Adolescent school injuries and classroom sex compositions in German secondary schools

Original Research article

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Abstract

School injuries are an important adolescent health problem. Previous research suggests that relevant risk behaviors for school injuries, risk-taking and aggression, are highly susceptible to peer effects. Specifically, evidence suggests that the ratio of males and females in peer groups (sex ratio) affects individuals' propensity for aggression and risk-taking. However, research so far has ignored potential associations of classroom sex ratios with adolescent school injury risks. In this paper, we investigate the association of classroom sex compositions with adolescent school injuries in a longitudinal survey dataset containing 13,131 observations from 9,204 adolescent students (ages 13-16) from secondary schools in Germany. The data also allow us to identify injuries that were due to aggressive behavior and analyze these injuries in detail. Results from multilevel logistic regression models reveal that adolescent students' risk for school injuries is significantly and positively associated with male-skewed classroom sex ratios. Moreover, we find an even stronger positive association between male-dominated classrooms and aggression-injury risks. Finally, we find that both boys' and girls' injury risks equally increase with a higher proportion of males in their classroom. We discuss the implications of our findings with regard to the sex ratio literature and potential interventions.

Keywords: School injury, sex ratio, adolescent health, peer effects, sex composition

1 **1 Background**

2 School injuries are a key public health problem (1–5). Injuries are the leading cause of
3 adolescent mortality (6–9), and even non-fatal injuries have several detriments, such as
4 temporary or permanent disabilities (3,10–12). These consequences entail a deterioration in
5 well-being and an increase in school absenteeism, potentially lowering academic achievement
6 of affected students (3,13–15). Schools have long been considered safe environments for
7 students, but they are now recognized as the site for a substantial number of injuries. Studies
8 reveal that about 25% of all injuries to children under the age of 17 occur at school (5,9,16–21).
9 For Germany, the social accident insurance reports that in 2019, a total of 1.17 million school
10 injuries required medical treatment (1). Adolescent students are particularly vulnerable to
11 school injuries, compared to both older and younger students (3,9,20,21). A recent review
12 estimates that school injuries account for approximately 30% of all injuries among adolescents
13 (ages 14–15), only second to leisure-related injuries, but exceeding those sustained in road
14 accidents or at home (22).

15 Despite the prevalence and consequences of adolescent school injuries, knowledge on
16 specific risk factors remains limited. In general, the literature attributes school injuries among
17 adolescents to the increase in risk-taking and violent behavior during adolescence (9,23,24).
18 Adolescents are more likely to engage in risky behavior than adults or children (25–30). In
19 particular, adolescence is the prime age stage for involvement in violence (31–33). These
20 crucial risk behaviors for adolescent school injuries are closely associated with peer effects (34–
21 40). However, peer contexts have rarely been considered in the literature on school injuries so
22 far. Previous studies have relied on medical record data to investigate patterns among injured
23 students (3,5,9,12,20,41). However, injury records lack information on non-injured
24 counterfactuals, inhibiting analyses of factors that might foster or prevent school injuries. A
25 few studies have analyzed data on both injured and non-injured students, but focused on
26 selected individual-level risk factors or the physical environment at schools (4,24,42,43). In this
27 paper, we focus on the potential role of classroom sex compositions for adolescent school
28 injuries to add a contextual perspective on school injuries.

29 A contextual perspective on adolescent school injuries is essential because both key risk
30 factors – risk-taking and aggression – are largely a group phenomenon. Adolescents spend more
31 time with their peers and exhibit the highest level of concern with being accepted in relevant
32 peer contexts than any other age group (44,45). The crucial role of peer contexts for adolescents

particularly concerns effects on risk-taking and aggression, since both behaviors disproportionately occur when adolescents are with their peers (27,46). An extensive body of literature documents that peer norms and behavior patterns of peers are a primary contextual factor for adolescent risk-taking, violence, and aggression (25,30,37–39,44,46,47). Social learning theory suggests that adolescents learn aggressive and risky behaviors the same way they learn other social behaviors: by observing others and imitating their behavior (48–50). Classmates constitute important peer contexts because adolescent students spend around 50% of their waking hours in school (51). Classroom norms and social ties within these contexts create peer pressure towards or away from risky or aggressive behavior, and adolescents are particularly susceptible to these peer group dynamics: adolescents, particularly boys, are more likely to engage in risky behavior and aggression when classroom peers display such behavior (35,52). Thus, given the importance of risk-taking and aggression for adolescent school injuries, classroom peer contexts constitute a crucial aspect in order to arrive at a better understanding of school injury risks.

