please check.

5.Table 2 state “multivariable LR”, what variables were used (gender and age?) and what were their relative weights (coefficients)? Also, present 2 more tables with the same statistics, one in the age group 10-17, and the other in the age group 18-24.

6.Statistics are the means to deduce cause, consequence and to provide actionable insights; not just present numbers that cannot be used. This is difficult to achieve with NEISS data because limited information is available (gender, age and nature of injury). According to this study (https://doi.org/10.1186/s40798-022-00530-y), In female athletes, out of 18 factors eligible for meta-analysis, only lower concentric dorsiflexion strength was identified as a risk factor (SMD = − 0.48, P = 0.005).

7.Use https://health.wvu.edu/media/5140/estradiol-all.pdf for age-related estrogen levels and https://doi.org/10.7759/cureus.43953 for Q-angles at various age levels to normalize for these factors in your analysis. i.e. find a quantitative relationship between Q-value and # of ankle injuries in females by age and find a quantitative relationship between estrogen levels and the # of ankle injuries in females by age. Then, either build a model that accounts for correction of these values in calculating ankle injuries or normalize to males to obtain comparable values. This will provide you with quantitative estimates of the importance of each factor in causing ankle injuries. Present this data, information, analysis and conclusions in the manuscript.

https://doi.org/10.1177/23259671251364261
https://d-nb.info/1279695587/34
https://doi.org/10.1177/1938640013509670
J Athl Train. 2007 Jul-Sep;42(3):381–387, “Ankle Injuries Among United States High School Sports Athletes, 2005–2006”
https://doi.org/10.1055/a-1192-5399
https://doi.org/10.3390/app15031612
https://biomedres.us/pdfs/BJSTR.MS.ID.009215.pdf
https://doi.org/10.2490/prm.20230042
https://doi.org/10.4172/2324-9080.1000168
https://doi.org/10.1186/s40798-022-00530-y
https://doi.org/10.1177/2325967121S00536
https://doi.org/10.3390/jfmk8020076

https://health.wvu.edu/media/5140/estradiol-all.pdf
https://health.wvu.edu/media/5140/estradiol-all.pdf
https://doi.org/10.7759/cureus.43953

--------------The reviewer comments are in italic and are unedited by the author------------

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Author response: I thank the reviewer for this helpful observation and agree that there is already a substantial body of literature documenting sex-based differences in sports injury patterns, including among adolescent and young adult athletes. My original wording overstated the novelty of this aspect of the work. In response, I have removed the sentence beginning "Despite these known differences…" from the Introduction; revised the Introduction to acknowledge the abundance of prior data explicitly and to position this study as building on that literature rather than filling an unexplored gap; and clarified the specific contribution of this study, in line with point 7. In particular, the revised final paragraph of the Introduction now emphasizes that the primary novelty lies in delineating how sex-based disparities in ankle and foot injury risk vary across four developmental stages (10–13, 14–17, 18–21, and 22–24 years) using nationally representative NEISS data, and in integrating these findings with an exploratory ecological analysis of population-level physiological factors (Q-angle and estrogen) to help inform developmentally targeted injury prevention strategies. These revisions make the manuscript show how it builds on strong existing research, while clearly highlighting its unique contribution: describing how ankle and foot injury risks change with age and connecting those patterns to age-related physiology.

Original paragraph: "Emerging research suggests that sports injury patterns—and specifically lower-body injuries like ankle sprains—may differ significantly by sex. Adolescent female athletes appear to be at elevated risk for certain types of injuries compared to males, particularly during puberty, when hormonal fluctuations and biomechanical changes may increase susceptibility. For example, Lin et al. (2019) report that adolescent girls are more likely to experience ankle injuries than boys in similar sports contexts.

Biological and physiological factors likely contribute to these disparities. Differences in sex hormone levels—especially estrogen, progesterone, and testosterone—affect musculoskeletal development, neuromuscular control, and soft tissue composition. Estrogen, in particular, has been linked to increased joint laxity and reduced collagen synthesis, which may weaken ligament structures and elevate injury risk (Chidi-Ogbolu et al., 2019). Progesterone, which fluctuates across the menstrual cycle, also influences mood, energy, and muscle recovery (Siegmund et al., 2024). These hormonal dynamics, combined with anatomical differences such as greater joint laxity, wider pelvis angles, and different hip-knee-ankle alignment in females (Erickson et al., 2012), can affect injury risk and type.

Despite these known differences, sex-based disparities in sports injury patterns remain underexplored in large-scale, nationally representative studies—particularly during the adolescent and young adult years, when participation in competitive sports peaks and developmental transitions are most pronounced. This study uses 2024 data from the National Electronic Injury Surveillance System (NEISS) to examine sex differences in sports-related injuries among youth aged 10–24. With a particular focus on ankle and foot injuries—the most common lower-body injury in this age group—assessments were performed on differences in injury location, severity, and product involvement. Understanding these patterns is essential for developing targeted injury prevention strategies, refining clinical care, and improving the safety and equity of youth sports." (Page 2)

Revised version (Introduction – corrected novelty & clear differentiator): "Sex-based differences in sports injury patterns were well-established in the literature. Multiple large-scale studies have documented that female athletes, particularly during adolescence, experienced higher rates of ankle and foot injuries compared with males across various sports and competition levels (5, 6). At the professional and semiprofessional level, female athletes suffered foot and ankle injuries at significantly higher rates than their male counterparts (5). The prevalence of chronic ankle instability was similarly elevated among females, with rates as high as 23.4% among high school and collegiate athletes (7). Risk factor profiles differed markedly by sex: males showed increased vulnerability related to prior injuries, higher body mass index, and reduced hip strength or balance, whereas females demonstrated risk primarily linked to lower concentric dorsiflexion strength (8). Among youth soccer players specifically, female athletes sustained ankle injuries at nearly twice the rate of males, with non-contact ankle injuries occurring at particularly elevated rates (9). These patterns persisted across multiple sports, including basketball, track and field, and volleyball, with injury rates consistently highest during competition rather than practice (10, 11). Despite the extensive body of literature documenting sex differences in sports injuries, far less is known about how these disparities change across developmental stages. Prior studies rarely compare early adolescence, mid-adolescence, late adolescence, and young adulthood within the same nationally representative dataset. This developmental perspective represents a critical gap addressed by the present study.

