Association between Body Composition and Sport Injury in Canadian Adolescents

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ABSTRACT

Purpose: To examine the association between overweight or obesity and sport injury in a population-based sample of Canadian adolescents. **Methods:** Cross-sectional analyses were performed using the Canadian Community Health Survey (2009–2010), a nationally representative sample ($n = 12,407$) of adolescents aged 12–19 years. Body composition was quantified using BMI, grouping participants into healthy weight, overweight, or obese. The outcome of interest was acute or repetitive strain injury sustained during sport in the previous year. We examined the relationship between sport injury and overweight or obesity compared with healthy weight using multivariate logistic regression, controlling for sex, ethnicity, physical activity, and socio-economic status. We also examined the interaction between physical activity and body composition in a secondary analysis with a subset of active adolescents. **Results:** No significant relationship was found between being overweight and sport injury (odds ratio [OR] = 1.04, 95% CI: 0.92, 1.17); however, a protective effect was seen between obesity and sport injury (OR = 0.67, 95% CI: 0.53, 0.84). Secondary analysis revealed that overweight youths with the highest activity level (quartile 4) did have increased odds of sport injury (OR = 1.38, 95% CI: 1.04, 1.83), yet obese youths with a moderate activity level (quartile 2) were protected compared with healthy-weight youths (OR = 0.46, 95% CI: 0.24, 0.91). **Conclusions:** Further examination of active adolescents is warranted. Studies should consider sport-specific differences and comprehensive measurement of exposure to sport.

Key Words: adolescent; athletic injuries; body composition; body mass index; risk factors.

RÉSUMÉ

Objectif : examiner le lien entre surpoids et blessures sportives dans un échantillon de la population d'adolescents canadiens. **Méthodes :** des analyses transversales ont été réalisées des résultats de l'Enquête sur la santé dans les collectivités canadiennes (2009–2010), un échantillon national représentatif ($n = 12\ 407$) d'adolescents de 12 à 19 ans. Les participants ont été regroupés en trois catégories (de poids normal, en surpoids et obèses) selon leur IMC. Le résultat d'intérêt était la survenance de blessure aiguë ou répétitive lors d'activités sportives dans la dernière année. Nous avons examiné la relation entre l'occurrence de blessures sportives et le fait d'être en surpoids ou obèses par rapport à un poids normal par régression logistique multiple, en contrôlant le sexe, l'ethnicité et le statut socioéconomique. Nous avons également examiné l'interaction entre l'activité physique et la composition corporelle dans une analyse secondaire d'un sous-ensemble d'adolescents actifs. **Résultats :** aucune relation significative n'a été observée entre le fait d'être en surpoids (rapport de cotes [RC] = 1,04, IC 95% = 0,92; 1,17) et l'occurrence de blessures sportives; un « effet protecteur » a toutefois été observé entre obésité et blessures sportives (RC = 0,67, IC 95% = 0,53; 0,84). L'analyse secondaire a révélé que les jeunes en surpoids les plus actifs (4^e quartile) étaient plus à risque de blessures sportives (RC = 1,38, IC 95% = 1,04; 1,83), mais que les jeunes obèses ayant un niveau d'activité modéré (2^e quartile) étaient protégés par rapport aux jeunes de poids normal (RC = 0,46, IC 95% = 0,24; 0,91). **Conclusions :** des études supplémentaires sur les adolescents actifs sont nécessaires. Ces études devraient tenir compte des différences entre sports et d'une mesure globale de l'exposition au sport.

The benefits of sport participation in youth are well established; they include facilitating optimal bone growth and muscle development as well as decreasing the risk of chronic diseases later in life.¹ The General Social Survey

reported that 54% of Canadians aged 15–19 years regularly participate in sport,² yet sport is the leading cause of injury requiring medical attention in Canadian adolescents.³ Injuries among youths have immediate impacts

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on health, such as increased pain and decreased social functioning.⁴ The long-term consequences of injury can be severe; for example, one systematic review reported that sustaining a knee joint injury had 3 times the risk of developing osteoarthritis later in life.⁵ An estimated 8% of youths drop out of sport every year after being injured, thus disengaging at a time that is critical to developing lasting behaviour that will promote an active lifestyle in the future.⁶

In Canada, the prevalence of overweight and obese youths is on the rise. The Canadian Health Measures Survey reported that the percentage of youths aged 15–19 years who are considered overweight or obese rose from 14% (both sexes) in 1981 to 31% in boys and 25% in girls in 2007–2009.⁷ With this substantial prevalence of obesity in youths, understanding its impact on pertinent areas of public health, such as sport injury, is paramount.