A key source of contextual peer effects on adolescent school injury risks might be the sex composition of a classroom, i.e. the sex ratio of boys and girls in a class. Evidence from experiments and observational data suggests that aggression and risk-taking are associated with the sex ratio in a given context (53–60). In particular, there is widespread concern that male-skewed social environments may be associated with higher levels of aggression and violence (53,57,58,61–65). Sex is one of the strongest correlates of violence, with male offenders outnumbering female delinquents, particularly in the most severe forms of physical violence (66–68). The literature identifies male status thriving and competitive orientation as key sources for levels of physical aggression by men, including male adolescents (68–70). In particular, adolescent boys exhibit a stronger orientation towards physical competition and domination than girls. Male adolescents are also more likely to consider physical aggression to be an effective means of attaining social status among peers (34,36,68). Empirical evidence suggests that this male tendency for physical rivalry is exacerbated in male-dominated contexts, resulting in higher levels of violence, particularly against other men (53,57,58,61,71–73). Moreover, previous research has demonstrated that peer effects on adolescent delinquency are contingent on the sex constellations of peers (36,40). For instance, there is evidence that higher levels of violence mediate the negative relationship between classroom shares of male students and academic performance (74,75) in classes with high shares of male students (76). Similarly, exposure to female in-school peer contacts decreases adolescent males' odds of engaging in

serious violence, while having more male friends is associated with increased violence by girls (34). Evidence for sex ratio effects on risk-taking also exists. For instance, male-dominated contexts appear to instigate risk-taking in experimental (54,55,77) and health-risky behavior in non-experimental studies (59,78,79). Similarly, a study of risk-related mortality in Northern Ireland suggests that women might behave more risk-prone in male-skewed sex ratio environments (80).

In sum, sex ratios have been shown to correlate with behavioral patterns that are relevant for school injury risks, particularly with aggression and violence. However, the role of classroom sex constellations for school injury risks has not been explored yet. In this paper, we use data from a German large-scale longitudinal school injury and health survey to explore whether classroom sex ratios are related to school injury risks (81). In particular, the data allow for separate analyses of school injuries resulting from aggression. Given the evidence on the link between sex ratios and aggressive behavior (53,57), our data offer a unique insight into the potential implications of classroom sex compositions for adolescent school injuries from violence.

2 Material and Methods

2.1 Data and Study Sample

Data for our study come from the German study on Health Behavior and Injuries in School Age (GUS, www.fzdw.de/gus), a large-scale panel survey of children and adolescents funded by the German Social Accident Insurance (DGUV - *Deutsche Gesetzliche Unfallversicherung*). GUS collected data in 14 of 16 German federal states, and the study comprises information on 18,365 students surveyed at least once during their secondary education between 2014 and 2019. Regarding selection, the survey draws upon a stratified random sample of public secondary schools in Germany, using the federal state, counties ("*Kreis*" and "*kreisfreie Städte*"), type and size of school as well as the urbanity of the school's location as strata.

GUS recruited students at the beginning of their secondary education. Students in Germany commonly enter secondary education after the 4th grade (ages 10-12) and either complete it with graduation after 9th or 10th grade (ages 15-17) or continue with upper secondary education. Thus, the first recruitment stage aimed at schools from all those eleven participating

federal states in the GUS sample where students enter the secondary school track at 5th grade. Here, the GUS team contacted 854 selected schools in 2014, of which 156 schools agreed to participate. In three German federal states, students enter secondary schools not before the 7th grade. Therefore, students from these states entered the study in the third panel wave based on the second recruitment in 2016. An additional 17 schools from the original sample of 120 schools participated in the study from these three states. At each participating school, GUS surveyed all students in the respective grade. The data was collected using a computer-assisted self-administered classroom survey, for which each student received a tablet device to answer the questionnaire during a (regular) school period (of 45 minutes). Trained interviewers introduced the survey, explained the handling of the devices, and helped students with potential technical or other problems.