Although sex-based disparities in youth and adolescent sports injuries are well established, important questions remain regarding how these patterns evolve across developmental stages. Most existing research examined single sports or individual institutions, potentially limiting generalizability across broader athletic populations. While associations between injury risk and specific physiological factors (Q-angle variations, hormonal fluctuations) have been identified, the extent to which these variables quantitatively explain observed sex differences when examined across developmental stages remains unclear.

Furthermore, comprehensive analyses spanning the extended adolescent and young adult years (ages 10–24) using nationally representative surveillance data were limited.

This study addressed these gaps using 2024 data from the National Electronic Injury Surveillance System (NEISS), a nationally representative database of emergency department visits across the United States. The analysis examined sex differences in sports-related injuries among youth aged 10–24, with particular focus on ankle and foot injuries. By conducting age-stratified regression analyses across four developmental periods (10–13, 14–17, 18–21, and 22–24 years), the study assessed how sex-based disparities evolved during critical developmental transitions. Additionally, an exploratory ecological-level analysis examined the relationships between population-level physiological factors (Q-angle, estrogen levels) and observed injury patterns, while acknowledging the inherent limitations of aggregate-level correlations in establishing individual-level causal mechanisms. Understanding these patterns was essential for developing targeted, evidence-based injury prevention strategies that acknowledged the unique physiological and developmental challenges faced by female adolescent athletes during peak participation years.

Although prior literature has documented sex-based differences in sports injuries across youth and adolescent athletes, important gaps remain. The present study aimed to build upon this work by delineating how sex disparities in ankle and foot injury risk vary across four developmental stages (10–13, 14–17, 18–21, and 22–24 years) using nationally representative NEISS 2024 data. A secondary objective was to integrate these epidemiological findings with an exploratory ecological analysis of age-related physiological factors—specifically Q-angle and estrogen levels—to examine whether broad developmental physiology may help contextualize the observed injury patterns. This framing represents the primary contribution of the study, distinguishing it from prior work that focuses on single age groups or single-sport cohorts." (Page 3, Methods section)

2. Present multicollinearity heat maps, VIF and R2 values for all the data used to form conclusions.

Author response: I appreciate this helpful suggestion. In response, I conducted and reported additional multicollinearity and model fit diagnostics. Specifically, I now present a correlation heatmap for all covariates included in the multivariable models (Supplementary Figure S1), in which all pairwise correlation coefficients are <0.32; variance inflation factors (VIFs) for each predictor (all <1.5); and model fit statistics, including R^2 values for each model (Supplementary Table S1). These results indicate no evidence of problematic multicollinearity. The corresponding methods have been added to the Methods section, and the detailed outputs are provided in the Supplementary Materials (Figure S1).

Original (Methods): "All regression models were checked for multicollinearity using variance inflation factors, and model fit was evaluated using deviance statistics and pseudo-R-squared values. Residuals were also reviewed to spot any outliers that could affect the results." (Page 4)

Revised (Methods): "All regression models were assessed for multicollinearity using variance inflation factors (VIF). VIF values less than 5.0 were considered acceptable, with values less than 2.0 indicating minimal collinearity (Supplementary Figure S1). Correlation matrices were generated to visualize pairwise correlations among predictor variables. Model fit was evaluated using multiple metrics: Nagelkerke pseudo R^2, McFadden pseudo R^2, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC). Residual diagnostics were performed to identify influential observations and assess model assumptions." (Page 4)

3. The manuscript must be written in third person, past perfect tense. References must appear sequentially numbered in the text enclosed in curved brackets.

Author response: I am grateful for this comment. The manuscript has been revised to use third person throughout (removing first-person constructions such as "I" and "my study" in accordance with the journal's style), to apply past tense consistently in the Methods, Results, and where appropriate in the Discussion and descriptions of prior work, and to cite references sequentially in the text using curved brackets (e.g., "(1), (2–4), (5)") as specified by the journal's guidelines. I have performed a thorough review to ensure that these changes have been applied consistently.

4. you state "....Females were more likely to have injuries involving multiple products....." In this context, what is a 'product'? This terminology is not representative of descriptive statistical analysis. Please check.

Author response: I thank the reviewer for highlighting this ambiguity. In the NEISS coding system, a "product" refers to any consumer item or piece of equipment associated with the injury event (e.g., sports gear, athletic footwear, gym flooring, playground equipment, or protective equipment). Product involvement is coded as a single product when only one item is associated with the injury and multiple products when two or more items are involved. I agree that the term "product" on its own is not intuitive, so I have clarified in the Methods that "products" refer to NEISS-coded equipment or objects associated with the injury event, revised the Results to use more precise wording such as "injury-related items" or "multiple injury-related items" when describing patterns, and updated relevant table notes to specify that "product involvement" is based on NEISS product codes and categorized as single versus multiple products.

5. Table 2 states "multivariable LR", what variables were used (gender and age?) and what were their relative weights (coefficients)? Also, present 2 more tables with the same statistics, one in the age group 10-17, and the other in the age group 18-24.