Previous systematic reviews have identified both non-modifiable and modifiable sport injury risk factors in youths, including sex, previous injury, sport exposure, and body composition.^{3,7} For example, studies have reported that youths with the highest level of sport participation were more than 2–4 times more likely to be injured than those with the lowest level of sporting activity.^{8,9} However, the evidence pertaining to the relationship between body composition and sport injury in adolescents has been inconclusive. For example, one recent study used a cross-sectional survey to investigate the role of BMI, as a proxy for body composition, in sport injury in high-school-age youths.⁹ It found that obese adolescents had greater odds of injury than healthy ones. Conversely, another study found that the volume of sport participation, but not BMI, was related to increased injuries in overweight and obese youths.⁸ Thus, the association between overweight or obesity and sport injury is clearly an area of research that demands further clarity.

There is strong evidence that neuromuscular training programmes are effective in the primary prevention of lower extremity injuries in youth sport by addressing aspects of strength, endurance, and balance.¹⁰ If overweight or obese youths have deficits in these areas, they may be at increased risk of injury, and those overweight and obese youths with the highest exposure to sport participation will be at the greatest risk of injury. If this is true, physiotherapists, as movement specialists, may be able to increase their role in the primary prevention of sport injuries in this sub-population of adolescents.

The Canadian Community Health Survey (CCHS) is a national, population-based survey collected by Statistics Canada that provides a unique opportunity to explore evidence of an association between overweight and obesity by BMI classification and sport injury. Specifically, the purpose of the current study was to use data from the 2009–2010 CCHS to examine the association between overweight or obesity and sport injury in adolescents aged

between 12 and 19 years, controlling for potential confounders of injury risk: sex, ethnicity, participation in physical activity (PA), and socio-economic status (SES). A secondary objective was to examine the interaction between overweight, obesity, and high levels of PA with regard to sport injury.

METHODS

Data for this study were obtained from the 2009–2010 CCHS, collected from January 2009 to December 2010. The CCHS is a voluntary, cross-sectional survey that collects information from randomly selected Canadians regarding health status, health care use, and health determinants using computer-assisted or telephone interviews. The target population includes all Canadians aged 12 years or older living in private dwellings in the 10 provinces and 3 territories. The CCHS captures approximately 98% of Canadians in this age group. Excluded are those individuals living on First Nations reserves or crown land, full-time members of the Canadian Forces, institutionalized individuals, and persons living in certain remote regions. Statistics Canada uses complex, multi-stage sampling to identify households and calculates survey sampling weights to account for the uneven probability of someone being selected to take part in the survey; in this way, it can interpret the results as a nationally representative sample and appropriately calculate variance around estimates. The combined household- and person-level response rates for the 2009–2010 CCHS were 72.3%. Additional details regarding the survey methodology have previously been published.¹¹ Ethical approval for this study was covered in Policy 89, “Research Involving Human Participants,” at the University of British Columbia.¹²

Sport injury, as the outcome of interest, included participants who had sustained either an acute injury or an injury resulting from repetitive strain during sport. An acute injury was determined by the answers to two survey questions. First, participants had to answer yes to the question “Not counting repetitive strain injuries, in the past 12 months, were you injured?” Second, to be classified as having sustained an acute sport injury, they had to indicate that the “activity when injured” was “sport or physical exercise.” Similarly, participants who answered yes to the question “In the past 12 months, did you have any injuries due to repetitive strain?” who then also reported that the injury resulted from “sport or physical exercise” were classified as having sustained a repetitive strain sport injury. Participants answering no to either of the “injury in the past 12 months” questions or indicating that the injury did not occur during “sport or physical exercise” were classified as not having an acute or repetitive strain sport injury.