We limit our analytical sample to adolescent age stages by focusing on students in the 8th and 9th grades. Consequently, students in our dataset are aged 13-15 (8th grade) and 14-16 (9th grade) in the 2017/18 and 2018/19 school years, respectively. Limiting our sample to data from 8th and 9th grade students ensures a close match between class compositions at the time of the survey and the injury. This is because GUS surveyed injuries retrospectively, i.e. students reported injuries from the past 12 months. Therefore, students might have reported injuries from the previous school year, given that the interviews mostly took place around the halfway mark of the school year. However, in many federal states, schools rearrange class compositions based on students' choices of major subjects before 7th grade. Consequently, injuries reported in the 7th grade panel wave might date back to 6th grade, where students were exposed to a different class composition. We circumvent this problem by excluding data for the 7th grade. Moreover, we focus on the adolescent age stages because research has demonstrated the extraordinary importance of peer constellations in this life stage (25,35,38,44,46,47,52). At the same time, adolescence correlates with increased risks for school injuries due to heightened propensities for aggressive behavior at this life stage.

2.2 Measures

2.2.1 Dependent variable

Our dependent variable captures if students reported sustaining an injury in the school environment within the last 12 months. The GUS questionnaire also asked students who

reported a school injury to specify the context of this injury (i.e., whether it happened during physical education, on the schoolyard, in the school building, or on the way to school). In case of multiple injuries, the questionnaire instructed students to report details on their most severe injury (i.e., the injury with the longest recovery time).

Our analysis focuses on injuries that took place on the schoolyard or in the school building. We expect these injuries to be related with classroom sex ratios because, in Germany, students spend most of their day together with the same group of students. In contrast, physical education often takes place in sex-specific groups of students from different classes. Therefore, we exclude injuries that occurred during physical education from our analysis to avoid mismatches between general class compositions and student group constellations at the time of the injury. Similarly, we exclude injuries occurring on the students' way to school because these injuries took place outside the school- and class context.

Since we expect injuries resulting from aggression to be particularly related to classroom sex ratios, we specifically focus on aggression-related injuries. Using a five-point Likert-scale ranging from "does not apply at all" to "fully applies", students were asked (1) whether someone else was responsible for this injury and (2) whether this injury resulted from their own fault. We categorize injuries as aggression-related if students attributed their injury to a third person (reflected by the answer choices "applies" or "fully applies" to the first statement) while rejecting the statement that the injury was their own fault ("does not apply" or "does not apply at all").

2.2.2 Classroom sex ratio

Our key independent variable is the classroom sex ratio, operationalized as the share of male students in a class. Students in the 8th and 9th grade in Germany typically spend the majority of their school day as a class with the same group of students. Therefore, classroom sex ratios capture the composition of the students' main peer group at school.

In GUS, students are linked to classes based on five-digit-codes, which all students entered into their questionnaire at the beginning of each survey. The first four digits identify the school, while the last digit distinguishes classes from the same school. Hence, students from the same class share the same identifier so that we can assign students to classes and calculate

classroom sex ratios based on this grouping. We operationalized the sex ratio as the classroom share of males ranging from 0% to 100% in order to avoid the asymmetrical distribution of proper ratios (82). Thus, a classroom sex ratio of 50% indicates an equal number of male and female students. We estimate classroom sex ratios based on respondents from each class. In order to ensure close approximations of the true classroom sex ratio, we limit our analytical sample to only those classes in which at least ten students participated in the survey. We do not find an indication for classroom sex ratios to be correlated with participation rates on the class level (Pearson's $r = .001$, $p = .764$, Figure S1 in Supplementary Material 1). Nevertheless, we check the robustness of our results against the sensitivity to outliers or sex ratios with a high potential of bias due to a considerable level of non-response by fitting our models to a number of sample variants. These three sample variants either exclude (1) girls- and boys-only classes, (2) classes with sex ratios below 10% or above 90%, or (3) classes with a class-level response rate below 80%. Contrasting the results based on these subsamples with those from our main sample helps us narrowing down the problem of misrepresented sex ratios from potentially sex-selective non-response. Results from the auxiliary models can be found in Supplementary Material 2.