Author response: I appreciate the reviewer's thoughtful comment and the recommendation to clarify and expand the multivariable analysis. I have revised the Methods and the legend for Table 2 to specify the covariates included in the multivariable logistic regression models: sex, age group, and sport- and injury-related characteristics, including injury location (body part), injury severity category, product involvement (single vs multiple products), and injury location category based on

NEISS (recreation/sports facility, school/daycare, public property). Categorical predictors were modeled using indicator variables, with male sex and recreation/sports facilities as the reference groups. To address the request regarding "relative weights," Table 2 now explicitly reports, for each covariate, the odds ratio (OR) with its 95% confidence interval and p-value, and the table labels have been updated to make the dummy-coded categories transparent (for example, "Sex: Female vs Male," "Location: School/Daycare," and "Location: Public property"), so that the direction and magnitude of each association can be directly interpreted from the ORs. As requested, I have also added two age-stratified tables with the same statistics: one for participants aged 10–17 years (Table 2A) and one for participants aged 18–24 years (Table 2B). Each table presents the ORs, 95% CIs, and p-values from the age-specific multivariable models, using the same reference categories (male sex and recreation/sports facilities) stated in the table notes. These new tables are cited in the Results section, where I briefly highlight the key similarities and differences between the two age groups. (Page 5-6)

6. *Statistics are the means to deduce cause, consequence and to provide actionable insights; not just present numbers that cannot be used. This is difficult to achieve with NEISS data because limited information is available (gender, age and nature of injury). According to this study (https://doi.org/10.1186/s40798-022-00530-y), In female athletes, out of 18 factors eligible for meta-analysis, only lower concentric dorsiflexion strength was identified as a risk factor (SMD = −0.48, P = 0.005).*

Author response: I thank the reviewer for this critical comment and agree that statistical analyses should support interpretable and actionable insights rather than simply reporting numbers. NEISS, with its limited variables (sex, age, diagnosis, body part, and basic context), cannot support strong causal inference or detailed risk-factor modeling, and the manuscript has been revised to make this explicit. Causal language has been tempered throughout the Introduction, Discussion, Limitations, and Conclusion, describing the NEISS analyses as descriptive and exploratory and avoiding terms such as "risk factor." The primary contribution is now framed as documenting a developmental pattern in sex-based ankle and foot injury risk—most pronounced during adolescence (OR 1.70, ages 10–17) and essentially absent by young adulthood (OR 1.08, ages 18–24)—rather than identifying causal mechanisms. The cited meta-analysis (DOI: 10.1186/s40798-022-00530-y) has been incorporated into the Discussion, noting that only lower concentric dorsiflexion strength emerged as a risk factor in female athletes and emphasizing that NEISS lacks the individual-level biomechanical and strength data needed to test such mechanisms. The Limitations and Future Directions sections were revised to clarify that the ecological Q-angle and estrogen analyses could not yield strong conclusions, and to emphasize that better answers will require future studies that follow athletes over time and directly measure factors such as strength, biomechanics, and training exposure. These types of studies are needed to turn the general developmental patterns observed here into practical injury-prevention strategies for young athletes. **Thus, for example, I have now added:** "This study had several important limitations. First, NEISS was a surveillance system designed for injury monitoring rather than etiological research. It lacked detailed information about individual-level exposures, training characteristics, playing time, sport-specific positions, skill levels, prior injury history, and individual physiological measurements. The inability to account for these factors limited the ability to draw causal inferences about specific mechanisms underlying observed patterns. Second, the ecological-level analysis of Q-angle and estrogen effects was constrained by the use of population-average values from published literature rather than individual-level measurements, the small number of age-sex strata providing limited statistical power, and the inherent ecological fallacy problem, whereby aggregate-level associations did not establish individual-level causation. The negative correlations and paradoxical normalization results underscore these limitations rather than indicating the protective effects of these physiological factors. Third, Q-angle normative data were derived from a study of adolescents with short stature, which may limit their generalizability to broader athletic populations. Fourth, NEISS recorded only

emergency department visits, potentially underrepresenting less severe injuries treated in other settings and introducing selection bias toward more acute or severe injury presentations. Fifth, the cross-sectional design precluded assessment of within-individual changes in injury risk over developmental stages or evaluation of longitudinal risk trajectories. Sixth, detailed information about menstrual cycle phase,
hormonal contraceptive use, pubertal stage, and other potentially relevant physiological variables was unavailable in NEISS data. Finally, the analysis could not distinguish between contact and non-contact injury mechanisms, account for differences in training load or competition intensity across age groups and sexes, or assess the influence of sport-specific factors, coaching quality, or environmental conditions. These unmeasured confounders may have influenced observed associations and limited the specificity of conclusions about underlying mechanisms." (Page 8-9)

7. Use https://health.wvu.edu/media/5140/estradiol-all.pdf for age-related estrogen levels and https://doi.org/10.7759/cureus.43953 for Q-angles at various age levels to normalize for these factors in your analysis. i.e. find a quantitative relationship between Q-value and # of ankle injuries in females by age and find a quantitative relationship between estrogen levels and the # of ankle injuries in females by age. Then, either build a model that accounts for correction of these values in calculating ankle injuries or normalize to males to obtain comparable values. This will provide you with quantitative estimates of the importance of each factor in causing ankle injuries. Present this data, information, analysis and conclusions in the manuscript.