The exposure of interest was participant BMI classification—healthy weight, overweight, or obese—as a proxy for body composition. BMI was calculated by dividing

self-reported weight (in kilograms) by height (in metres) squared. Adolescents aged 12–17 years were classified according to the Coles Classification system using age- and sex-specific cut-points.¹³ Participants aged 18–19 years were classified using accepted adult standards.¹⁴

Established risk factors for sport injury that were also related to BMI were included in the final model as confounders. Participant ethnicity was dichotomized as white or visible minority. Highest household education, as a proxy for SES, classified participants into quintiles. PA participation was used as a proxy for amount of sport exposure, and it was measured using the standardized and validated Physical Activity Index.¹⁵ This index is derived from participants' self-reported leisure PA over the previous 3 months. It is calculated using the frequency and duration per reported activity and the established metabolic equivalents (METs) corresponding to the intensity of each activity, as set by the Canadian Fitness and Lifestyle Research Institute.

During variable examination, PA was explored as a continuous variable and as a categorical variable. The final model included the continuous PA variable to minimize the potential residual confounding by PA that could arise with the categorical variable. The potential interaction between BMI category and PA was explored.

Descriptive characteristics, including BMI classification as well as acute, repetitive strain, or overall sport injury incidence, were reported as frequencies (percentages) and means (SD). Bivariate logistic regression was performed to examine the relationship between BMI and sport injury. The crude association between each risk factor and both sport injury and BMI was inspected. Multiple logistic regression analysis was used to examine whether either overweight or obesity, compared with healthy weight, was associated with increased odds of sport injury among adolescents, controlling for sex, ethnicity, PA participation, and household education. A secondary analysis was conducted to explore the possibility that the relationship between BMI and sport injury was modified at higher levels of PA. The physical activity index in the CCHS classified adolescents as active if they achieved 3 METs per day of PA ($n = 6,163$).¹¹ The active subset of the sample was stratified into four quartiles. Approximately 1,540 adolescents were in each group, with slight variation resulting from individuals with the same METs per day of PA being grouped together. The relationship between BMI and sport injury was examined within these PA strata.

The assumptions necessary for logistic regression analysis were considered. All estimates were weighted using probability weights, derived from frequency weights provided by Statistics Canada. Analyses were performed with SAS version 9.3 (SAS Institute, Cary, NC).

RESULTS

From the full CCHS survey ($n = 124,188$), the current study retained all adolescents aged 12–19 years

($n = 14,476$). Excluded were 232 participants classified as underweight because these data were available only for respondents aged 18–19 years. A total of 1,837 (12.9%) eligible respondents were excluded for missing data. This represented those not reporting height or weight ($n = 1,507$), ethnicity ($n = 337$), injury status ($n = 162$), and PA ($n = 4$). (Some participants had missing data in multiple categories.) In addition, a number of respondents did not answer the question regarding highest household education ($n = 1,856$), but were included as a “not stated” category to avoid excluding these individuals. The final analytic sample consisted of 12,407 respondents. Given this sample size, the power of this study to detect a 10% increased odds of injury in overweight and obese youths compared with healthy-weight counterparts was 94% and 90%, respectively ($\alpha = 0.05$).

In the final sample, 21.0% of respondents had sustained one or more acute or repetitive strain sport injuries in the past year, with males sustaining more injuries than females. The majority of adolescents were categorized as healthy weight (78.5%), with 16.3% and 5.2% in the overweight and obese categories, respectively. Age was reasonably equally distributed across categories, with slightly fewer 18- to 19-year-olds in the sample. Almost three-quarters (74.2%) of the adolescents reported their ethnicity as white. The distribution of highest household education was skewed, with the highest proportion (67.2%) reporting post-secondary graduation. Reported METs of daily PA varied from 0.0 to 36.2, with more than 95% of adolescents reporting less than 11 METs/day. Demographic details are found in Table 1.

In examining the odds of sport injury, unadjusted analysis found no significant association for those who were overweight compared with those who were healthy weight (see Table 2). However, the unadjusted OR suggested that obesity was protective against sustaining a sport injury (OR = 0.64, 95% CI: 0.51, 0.80). When PA was explored by quintile, a linear relationship was observed, whereby increased PA participation was related to more sport injuries. There was no evidence of a significant interaction between PA and BMI category. The final multivariate model showed the same pattern: Overweight compared with healthy weight was not found to be associated with increased odds of sport injury, yet obesity was seen to decrease odds of sport injury by 33% (OR = 0.67, 95% CI: 0.53, 0.84) after controlling for sex, ethnicity, household education, and PA participation.