2.2.3 Control variables

Our data enable us to adjust our estimates for a set of potential individual- and aggregate-level confounders of adolescent school injuries. On the individual level, we include sex, migrant background (based on parental country of birth), family affluence, and a mental health index as controls in our models.

We measure parental socioeconomic status with the family affluence scale (FAS) proposed by Currie et al. (83). Specifically, students report how many times they went on holidays within the last year, how many cars there are in their household, whether they have a room of their own and how many books are present in their household. The FAS has been validated at both national and international levels and shown to have good criterion validity regarding socioeconomic status (SES) and various health outcomes. FAS is less affected by non-response and recall error than SES measures that rely on children's reports of household income or parental occupation (83). Information on students' mental health comes from eight items in which students were asked on how many days during the last week they (1) were

irritated and in a bad mood, (2) felt fit and comfortable, (3) were full of energy, (4) felt sad, (5) felt lonely, (6) slept badly, (7) had problems concentrating, and (8) felt unhappy and depressed ($\alpha=.85$). Higher values indicate a better mental health status, thus six of the items were coded reversely.

On the class level, we integrate controls for the class mean of family affluence and the number of students in each class. We standardize the class mean of family affluence based on the wave-specific means and standard deviations (on the class level). Information on the number of students in the respective class also comes from the student questionnaire in which, at the very beginning of the survey, students were requested to specify the number of students in their class. In the rare cases of deviating responses between students from the same class, we assigned the class mode to all students in the respective class. Moreover, we control for differences between schools by integrating school type (with the Gymnasium as the most advanced school type in secondary education vs. all other school types), region (East vs. West Germany), and urbanity (with schools located in cities with more than 100,000 inhabitants coded as urban) as controls. Finally, we adjust for time trends using a dummy variable for the two panel waves in our data.

Table 1 displays the distribution of all variables included in the statistical models for our analytical sample. Students with missing values were deleted listwise. Values for the indexes of risk-seeking behavior, mental health status, and family affluence were only calculated if students responded to at least half of the items used for index construction. In total, our main analyses rely on two panel waves comprising 13,131 observations from 9,204 students in 520 classes at 132 schools.

211 **Table 1: Sample characteristics. Students from 8th and 9th grade, GUS data 2018-2019.**

Dependent variables				
% of obs. with injury on yard or building				4.4
% of obs. with injury on yard or building due to aggression				1.3
Continuous independent variables				
	mean	sd	min	max
Mental health (individual-level)	2.87	.75	0	4
Family affluence (individual-level)	3.05	.72	0	4
Family affluence (class-level, z-standardized)	0	1	-4.73	2.08
Classroom sex ratio	46.5	14.2	0	100
Class size (number of students usually in class)	26.2	3.1	15	33
Dichotomous independent variables				
% of obs. from male students				46.2
% of obs. from students with migrant background				30.6
% of obs. from students at the Gymnasium (upper secondary)				60.4
% of obs. from students at East German schools				15.3
% of obs. from students at rural schools				76.5
% of obs. from grade 9				45.6
Number of observations				13,131
Number of students				9,204
Number of classes				520
Number of schools				132

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214 **2.3 Analytical approach**

215 Since we have a dichotomous dependent variable and hierarchical data (observations nested in
 216 students, and students nested in classes), we estimate multilevel logistic regression models to
 217 analyze the effect of classroom sex ratios on the individual likelihood to suffer an injury that
 218 took place either on the schoolyard or in the school building. Including random intercepts for
 219 students and classrooms allows us to adjust for time-invariant unobserved characteristics of
 220 school classes and students, respectively (84). We also estimated models including a random
 221 intercept for schools as a fourth level but did not include them here since they essentially yield
 222 the same results.