Author response: I thank the reviewer for this constructive suggestion and for directing me to the WVU estradiol reference ranges and age-related Q-angle data. In response, I have incorporated these sources and implemented the requested quantitative analysis as an exploratory ecological-level component of the study. Specifically, I used age-stratified ankle injury rates in females across four developmental groups (10–13, 14–17, 18–21, and 22–24 years) and linked them to age- and sex-specific Q-angle and estradiol reference values from the cited literature. I then fitted linear regression models relating female ankle injury rates to the Q-angle alone, to log-transformed estrogen levels alone, and to both variables jointly, and calculated standardized regression coefficients to assess their relative contributions. I also attempted to "normalize" female ankle injury rates using these regression estimates and to compare them with male rates, as suggested. As explained in the Methods, Results, and Limitations sections, these analyses had major constraints because they used only broad, age-group averages and included just four female age categories. Because of this, the correlations and regression results were inconsistent and sometimes even suggested patterns that did not make biological sense—for example, showing higher injury rates when Q-angle or estrogen levels were lower. These findings do not indicate true protective effects; instead, they show the limits of linking population-level physiological averages to injury rates from surveillance data. For this reason, the results are presented only as exploratory and helpful in generating ideas for future work, not for producing adjusted injury rates or strong conclusions about causation. The Discussion and Limitations sections now clearly state that NEISS data, even when combined with published Q-angle and estrogen values, cannot support reliable causal modeling. The manuscript also explains that firm answers will require future studies that track individual athletes and directly measure their physiological, biomechanical, and training characteristics.

For example, I have now added: Contrary to expectations based on individual-level mechanistic hypotheses, both Q-angle and estrogen showed negative correlations with female ankle injury rates across age groups (Q-angle: r = -0.635, p = 0.365; estrogen: r = -0.635, p = 0.365). Regression analyses yielded negative coefficients for both variables (Q-angle: -0.91% per degree, 95% CI: -4.28 to 2.46; estrogen: -2.36% per log-unit, 95% CI: -11.92 to 7.21), indicating that at the population level, higher average Q-angle and estrogen values were associated with lower, rather than higher, injury rates (Supplementary Figure S2, S3). (Page 6); **and**
Attempts to "normalize" female injury rates by adjusting for these physiological differences using regression coefficients resulted in paradoxical findings: the sex difference in ankle injury risk

increased rather than decreased after adjustment. The raw female-male difference of 5.47 percentage points increased to 6.99 percentage points after Q-angle adjustment and to 12.34 percentage points after combined Q-angle and estrogen adjustment. (Page 6-7)

Thank you for addressing my comments. The paper is much improved from its original version. However, you will still need to correct for participation rate confounding. Please see my comments below.

0.Some of your methods are opaque and hence cannot be replicated by interested readers. Please provide sufficient details regarding your methods - including methods of statistical analysis and data sources - in the manuscript so that your experiment can be replicated.

1.Please indicate where you obtained the data for the age groups from? For example, were did you find data for # of injuries in age groups 10-13, 14-17, 18-21 and 22-24 ? Is this data obtainable from the NEISS dataset?(I did not find this in Table 1). Please confirm and explicity state so in the manuscript.

2.I believe your data may be confounded (in part) by participation rates. Normalizing injuries per 100 participants gives the risk per athlete, which is the biologically meaningful unit. Hence, I input your data into chatgpt to get an estimate of ankle/foot injury rate per 100 participants (R-per-100) for these four age groups. My reasoning was that since participation rates drop off with age, the (R-per-100) should not drop off as significantly as raw counts.

chatgpt.com output for US female population per census and participation rates.

Step 1: Recall estimated female populations and participation rates

Age Group Female Population (millions) Participation Rate Estimated # of Female Participants

10–13 8.5 61% 8.5 × 0.61 ≈ 5.19 M

14–17 8.5 56% 8.5 × 0.56 ≈ 4.76 M

18–21 9.0 25% 9.0 × 0.25 ≈ 2.25 M

22–24 6.5 25% 6.5 × 0.25 ≈ 1.63 M

(Participation rates for 18–24 are approximate.)

Chatgpt then translated this into rate-per-100

Age Group Injuries Participants (M) Injury Rate per 100 participants

10–13 11,433 5.19 11,433 ÷ 5,190,000 × 100 ≈ 0.22%

14–17 10,958 4.76 10,958 ÷ 4,760,000 × 100 ≈ 0.23%

18–21 6,293 2.25 6,293 ÷ 2,250,000 × 100 ≈ 0.28%

22–24 3,952 1.63 3,952 ÷ 1,625,000 × 100 ≈ 0.24%

As you can see, the ankle/foot injury rate per 100 participants does not show as significant a decline (in fact, it stays constant) in later years as raw counts. This means that, even with fewer raw count female participants in later years, each young adult female has a comparable or slightly higher individual risk. Hence, for injury prevention, interventions should target both adolescents and young adults. Please examine this data and approximations and include in your manuscript as appropriate.

3.Examine your negative estrogen correlation in the context of point 1. Normalized per 100 female participants you may find that higher estrogen in young adulthood is not associated with lower injury risk. Estrogen is therefore a poor population-level proxy for injury risk across development because its age trajectory does not align with normalized injury incidence.The original negative correlation may have been spurious, caused by fewer participants at older ages, not by estrogen levels. Perform a similar calculation for the Q-angle.

4.Similarly for comparison, please compare all statistical parameters, odds-ratios, etc. with normalized injury level risk - not raw count injury level risk.You will need to calculate male data similar to that calculated for females in point 2. I realize this may change your manuscript's results and conclusions significantly; but this would be the correct biologically meaningful comparison.

5.You have used unweighted NEISS data. Hence, please remove all claims regarding the data being 'nationally representative". For example, "This study examined sex differences in sports-related injury patterns among youth aged 10–24 years, using nationally representative NEISS 2024 data" is misleading and incorrect. The "national representative' claim should be replaced by results in sampled hospitals.

6.The bibliography is limited in breadth for a topic with extensive prior work (and limits the robustness of your approach and presentation), includes a duplicated citation, and contains at least one apparent year mismatch (e.g., a 2007 JAT article listed as 2024); foundational ankle sprain epidemiology and prevention studies are under-cited. The content aligns with the title and keywords by focusing on sex disparities in ankle injuries across developmental stages, but major prior literature is omitted. Missing key works (list only author(s), journal, year): Fong et al., Sports Medicine, 2007; Doherty et al., Sports Medicine, 2014; Waterman et al., American Journal of Sports Medicine, 2010; Attenborough et al., British Journal of Sports Medicine, 2014; Hiller et al., Medicine & Science in Sports & Exercise, 2011; Verhagen et al., British Journal of Sports Medicine, 2004; Delahunt et al., British Journal of Sports Medicine, 2014; Gribble et al., Journal of Athletic Training, 2016; McGuine et al., American Journal of Sports Medicine, 2011.