When examining confounders, we found that being female or a visible minority was associated with decreased odds of sport injury. Conversely, each 1 MET increase in daily PA was associated with increased odds of sport injury. Odds of sport injury significantly increased for those with higher household education in all categories relative to the reference category of less than secondary education.

In the secondary analysis, large variability was seen in METs for those classified as active: from 3.0 to 36.2.

Table 1 Demographic and Injury Characteristics of Canadian Community Health Survey (2009–2010), Adolescents Aged 12–19 Years

Variable	No. (%) [*] of sample		
	Full (<i>n</i> = 12,407)	By injury status [†]	
		Yes (<i>n</i> = 2,622; 21.1) [†]	No (<i>n</i> = 9,785; 78.9) [†]
Type of injury [†]			
Acute injury			
Yes	2,245 (18.4)		
No	10,162 (81.6)		
Repetitive strain injury			
Yes	547 (4.1)		
No	11,860 (95.9)		
BMI category			
Normal weight	9,505 (78.5)	2,036 (79.2)	7,469 (78.3)
Overweight	2,146 (16.3)	467 (17.2)	1,679 (16.1)
Obese	756 (5.2)	119 (3.6)	637 (5.6)
Sex			
Male	6,372 (51.4)	1,611 (59.7)	4,761 (49.2)
Female	6,035 (48.6)	1,011 (40.3)	5,024 (50.8)
Age, y			
12–14	4,443 (35.1)	1,073 (39.1)	3,370 (34.0)
15–17	4,954 (40.2)	1,095 (41.2)	3,859 (40.0)
18–19	3,010 (24.7)	454 (19.7)	2,556 (26.0)
Ethnicity			
White	9,790 (74.2)	2,131 (77.6)	7,659 (73.3)
Visible minority	2,617 (25.8)	491 (22.4)	2,126 (26.7)
Highest household education			
Less than secondary	419 (3.0)	54 (1.6)	365 (3.4)
Secondary graduation	1,226 (8.6)	209 (7.3)	1,017 (8.9)
Some post-secondary	725 (6.6)	126 (5.4)	599 (6.9)
Post-secondary graduation	8,181 (67.2)	1,843 (71.7)	6,338 (66.0)
Not stated	1,856 (14.6)	390 (14.0)	1,466 (14.8)

*Percentages are weighted using Statistics Canada survey weights to adjust for sampling probabilities and generate population-based estimates.

†Some individuals sustained both an acute and repetitive strain injury in the year, so the number of combined injuries adds up to more than the total. Total injuries count each individual only once.

When this active subset was divided into quartiles, multi-variate analysis revealed that overweight youths in quartile 4 (highest PA) were at significantly increased odds of sport injury (OR = 1.38, 95% CI: 1.04, 1.83) compared with their healthy-weight counterparts (see Table 3). Conversely, obese youths in quartile 2 appeared to be at significantly decreased odds of injury compared with their healthy-weight counterparts (OR = 0.46, 95% CI: 0.24, 0.91). No other significant relationships were seen.

DISCUSSION

This study investigated the association between BMI-classified overweight or obesity and sport injury in a population-based sample of Canadian adolescents. After adjusting for known risk factors, the multivariate analysis did not reveal that overweight and obese youths were at increased odds of sport injury; this was contrary to our original hypothesis. Face validity was supported by the relative association of each confounder with sport injury, a finding that aligned with those from previous research.^{3,16,17} It is interesting that in the secondary analysis, stratification by PA found that the most highly

active sub-group of overweight adolescents was indeed at 38% increased odds of injury compared with the healthy-weight sub-group, and obese youths in the second PA quartile were found to be at reduced odds of injury. On the basis of this result, it is plausible that highly active overweight youths may be a unique sub-group of adolescents at high risk of sport injury, but this requires further investigation. In addition, it appears that the influence of body composition on the risk of sport injury is different in obese youths than overweight youths. However, the low number of participants in the active obese strata (59–85 participants per quartile) reinforces the exploratory nature of this secondary analysis.