Our main analysis consists of two parts. In the first part, we analyze the association of classroom sex ratios with school injuries on the schoolyard or in the school building. A second model series focuses only on injuries on the schoolyard or in the school building that resulted from third-party aggression. For both analyses, we report the full results from logistic regression models as odds ratios. Moreover, we transform the output from the logistic regression model to marginal effects. We then scale the differences in the estimated probability of the outcome by the baseline probability of experiencing the respective type of school injury. Therefore, our graphs show the percentage difference in the probability of the outcome at different levels of the sex ratio variable relative to the mean probability of the outcome in the analytical sample. Additionally, we report the relative risk of experiencing the respective type of school injury at the 10th and 90th percentile of the sex ratio distribution in our sample, which corresponds to a 29.4 (10th percentile) and 63.6 percent (90th percentile) share of male students. Finally, we test whether the association between the classroom sex ratio and injury risks differs between male and female students by integrating an interaction term for the individual's sex and the sex ratio as well as a random slope for sex into our model (85,86).

3 Results

3.1 Any-cause school injury risks and classroom sex ratios

In a first model, we analyze the association of classroom sex ratios with reports of any injury on the school premises. Results from a bivariate multilevel logistic regression model reveal a positive and statistically significant association between school injury risks and classroom sex ratios ($OR = 1.017, p < 0.001$, see Table S1 & Fig. S2 in Supplementary Material 1). Multivariate results support this result. Table 1 displays the results from a multilevel logistic regression model. We find a positive and statistically significant association between classroom sex ratios and students' susceptibility for school injuries ($OR = 1.012, p = 0.012$).

250 **Table 2: Odds Ratios from multilevel logistic regression predicting the risk of injury on**
 251 **the school premises. Students from 8th and 9th grade, GUS data 2018-2019.**

	Variable	OR	se	p	95% CI	
Fixed part	Classroom sex ratio (% male students)	1.012	0.0046	0.012	1.003	1.021
	Class size	0.996	0.02	0.853	0.958	1.036
	Class mean of family wealth	0.877	0.063	0.069	0.761	1.010
	Basic/intermediate secondary school	Ref.				
	Upper secondary school	0.621	0.099	0.003	0.455	0.847
	West German school	Ref.				
	East German school	1.056	0.195	0.768	0.735	1.517
	Urban school	Ref.				
	Rural school	0.908	0.143	0.539	0.667	1.236
	Sex: Female	Ref.				
	Sex: Male	1.793	0.224	<.001	1.402	2.291
	Migrant background: No	Ref.				
	Migrant background: Yes	1.368	0.179	0.017	1.059	1.767
	Mental health	0.521	0.039	<.001	0.449	0.604
	Family wealth	1.417	0.130	<.001	1.184	1.696
	8th grade	Ref.				
	9th grade	0.464	0.052	<.001	0.372	0.579
	Constant	0.02	0.015			
Random part	σ^2	0.258	0.123		0.101	0.658
	τ^2	3.414	0.751		2.218	5.256
	LogLikelihood	-2,243.896				
	N(students)	9,204				
	N(class)	520				
	N	13,131				

252 Models include individual- and aggregate-level variables as fixed effects and the respective class and the person
 253 identifier as random effects. The terms σ^2 and τ^2 represent the variance between classes and individuals, respectively.
 254

255 Moreover, the model suggests a higher injury risk for male students, students with a migration
 256 background, and higher family wealth. In contrast, students attending upper secondary schools
 257 and students scoring high on our mental health index are less likely to suffer from injuries on
 258 the schoolyard or in the school building. Finally, we find a negative association of injury risks
 259 with age, given that observations in 8th grade exhibit significantly lower odds of sustaining an
 260 injury compared to those in 9th grade.

261 Figure 1 illustrates that, despite the small odds ratio coefficient, the effect estimate for
 262 classroom sex ratios is far from negligible. In fact, the small odds ratio is mainly due to the

scaling of the sex ratio to a range between 0 and 100 percent share of male students in a class. Therefore, the odds ratios reflect the change in injury risk for an increase in the share of male students by one percentage point. Figure 1 reveals a substantial variation in the percentage differences in the probability of sustaining an injury relative to the baseline probability across the range of the sex ratio. This is also apparent when comparing predicted injury risks. For instance, for classes in which 29.4 percent of the students are boys (the 10th percentile), the model predicts a mean probability of injury on the school premises of 3.83 percent. In contrast, for classes with a 63.6 percent share of male students (the 90th percentile), the respective value is 5.11 percent. In other words, the risk of a school injury increases by 33.5 percent when moving from the 10th to the 90th classroom sex ratio percentile.