Response to Reviewer Comments — Round 2

Manuscript: Female Adolescents at Higher Risk: Sex Differences in Sports-Related Ankle Injuries Across Development Stages

Authors: Ellie Kong

Journal: Journal of High School Science

I thank the reviewer for the constructive and thorough comments. The paper has been substantially revised to address each point. Below I provide a point-by-point response. All changes are marked in the revised manuscript.

Comment 1: Methods Transparency

Some of your methods are opaque and hence cannot be replicated by interested readers. Please provide sufficient details regarding your methods — including methods of statistical analysis and data sources — in the manuscript so that your experiment can be replicated.

Response: I have expanded the Materials and Methods section with the following additions:

1. **NEISS variable codes** are now explicitly listed for body part categories (codes 0, 30–38, 75–94), diagnosis severity classifications (codes 41–42, 46–51, 53–63, 64–70), and location categories (codes 1, 2, 4–9).
2. **R software packages** used for each analysis component are now specified: nnet for multinomial logistic regression, gtsummary and gt for summary tables, broom for model result extraction, car for VIF computation.
3. **Inclusion/exclusion criteria** are stated more precisely, including the definition of "sports-related injuries" (cases occurring at recreation/sports facilities, schools/daycare, or public property based on the NEISS location variable).
4. A new **Software and Reproducibility** subsection specifies R version 4.4.1 and notes that analysis scripts are available upon request.

These changes appear in the "Materials and Methods" section of the revised manuscript (subsections: Outcome Variables, Statistical Analysis, Software and Reproducibility).

Comment 2: Age Group Data Source

Please indicate where you obtained the data for the age groups from? For example, where did you find data for # of injuries in age groups 10-13, 14-17, 18-21, and 22-24? Is this data obtainable from the NEISS dataset? (I did not find this in Table 1). Please confirm and explicitly state so in the manuscript.

Response: The age groups were derived directly from the individual-level patient age variable in the NEISS dataset. Each case record includes the patient's age at the time of the emergency department visit; I recoded this variable into four developmental categories. I have added a new subsection ("Age Group Classification") to Materials and Methods that explicitly states:

"Age groups were derived directly from the individual-level patient age variable recorded in the NEISS dataset. Each case was classified into one of four developmental categories based on age at the time of the emergency department visit: 10–13 years (n = 31,611), 14–17 years (n = 31,099), 18–21 years (n = 15,858), and 22–24 years (n = 9,588). These counts are reported in Table 1." The counts in Table 1 correspond to these age groupings (see Table 1, "Age group, years, n (%)" rows).

Comment 3: Participation Rate Normalization

I believe your data may be confounded (in part) by participation rates. Normalizing injuries per 100 participants gives the risk per athlete, which is the biologically meaningful unit.

Response: I agree that participation rate normalization is an important complementary analysis. I have conducted a comprehensive participation-normalized analysis using:

- **U.S. Census Bureau Vintage 2024** population estimates by single year of age and sex (NC-EST2024-AGESEX-RES, downloaded from census.gov)
- **Sports participation rates** estimated from CDC National Health Interview Survey (2020), SFIA participation reports (2024), and NFHS high school athletics surveys (2024–25)

Key Results

Female ankle injury rate per 100 estimated participants:

Age Group	Rate per 100	Change from 10–13
10–13	0.0198	—
14–17	0.0194	−2%
18–21	0.0109	−45%
22–24	0.0076	−62%

The normalized rates still decline substantially with age (62% reduction from ages 10–13 to 22–24). This was consistent across all sensitivity scenarios tested, including the reviewer's ChatGPT-generated participation estimates (63% decline), higher female participation assumptions (66% decline), and lower female participation assumptions (54% decline).

I note that the reviewer's ChatGPT analysis used total ankle/foot injury counts from the full NEISS dataset (e.g., 11,433 for females ages 10–13), which includes injuries at all locations (home, workplace, etc.). Our analysis is restricted to sports-related locations only (recreation/sports facilities, schools, public property), yielding 804 female ankle injuries at ages 10–13. When the correct sports-location-filtered data are used with verified Census population denominators, the developmental decline in per-participant risk is confirmed.

A new "Participation Rate Normalization" subsection has been added to Materials and Methods, a new "Participation-Normalized Injury Analysis" subsection has been added to Results, and a new Figure 3 and Table 4 present the normalized findings. Sensitivity analyses across four participation rate scenarios are reported.

Comment 4: Re-examine Estrogen and Q-Angle Correlations

Examine your negative estrogen correlation in the context of point 1. Normalized per 100 female participants you may find that higher estrogen in young adulthood is not associated with lower injury risk.

Response: I re-ran the ecological correlations using participation-normalized rates. The results were opposite to the reviewer's prediction:

Factor	Raw Correlation	Normalized Correlation
Q-angle	r = −0.844, p = 0.156	r = **−0.971**, p = **0.029**
Estrogen	r = −0.832, p = 0.168	r = **−0.968**, p = **0.032**

The negative correlations became **stronger and statistically significant** after participation normalization, not weaker. This demonstrates that the original negative correlations were **not artifacts of declining participation rates at older ages**. Instead, they reflect genuine ecological confounding by age: both Q-angle and estrogen increase with age, while per-participant ankle injury rates decrease with age due to neuromuscular maturation and training adaptations.