The literature examining this relationship across multi-sports in adolescents is limited, and the overall association remains inconclusive. A recent study reached conclusions similar to the current one: It examined 3,846 youth sport participants in the Netherlands and found that compared with healthy-weight participants, the odds of sports injury were 27% less for overweight participants (OR = 0.73, 95% CI: 0.53, 1.00).¹⁸ Conversely, Richmond and colleagues⁹ examined cross-sectional data from high

Table 2 Unadjusted and Adjusted Logistic Regression Results of the Relationship between Body Composition and Sport Injury

Variable	OR (95% CI)	
	Unadjusted	Adjusted*
BMI category		
Normal weight	1.00	1.00
Overweight	1.06 (0.94, 1.19)	1.04 (0.92, 1.17)
Obese	0.64 (0.51, 0.80)†	0.67 (0.53, 0.84)†
Sex		
Male	1.00	1.00
Female	0.65 (0.60, 0.71)†	0.73 (0.67, 0.80)†
Ethnicity		
White	1.00	1.00
Visible minority	0.79 (0.72, 0.88)†	0.78 (0.71, 0.87)†
Highest household education		
Less than secondary	1.00	1.00
Secondary education	1.71 (1.20, 2.44)†	1.52 (1.06, 2.19)†
Some post-secondary	1.63 (1.13, 2.36)†	1.48 (1.02, 2.16)†
Post-secondary graduation	2.27 (1.64, 3.14)†	2.01 (1.45, 2.80)†
Not stated	1.97 (1.40, 2.77)†	1.65 (1.17, 2.34)†
Daily physical activity‡	1.12 (1.11, 1.13)†	1.11 (1.10, 1.13)†

*Adjusted for sex, ethnicity, household education, and physical activity.

†CIs that do not cross.

‡Per 1-MET increment.

Table 3 Adjusted Logistic Regression Results of the Relationship between Body Composition and Sport Injury in Active Adolescents with Confounders, Stratified by Daily Physical Activity Level

Daily physical activity quartile (METS/day)	BMI category, OR (95% CI)		
	Normal weight	Overweight	Obese
Quartile 1 (3.0–3.9)	1.00	0.98 (0.71, 1.37)	0.54 (0.26, 1.13)
Quartile 2 (4.0–5.0)	1.00	1.03 (0.75, 1.42)	0.46 (0.24, 0.91)*
Quartile 3 (5.1–8.0)	1.00	0.89 (0.65, 1.20)	0.79 (0.45, 1.38)
Quartile 4 (≥ 8.1)	1.0	1.38 (1.04, 1.83)*	0.78 (0.43, 1.44)

Note: Analysis adjusted for sex, ethnicity, household education, and daily physical activity.

*CIs that do not cross 1.

METS = metabolic equivalents.

school students in Alberta and reported that obese adolescents had 1.34 (95% CI: 1.02, 1.80) increased odds of all sport injury compared with normal-weight adolescents. This lack of consensus may be a result of variability in the definitions and quantification of sport injury, body composition, and level of sport participation.

Accurately measuring body composition in adolescents is challenging.¹⁹ Although BMI is the most commonly used proxy for determining adiposity in youths, indices such as sum of skin folds or dual-energy X-ray absorptiometry are considered gold standards.²⁰ The proportions of overweight (16.3%) and obese (5.2%) youths in the current study are slightly lower than expected on the basis of national Canadian data,⁷ although evidence has suggested that adolescents may underestimate their weight in self-reported data, particularly those who are overweight.²¹ This may result in a low BMI calculation

and misclassification (e.g., overweight classified as normal weight). This reporting bias is independent of sport injury status and considered non-differential, biasing results toward the null. It is one plausible reason for the non-significant findings in the current study.

As a surrogate measure of adiposity, BMI has been criticized for not accounting for the amount of muscle mass relative to height in athletes and young adults.²² A recent cohort study examined sport injury risk in a heterogenic group of youths while comparing two different measures of overweight: BMI and total body fat percentage (TBF%).²³ When BMI was used, overweight youths did not show an increased incidence rate ratio (IRR) of injury compared with healthy-weight youths, yet when measured by TBF%, the IRR was 1.34 (95% CI: 1.07, 1.68) times greater for overweight youths. This suggests that classifying youths as overweight by TBF%

is more likely to predict injury than classifying them by BMI. Furthermore, in the current study, using BMI as an estimate of body composition may have influenced the results if some youths with higher muscle mass were incorrectly classified as overweight or obese.