Figure 1: Adjusted predictions for school injury from multilevel logistic predicting the risk of injury on the school premises. Students from 8th and 9th grade, GUS data 2018-2019.

In a complementary model, we test whether boys' and girls' injury risks are differently associated with classroom sex ratios. Thus, we also test whether the association between classroom sex ratios and injury risk varies between boys and girls. However, Table S2 and Figure S3 reveal that this is not the case (in Supplementary Material 1). We do not find a significant coefficient for the interaction term for individual sex and classroom sex ratios.

Accordingly, the difference in slopes between male and female students' predicted relative injury risks remains negligible across the range of the sex ratio variable. In sum, this indicates that the association between classroom sex ratios school injury risks are similar across the sexes. Both male and female students similarly experience increased injury risks in classes with a higher share of male students.

3.2 Aggression-related school injuries and classroom sex ratios

In our second series of analyses, we focus on aggression-related school injuries. Bivariate results again suggest a positive and statistically significant association of classroom sex ratios with school injuries from aggression (Table S3 and Fig. S4, in Supplementary Material 1). This association persists even after adjusting for individual- and contextual-level control variables. Specifically, Table 2 reveals that classroom sex ratios correlate significantly and positively with school injuries from aggression (OR = 1.022, $p=0.010$). Note that the odds ratio coefficient for the classroom sex ratio is higher for these aggression-related injuries than for all reported injuries on the school premises (OR = 1.012, see Table 2).

Table 3: Odds Ratios from multilevel logistic regression predicting the risk of injury from aggression on the school premises. Students from 8th and 9th grade, GUS data 2018-2019.

	Variable	OR	se	p	95% CI	
Fixed part	Classroom sex ratio (% male students)	1.022	0.0086	0.010	1.005	1.039
	Class size	1.043	0.038	0.252	0.970	1.121
	Class mean of family wealth	1.103	0.146	0.459	0.851	1.429
	Basic/intermediate secondary school	Ref.				
	Upper secondary school	0.315	0.094	<.001	0.176	0.566
	West German school	Ref.				
	East German school	1.700	0.553	0.103	0.898	3.216
	Urban school	Ref.				
	Rural school	0.697	0.197	0.202	0.401	1.213
	Sex: Female	Ref.				
	Sex: Male	2.038	0.475	0.002	1.291	3.218
	Migrant background: No	Ref.				
	Migrant background: Yes	1.697	0.411	0.029	1.056	2.726
	Mental health	0.560	0.075	<.001	0.431	0.727
	Family wealth	1.566	0.270	0.009	1.117	2.196
	8th grade	Ref.				
	9th grade	0.378	0.081	<.001	0.249	0.575
	Constant	0.00032	0.00048			
Random part	σ^2	0.528	0.357		0.140	1.986
	τ^2	5.146	1.413		3.004	8.815
	LogLikelihood	-799.716				
	N(students)	8,962				
	N(class)	520				
	N	12,713				

Models include individual- and aggregate-level variables as fixed effects and the respective class and the person identifier as random effects. The terms σ^2 and τ^2 represent the variance between classes and individuals, respectively.

Figure 2 displays this steeper slope for the relative risk of aggression-related injuries compared to the slope from the model for all injuries. In particular, we find that the risk of school injuries from aggression increase more pronouncedly across the range of classroom sex ratios than any-cause school injury risks. This is also confirmed when we compare classes with a share of male students corresponding to the 10th and the 90th percentile, respectively. Here, the predicted risks are 0.91 and 1.62 percent, translating into a difference of 78 percent. For comparison, the equivalent increase for all injuries was 33.5 percent. Note, however, the considerably broader confidence intervals compared to Figure 2. This is attributable to the lower

mean risk of aggression-related injuries compared to all injuries (1.3% vs. 4.4%), as displayed in Table 1.

Figure 2: Adjusted predictions for school injury from aggression from multilevel logistic predicting the risk of injury from aggression on the school premises. Students from 8th and 9th grade, GUS data 2018-2019.