I agree with the reviewer's broader point that estrogen is a poor population-level proxy for injury risk across development. I have added the following to the revised Discussion:

"Estrogen is therefore a poor population-level proxy for injury risk across development because its age trajectory does not align with injury incidence, whether measured as raw proportions or participation-normalized rates."

The ecological analysis section of the Results and Discussion has been updated with the normalized correlation findings. These results reinforce—rather than contradict—our original interpretation that the negative correlations reflect ecological fallacy rather than true protective effects.

Comment 5: Normalize All Statistical Comparisons

Similarly for comparison, please compare all statistical parameters, odds-ratios, etc. with normalized injury level risk — not raw count injury level risk. You will need to calculate male data similar to that calculated for females in point 2.

Response: I have computed participation-normalized rates for both sexes across all four age groups. Male data are included in the new Figure 3 and Table 4.

Regarding the odds ratios from the multinomial logistic regression models (Tables 2, 2A, 2B): these estimate the relative odds of having an ankle injury *versus other injury types* among individuals who presented to the emergency department. They are within-sample conditional estimates that are not directly affected by external participation-rate denominators. The OR of 1.70 for ages 10–17 means that among injured adolescents, females are 70% more likely than males to have an ankle injury (vs. other body parts). This is a valid within-sample comparison.

To produce true "participation-normalized" odds ratios, one would need to construct a pseudo-population of all sports participants (injured + non-injured) and estimate the probability of ankle injury from that expanded dataset. This is beyond what NEISS can support, as the non-injury denominator is unknown.

Instead, I have added the participation-normalized rate analysis as a **complementary perspective** alongside the existing regression results. The revised manuscript now clearly distinguishes between:

1. **Within-sample comparisons** (ORs): "Among injured athletes, females are more likely to have ankle injuries" — Tables 2A/2B
2. **Per-participant risk** (rate per 100): "Per 100 sports participants, the ankle injury rate is X" — new Table 4/Figure 3

A paragraph in the Results section now explicitly notes this distinction. I believe this dual-perspective approach provides the most informative analysis possible with the available data.

Comment 6: Remove "Nationally Representative" Claims

You have used unweighted NEISS data. Hence, please remove all claims regarding the data being "nationally representative."

Response: I agree. I identified eight instances of "nationally representative" language across the manuscript and have revised all of them. Key changes:

Location	Original	Revised
Abstract	"using nationally representative data"	"using large-scale emergency department surveillance data"
Methods	"a nationally representative sample of U.S. hospital emergency departments"	"a surveillance system operated by the CPSC that collects injury data from a stratified probability sample of approximately 100 U.S. hospital emergency departments. Because sample weights were not applied, results reflect injury patterns observed in NEISS-participating hospitals rather than nationally representative estimates."

Location	Original	Revised
Discussion	"using nationally representative NEISS 2024 data"	"using unweighted NEISS 2024 data from a national sample of hospital emergency departments"
Conclusion	"This nationally representative analysis"	"This analysis of 88,156 sports-related injuries from NEISS-participating hospitals"

Additionally, a new limitation has been added:

"This study used unweighted NEISS data, which reflects injury patterns in sampled hospitals but does not produce nationally representative population-based estimates. Applying NEISS sample weights would be necessary for nationally generalizable incidence estimates."

All eight instances are documented in manuscripts/R2/manuscript_revisions_guide.md.

Comment 7: Strengthen and Correct the Bibliography and Citations

Thank you for highlighting that the bibliography required broader coverage for a topic with extensive prior work, and for noting the duplicated citation and apparent year mismatch. I agree that these issues limited the robustness of the framing and presentation. In response, I conducted a targeted, comprehensive literature review focused on foundational ankle sprain epidemiology, chronic sequelae (including chronic ankle instability), consensus/clinical guidance, and prevention studies—particularly those relevant to developmental stage and sex-based comparisons. I have incorporated these works into the Introduction and Discussion to strengthen the manuscript's epidemiologic foundation, clinical relevance, and prevention implications.

Foundational ankle sprain epidemiology and clinical context (added/expanded):

I added and/or strengthened citation of key epidemiologic and synthesis studies to anchor the burden, incidence, and clinical relevance of ankle sprain injuries, including *Fong et al. (2007)*, *Doherty et al. (2014)*, and *Waterman et al. (2010)*. I also strengthened the adolescent/sex-comparison framing by adding large-scale high school surveillance evidence (e.g., *Swenson et al., 2013*) to better support statements regarding sex differences in ankle injury patterns in youth sport cohorts.

Chronic sequelae and chronic ankle instability (added/expanded):

To strengthen the discussion of longer-term outcomes and recurrent injury risk, I added/expanded citation of foundational chronic ankle instability literature, including *Attenborough et al. (2014)* and *Hiller et al. (2011)*, to support current conceptual models and the relevance of CAI to recurrent sprain cycles and persistent functional limitations.

Consensus/guidance literature (added/expanded):

I expanded citation of International Ankle Consortium consensus and evidence review documents (e.g., *Gribble et al., 2016; Delahunt et al., 2018*) to strengthen the clinical assessment/management framing and the discussion of longer-term consequences following acute lateral ankle sprain.

Prevention studies (added/expanded):

I expanded the prevention literature to include evidence supporting neuromuscular/balance-based interventions in adolescent cohorts, including *McGuine & Keene (2006)*, and aligned prevention statements in the Discussion with this evidence base.

Reference list corrections and quality control:

I performed a complete bibliography audit to address the issues you raised. Specifically, (1) removed duplicated reference(s); (2) corrected citation errors (including year mismatches); (3) verified author order, title, journal, year, volume/issue, pages, and DOI against publisher records; (4) reconciled in-text citations with the revised reference list; and (5) standardized formatting to the journal's required style.

Collectively, these changes broaden the bibliography, correct citation issues, and improve the manuscript's grounding in established ankle sprain epidemiology, sequelae, and prevention research.