The main findings of this study are contrary to the original hypothesis. Previous studies suggested that adiposity causes increased musculoskeletal strain and impaired postural control in youths with a disproportionately large body mass.^{24,25} This suggestion may be especially relevant during sporting activities that involve rapid changes in direction and complex motor control. It is likely that these highly coordinated tasks apply to some sports more than others, meaning that in a broad, multi-sport study such as the current project, the risk of injury among overweight or obese youths in individual sports may be diluted. For example, previous studies involving just football²⁶ found that high-BMI players were at increased risk of sport injury. Future work may wish to focus on individual sports, especially those that involve these potentially high-risk-movement skills, such as soccer and basketball. In addition, it is possible that overweight or obese youths self-select to sports with lower injury rates, such as swimming or tennis,³ a fact that the current study would not reveal.

The results of the current study concur with the strong body of evidence that PA increases sport injuries in youths.²⁷ It may also be important to consider additional elements of participation, such as competitive-level or game-versus-practice situations. Increased risk of injury (relative risk [RR] = 2.45, 95% CI: 1.15, 5.81) has been found in the most elite division of hockey players compared with lower levels.²⁸ Previous research has shown that injury rates per athlete exposure are significantly higher in competitions than in practices (RR = 2.73, 95% CI: 2.58, 2.90).²⁹ Unfortunately, these components of sport exposure were not available in the CCHS, and they may be differently distributed among BMI categories, although it is possible that these unmeasured aspects of sport participation, such as level of competition, were captured during the secondary analysis. Youths in the highest quartile of PA are likely to have greater skill and be playing at a more competitive level, a suggestion that may explain the increased odds of injury in overweight highly active youths compared with the insignificant findings in the main analysis.

Level of engagement may also be an unmeasured factor. Perhaps obese youths who play on a soccer team do not have the skill, confidence, or fitness to engage in aggressive situations. Evidence that obese youths have lower cardiovascular fitness and decreased leg strength means that they may purposefully avoid physically demanding situations and consequently escape injuries during their sporting activities.³⁰ This may explain the protective effect of obesity seen in the current study.

This study provides a unique contribution to the field of sport injury research because the relationship between BMI and sport injury in adolescents has not been examined before in a large national survey with the ability to control for many potentially confounding variables. Using BMI makes this study easier to compare with other studies; however, it was calculated with self-reported data, and participants may have under-reported their weight because of a social desirability bias. It is important to note that this non-differential bias would be in the direction of a null result. The CCHS data enabled us to control for confounding by PA participation, as a proxy for sport exposure, and investigate important interaction effects. However, it may have overestimated sport participation, and it did not capture detailed information on type of sports, a measure that may prove helpful for further research. Recognizing the inherent temporal limitations of a cross-sectional study design, this research aims to stimulate debate on the topic and inform the research field to guide future studies.

CONCLUSIONS

Given the alarming worldwide trends in adolescent body composition, this is timely work. It highlights the complexity of examining sport injury risk factors and contributes to the evidence base by examining the relationship between body composition and sport injury. The main results showed no significant relationship between overweight and sport injury, although a protective effect was seen between obesity and sport injury. Secondary analyses suggested that being overweight is a risk factor in highly active youths. Physiotherapists who treat sport injuries should be aware that the relationship between BMI and sport injury requires further investigation. Future research should continue to consider body composition as a sport-specific injury risk factor to comprehensively evaluate the finer nuances of sport-specific participation.

KEY MESSAGES

What is already known on this topic

Sport is the leading cause of injury requiring medical attention in Canadian adolescents, but evidence of the association between being overweight or obese and sport injury in this age group has been inconclusive. As primary health care practitioners working with injured youths, physiotherapists should be educated about injury risk factors.

What this study adds

This study is the first to examine the association between BMI and sport injury in adolescents using a large national survey that controlled for many potentially confounding variables. It highlights the complexity of this association, particularly that body composition may

affect sport injury risk differently in active overweight and obese youths. For example, among highly active youths, those who are overweight may be a sub-group at increased risk of sport injury; however, those who are obese may be protected from sport injury. In the future, physiotherapists may have a role to play in developing targeted interventions for high-risk sub-groups to reduce the overall burden of sport injuries on public health.

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