Finally, we do not find an indication that boys' and girls' risks of aggression-related injuries are differently related to the classroom sex ratio. Figure S5 and Table S4 display the results from regression models that included an interaction effect for sex and classroom sex ratios (in Supplementary Material 1). While there is a slight divergence in the slopes of predicted risk between boys and girls, this difference remains small across the entire range of the classroom sex ratios. In sum, our results suggest the risk of aggression-related injuries to increase as the share of male students gets larger – and this holds true for boys and girls alike.

3.3 Robustness checks

Finally, auxiliary models confirm that our results are robust against a number of alternative sample definitions. Therefore, we rule out that our findings might be due to a few outliers in

terms of the classroom sex ratio. Specifically, the coefficient estimate for classroom sex ratios remains the same even when dropping classes with the most extreme sex ratios from the sample. Models fitted to subsamples that exclude single-sex classes or classes with a share of male students below 10% or above 90% suggest a positive association between classroom sex ratios and school injuries similar to our main results presented above. An additional model variant fitted to a sample of only those observations with at least 80% response rate on the class-level yields a comparable positive association. However, the coefficient is not significant due to the reduced number of cases in this model (Figures S2.1-S2.2 and Tables S2.1-S.2.2, Supplementary Material 2).

For the aggression-related injuries, models fitted to these alternative sample definitions also support our main findings. The coefficients and predicted relative risks are essentially the same across the sample specifications. Moreover, coefficients for the classroom sex ratio in models predicting aggression-related school injuries are larger than the corresponding estimate in the models for the overall school injuries. However, the reduced sample size turns the coefficient for the classroom sex ratios insignificant when limiting our sample to observations with a minimum class-level response rate of 80%. Nevertheless, the coefficient and predictions based on this restrictive sample definition support the overall finding of a positive association between aggression-related school injury risks and shares of male students in the classroom. The full results from these auxiliary models can be found in Supplementary Material 2 (Figures S2.3-S2.4 and Tables S2.3-S2.4).

4 Discussion

In this paper, we use nationwide survey data from Germany to investigate the link between classroom sex ratios and adolescent school injuries. School injuries are a major public health problem with important implications for students' quality of life and academic achievement (2–4,10,13–15,17,18,87). However, empirical evidence on contextual risk factors for adolescent school injuries has been lacking so far. This is despite the fact that key risk factors for adolescent school injuries – aggression and risk-taking – have consistently shown to be highly susceptible to contextual influences. Moreover, a growing body of literature suggests that male-skewed sex ratios increase adolescent risk-taking and in particular physical aggression (34,36,40,53,54,57–59,61,71–73,76,77). In this paper, we bring together these spheres of expertise to explore the role of classroom sex compositions as a contextual risk factor for adolescent school injuries.

Overall, our analysis reveals four main findings. First, we find that adolescents face higher risks to sustain school injuries when they are part of a male-skewed classroom. Second, additional models suggest that boys' and girls' injury risks are similarly associated with the share of male students in a classroom. Third, the association between classroom sex ratios and injury risks is even more pronounced when we focus our analysis on only those injuries that are attributable to aggression by other students. Thus, students in male-skewed classroom contexts are more likely to report an aggression-related school injury. Fourth, again, we do not find evidence that boys' or girls' aggression-related injury risks are differently associated with classroom sex ratios. In other words, both boys and girls are at higher risk of sustaining an aggression-related injury when they are part of a male-skewed classroom sex ratio.

Our findings illustrate the need to integrate a contextual perspective in research on school injuries, particularly among adolescents. Previous studies have emphasized the crucial role of school facilities, environmental factors, and individual characteristics of students for school injury risks (4,43). Our results offer a complementary perspective by highlighting the social context of injury risks. This is not to downplay environmental risk factors such as weather, yard facilities, or architectural aspects for school injuries. However, the way students interact with these facilities and with one another is crucial for how likely these hazards translate into injuries. The role of interactions particularly applies to adolescent behavior. Contextual peer effects are particularly relevant for adolescents, including adolescent risk-behavior and aggression. An extensive body of literature demonstrates the relevance of contextual factors for

adolescent health behavior (25,27,30,37–39,44,46,47). Our results illustrate the specific relevance of social contexts at school for adolescent school injuries.