Summary of Changes

Change	Section(s) Affected
Expanded Methods with NEISS codes, R packages, inclusion criteria	Materials and Methods
Added age group classification subsection	Materials and Methods
Added participation normalization methods	Materials and Methods
Added participation-normalized results (Figure 3, Table 4)	Results
Updated ecological analysis with normalized correlations	Results
Added note distinguishing within-sample ORs from per-participant rates	Results
Revised Discussion with participation-normalization context	Discussion
Added limitation on unweighted data	Limitations
Added limitation on estimated participation rates	Limitations
Removed 8 “nationally representative” claims	Abstract, Introduction, Methods, Discussion, Conclusion
Updated Conclusion with normalization findings	Conclusion

New Figures and Tables

- **Figure 3:** Participation-Normalized Injury Analysis (4-panel)
- **Table 4:** Participation-Normalized Ankle Injury Rates by Age Group and Sex
- **Supplementary Table:** Sensitivity Analysis of Participation Rate Assumptions

New Data Sources

- U.S. Census Bureau Vintage 2024 population estimates (NC-EST2024-AGESEX-RES)
- CDC NHIS 2020, SFIA 2024, NFHS 2024–25 (participation rate estimates)

Thank you for addressing my comments. A few inconsistences and deficiencies remain, which I have listed below.
Best practice is to make script(s) available in a repository (such as GitHub), rather than have them ‘available upon request’.
There appears to be a sample inconsistency between the methods and results (33977 versus 88156).
The ecological conclusion should remove statistical inference and frame the result as descriptive only. The language below is what chatgpt recommends (and which i agree with): Please rewrite in your own words.
-The ecological correlations observed between Q-angle, estrogen levels, and ankle injury rates should be interpreted cautiously because they are based on only four age groups. With such a small sample size, correlation coefficients and p-values are highly unstable and cannot support statistical inference. The negative associations likely arise from age confounding: both Q-angle and estrogen

increase with age, whereas ankle injury rates decline with age due to neuromuscular maturation and training adaptations. Thus, the ecological analysis should be viewed as descriptive rather than evidence of causal or protective physiological effects.

Your manuscript still implies a (female) biological susceptibility that is not supported by the normalized risk estimates. This is because ankle injuries represent a larger share of female injuries (but absolute risk among both males and females is identical). Hence, replace language such as “adolescent females had 70% higher odds of ankle injuries” with something such as “ankle injuries accounted for a larger proportion of injuries among adolescent females, although participation-normalized analyses suggest similar or lower per-participant ankle injury risk compared with males.”

Similarly, in the abstract, replace “Sports-related ankle injuries disproportionately impact female adolescent athletes.” with “Ankle injuries represent a larger proportion of sports-related injuries among female adolescents, although participation-normalized analyses suggest that absolute ankle injury risk is comparable between sexes.” or something similar.

PLEASE check the entire manuscript and RECONCILE the participation normalized versus the per-participant basis explanation.

After the revisions, the strongest scientifically defensible conclusion of the paper is actually "Sex differences in ankle injuries are largely developmental
and largely reflect injury distribution rather than absolute risk. Which is still a good result — just less dramatic than the abstract and the paper suggests.

replace ‘rates per 100 participants’ with “scaled injury counts relative to estimated participation levels” or something similar. This is because:

The participation-normalized analysis divides unweighted NEISS injury counts by national population participation estimates. Because the NEISS data represent a stratified sample of emergency departments rather than national injury counts, the numerator and denominator are not on the same population scale. As a result, the calculated “rates per 100 participants” should not be interpreted as true incidence rates. clarify that these values represent scaled sample comparisons rather than population injury rates.

Response to Reviewer Comments — Round 3

Manuscript: Sex Differences in Sports-Related Ankle Injuries Across Developmental Stages Reflect Injury Distribution Rather Than Absolute Risk

Authors: Ellie Kong

Journal: Journal of High School Science

Comment 1. *Best practice is to make script(s) available in a repository (such as GitHub), rather than have them ‘available upon request’.*

Author response:

Thank you for this suggestion. I have created a public GitHub repository containing all analysis scripts and have revised the manuscript accordingly. The repository is available at: github.com/elliegkong/NEISS.

Comment 2. There appears to be a sample inconsistency between the methods and results (33977 versus 88156).

Author response:

Thank you for identifying this inconsistency. I agree that the original wording did not clearly distinguish between the total number of sports-related injury records initially identified in the 2024 NEISS dataset and the final analytic sample used after applying the study’s inclusion and exclusion criteria. Specifically, 88,156 refers to the initial set of sports-related injury records among individuals aged 10–24 years identified from the 2024 NEISS dataset. After restricting the sample to relevant sports-related settings and excluding records with missing sex, non-sports-related injury locations, or incomplete injury information, the final analytic sample was 33,977. I have revised the Methods and Results sections to clarify this distinction and to ensure that all reported descriptive and regression counts are labeled consistently.

Comment 3. *The ecological conclusion should remove statistical inference and frame the result as descriptive only. The language below is what chatgpt recommends (and which i agree with): Please rewrite in your own words.*
-The ecological correlations observed between Q-angle, estrogen levels, and ankle injury rates should be interpreted cautiously because they are based on only four age groups. With such a small sample size, correlation coefficients and p-values are highly unstable and cannot support statistical inference. The negative associations likely arise from age confounding: both Q-angle and estrogen increase with age, whereas ankle injury rates decline with age due to neuromuscular maturation and training adaptations. Thus, the ecological analysis should be viewed as descriptive rather than evidence of causal or protective physiological effects.
Author response:
Thank you for this important comment. I agree that the ecological analysis should be interpreted as descriptive only. Because these analyses were based on only four aggregated age groups, the correlation coefficients and p-values are unstable and not appropriate for formal statistical inference. I therefore revised the manuscript to remove inferential emphasis, including references to statistical significance, and to clarify that the observed inverse ecological associations between Q-angle, estrogen, and ankle injury rates likely reflect age-related confounding at the group level rather than evidence of causal or protective physiological effects. I now explicitly frame this analysis as exploratory and descriptive, and I emphasize that surveillance-based ecological patterns cannot be used to infer individual-level mechanisms. The revised section is provided below.
Exploratory Analysis of Physiological Mechanisms
An exploratory ecological analysis examined age-group-level patterns between population-average physiological factors (Q-angle and estrogen levels) and female ankle injury rates across four age strata (Table 3). Because these analyses were based on only four aggregated age groups, they are descriptive only and are not suitable for formal statistical inference.
Across the four age groups, both Q-angle and estrogen showed inverse ecological correlations with female ankle injury rates (both $r = -0.635$). When participation-normalized rates were examined, the inverse correlations were stronger (Q-angle: $r = -0.971$; estrogen: $r = -0.968$). However, because these estimates were derived from only four aggregated age groups, they are unstable and should be interpreted descriptively rather than inferentially.
Overall, age groups with higher average Q-angle and estrogen levels tended to have lower female ankle injury rates, and a similar inverse pattern was observed when injury rates were normalized per 100 estimated sports participants (Supplementary Figures S2 and S3). These aggregate-level findings run counter to individual-level mechanistic hypotheses and should not be interpreted as evidence that higher Q-angle or estrogen is protective against ankle injury.
The most likely explanation for these inverse ecological patterns is age-related confounding. Q-angle and estrogen generally increase across female development, whereas ankle injury rates may decline across later adolescence and young adulthood because of neuromuscular maturation, training adaptation, and sport-specific skill development. As a result, age-group-level comparisons may produce associations that do not reflect individual-level causal relationships.
Accordingly, this ecological analysis should be interpreted as descriptive and hypothesis-generating only. These findings illustrate the limitations of surveillance-based aggregate analyses for evaluating physiological mechanisms and underscore the need for prospective studies with individual-level physiological measurements, exposure data, and longitudinal follow-up.
Comment 4. *Your manuscript still implies a (female) biological susceptibility that is not supported by the normalized risk estimates. This is because ankle injuries represent a larger share of female injuries (but absolute risk among both males and females is identical). Hence, replace language such as "adolescent females had 70% higher odds of ankle injuries" with something such as "ankle injuries accounted for a larger proportion of injuries among adolescent females, although participation-normalized analyses suggest similar or lower per-participant ankle injury risk compared with males."*
Similarly, in the abstract, replace "Sports-related ankle injuries disproportionately impact female

adolescent athletes." with "Ankle injuries represent a larger proportion of sports-related injuries among female adolescents, although participation-normalized analyses suggest that absolute ankle injury risk is comparable between sexes." or something similar.
PLEASE check the entire manuscript and RECONCILE the participation normalized versus the per-participant basis explanation.
After the revisions, the strongest scientifically defensible conclusion of the paper is actually "Sex differences in ankle injuries are largely developmental
and largely reflect injury distribution rather than absolute risk. Which is still a good result — just less dramatic than the abstract and the paper suggests.

Author response:

Thank you for this important and insightful comment. I agree that the prior wording could be interpreted as implying greater female biological susceptibility to ankle injury, which is not supported by the participation-normalized analyses.

In the revised manuscript, I have clarified the distinction between (1) within-sample differences in the distribution of injury locations among injured individuals presenting to the emergency department and (2) participation-normalized per-participant injury risk. In particular, odds ratios from the regression models are now explicitly described as reflecting the relative likelihood that an injury involves the ankle/foot versus other body regions within the injured sample, rather than differences in absolute injury risk.

I have revised all relevant language throughout the manuscript to remove implications of increased female susceptibility. Statements such as "adolescent females had 70% higher odds of ankle injuries" have been replaced with wording indicating that ankle/foot injuries accounted for a larger proportion of injuries among adolescent females. Corresponding clarifications have been added to emphasize that participation-normalized analyses indicate comparable per-participant ankle injury risk in early adolescence and lower female per-participant ankle injury rates from mid-adolescence onward.

These revisions have been applied consistently across the abstract, results, discussion, and conclusion. In addition, to ensure that the title accurately reflects the revised interpretation and does not imply elevated female risk, I have changed the title to **"Sex Differences in Sports-Related Ankle Injuries Across Developmental Stages Reflect Injury Distribution Rather Than Absolute Risk."**

The manuscript now emphasizes that observed sex differences in ankle injuries are largely developmental and primarily reflect differences in injury distribution rather than elevated absolute per-participant risk among females.

Comment 5. *Replace 'rates per 100 participants' with "scaled injury counts relative to estimated participation levels" or something similar. This is because:*
The participation-normalized analysis divides unweighted NEISS injury counts by national population participation estimates. Because the NEISS data represent a stratified sample of emergency departments rather than national injury counts, the numerator and denominator are not on the same population scale. As a result, the calculated "rates per 100 participants" should not be interpreted as true incidence rates. clarify that these values represent scaled sample comparisons rather than population injury rates.

Author response:

Thank you for this important clarification. I agree that the terminology "rates per 100 participants" could be misinterpreted as representing true population-based incidence rates. Because NEISS data are unweighted and represent a stratified sample of emergency department visits rather than national injury counts, the numerator and denominator are not on the same population scale.

I have revised the manuscript throughout to replace "rates per 100 participants" with terminology such as "scaled injury counts relative to estimated participation levels" and have added clarification that these values represent relative comparisons rather than true incidence rates. These revisions have been incorporated in the Abstract, Methods, Results, Discussion, and Conclusion sections.

Thank you for addressing my comments. Accepted.