Interventions to prevent adolescent school injuries should therefore also take into account the sex composition of classrooms. Ensuring a mix of boys and girls in classrooms could help reduce the number of school injuries. Moreover, interventions should target specifically male-dominated classes. The literature suggests that the increase in injury risks in male-skewed classrooms results from higher levels of risk-taking and aggression in male-skewed contexts (34,40,53,55,57,58,61,63). Both risk-taking and aggression have an important signaling function since it often confers status, particularly to adolescent males. Therefore, successful interventions should aim to specifically provide adolescents with alternative, safer forms of status attainment. Specifically, interventions should guide adolescents towards alternative means of gaining social acceptance and respect, where adolescents can attain status without contests or engaging in antisocial behavior (88).

On a more general level, our findings offer further support to concerns that male-skewed sex ratios are associated with an increase in aggression and violence (53,57,58,61–63,65). Our results suggest that aggression-related injuries are more prevalent in male-skewed classrooms. Therefore, our findings question recent propositions that the incidence of violence should decrease as sex ratios become increasingly male-skewed (89,90). However, theoretical frameworks suggesting a negative association between sex ratios and violence draw upon theories of the marriage market and mating behavior (61,90), which are less applicable to our study population of adolescent students. Moreover, our data cannot further elucidate the mechanisms behind the link between classroom sex ratios and aggression-related injury risks. Generally, the literature either draws upon biological differences between the sexes or gender-specific social expectations to explain sex ratio effects in behavior (62,91). While these approaches differ in their theoretical frameworks, both identify male status thriving and competitive orientation as prime sources for higher male involvement in physical aggression and health-detrimental risk-taking (68–70). One potential mechanism might be hormonal reactions to sex compositions. Specifically, experimental studies reveal that participants in male-skewed groups experience higher testosterone levels (92,93), and levels of testosterone have been linked to aggressive behavior (94). However, we acknowledge that we are not able to adjudicate on such pathways based on our results. In particular, our data do not contain information on aggressors. Therefore, we cannot establish whether a male-skewed classroom sex ratio instigates aggression primarily by male or female students. The literature on sex ratio

effects on violent offending primarily focuses on male offenders (57,58,89,90). Yet, there is evidence that female violence also increases when sex ratios are male-skewed. In particular, research shows that girls' delinquency is higher if they affiliate with male friends (95–97) and that having more male friends is associated with more antisocial behavior in girls (34,98). However, the lack of information on offenders prevents us from establishing whether the surplus injuries from aggression are actually driven by *male* aggression. Future studies should consider collecting details on the aggressor(s) to further explore the underlying mechanisms.

This paper uses nationwide survey data with self-reports on school injuries. Compared to studies relying on medical records, our data provide crucial information on the classroom context and information on non-injured students. Nevertheless, analyses of survey data come with certain limitations. First, information on school injuries is collected retrospectively, limiting the level of medical detail and entailing the risk of recall error or recall bias. However, given that the survey focuses on severe injuries that required medical treatment, we expect that most affected students will be able to recall such a memorable event. A second limitation is that the aggression-related school injuries might not be distinctly distinguishable from injuries resulting from other causes. In certain instances, injuries might be attributable to both third-party aggression as well as own risk-taking. Given that we find a similar association for both, all injuries and aggression-related injuries can, however, be considered as indicative of an overall association of sex ratios and injury risks. Moreover, while we can reconstruct classroom sex ratios, our data do not contain information on how closely students from a class interact with each other. Network approaches to peer effects frequently use directed friendship relations where students nominate their best friends to reconstruct peer contexts for each student (34,36,40,47). Such information would help to approximate closer the sex composition of students' peers. Nevertheless, network-based approaches also suggest that not only close friends, but also more distal peers do affect behavior in profound ways (47). Consequently, our results constitute a baseline for a combined measure of sex compositions in close and distant peers at school. Finally, we cannot fully avoid problems of unobserved heterogeneity between schools and classes from differential preferences of boys and girls with respect to STEM or liberal arts (99). However, we are able to attenuate this problem by adjusting for time-invariant unobserved characteristics of school classes by including random intercepts at the class-level. Given the nationwide scope and longitudinal nature of our data, we consider our results a meaningful first step towards a more detailed exploration of school injury risks and classroom sex ratios as well as contextual effects in general.

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