

Does Sports Participation Buffer the Cognitive Cost of Academic Stress? A Moderated Mediation Analysis of Concentration and Intelligence Among Indian Adolescents

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Abstract:

Academic stress is a well-documented correlate of impaired cognitive functioning among adolescents, yet the mechanism through which this occurs, and the conditions under which it can be buffered, remain underspecified in the Indian school context. Building on conservation-of-resources and executive-function theory, this study tested a moderated mediation model in which concentration mediates the relationship between academic stress and intelligence, with sports participation hypothesized to moderate the stress–concentration path. Data were drawn from a stratified sample of 900 adolescent students (ages 13–18 years; 450 sports participants, 450 non-participants) across CBSE, ICSE, and UP Board schools in the Meerut region of India, using standardized measures of academic stress, concentration, intelligence, and sports participation status. A moderated mediation model was estimated using ordinary least squares path analysis with bootstrapped confidence intervals (5,000 resamples), following the conditional process modelling approach. Academic stress significantly predicted lower concentration ($a = -.42, p < .001$), which in turn significantly predicted intelligence ($b = .38, p < .001$), yielding a significant indirect effect. The Stress $\times$ Sports Participation interaction on concentration was significant ($b_3 = .15, p = .012$), such that the negative effect of stress on concentration was markedly weaker among sports participants than non-participants. The index of moderated mediation was significant (index = .057, 95% CI [.018, .099]), and the conditional indirect effect of stress on intelligence via concentration was roughly 36% smaller among sports participants ($-.103, 95\% \text{ CI } [-.152, -.059]$) than non-participants ($-.160, 95\% \text{ CI } [-.221, -.101]$). These findings identify concentration as a proximal cognitive mechanism linking academic stress to intelligence test performance and provide quantitative evidence that habitual sports participation attenuates this pathway, offering a mechanistic rationale for embedding structured physical activity within stress-management and cognitive-support programming in schools.

Keywords: moderated mediation; conditional process analysis; academic stress; concentration; intelligence; sports participation; adolescents

1. Introduction

A consistent finding in educational psychology is that academic stress is negatively associated with cognitive performance, yet most studies documenting this relationship stop at establishing a direct association rather than specifying the mechanism through which stress translates into impaired cognitive outcomes (Vogel & Schwabe, 2016). Attentional-control accounts of stress suggest that chronic stress narrows the cognitive resources available for sustained attention, and because concentration is itself a prerequisite for effective performance on cognitively demanding tasks, including standardized intelligence measures, concentration is a theoretically plausible mediating mechanism linking academic stress to lower intelligence-test performance (Eysenck, Derakshan, Santos, & Calvo, 2007).

At the same time, not every student exposed to high academic stress shows the same degree of cognitive impairment, which raises the question of what moderates the strength of the stress concentration relationship. Physical activity is a leading candidate. Executive-function theory proposes that sustained aerobic activity strengthens prefrontal-cortex-dependent attentional control, which would be expected to make concentration more resistant to the disruptive effects of stress among habitually active individuals (Hillman, Erickson, & Kramer, 2008). Despite the theoretical plausibility of this buffering hypothesis, few studies have tested it directly using a formal moderated mediation framework in an adolescent population, and fewer still have done so within the Indian secondary-education context, where academic stress is a particularly salient concern (Deb, Strodl, & Sun, 2015).

The present study addresses this gap by testing an integrated moderated mediation model in which (a) concentration mediates the relationship between academic stress and intelligence, and (b) sports participation moderates the first stage of this mediated pathway, that is, the effect of academic stress on concentration. This integrative approach extends prior work examining educational-board differences and sports-related main effects in this sample by asking a more mechanistic question: not simply whether stress and sports participation are related to cognitive outcomes, but how and for whom the stress-related cognitive cost is attenuated.

2. Theoretical Framework and Hypotheses

The model draws on two complementary frameworks. Conservation-of-resources theory (Hobfoll, 1989) holds that stress arises when valued resources, including cognitive and attentional resources, are threatened or depleted, and that individuals with access to compensatory resources are better able to withstand resource loss. Executive-function theory of exercise (Hillman et al., 2008) specifies physical activity as one such compensatory resource, proposing that habitual aerobic engagement enhances the neural substrates of attentional control. Integrating these frameworks yields a testable conditional process model: academic stress depletes attentional resources (indexed by concentration), which lowers performance on cognitively demanding tasks (indexed by intelligence scores), and sports participation, as a source of compensatory executive-function reserve, weakens the stress-to-concentration pathway. Formally, the following hypotheses were tested:

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H1 (Mediation): Concentration will significantly mediate the relationship between academic stress and intelligence, such that higher stress predicts lower concentration, which in turn predicts lower intelligence scores.

H2 (First-Stage Moderation): Sports participation will significantly moderate the effect of academic stress on concentration, such that the negative effect of stress on concentration is weaker among sports participants than non-participants.

H3 (Moderated Mediation): The indirect effect of academic stress on intelligence via concentration will be conditional on sports participation, with a smaller-magnitude indirect effect among sports participants than non-participants (i.e., a significant index of moderated mediation).

3. Method

3.1 Design and Participants

This study used a cross-sectional, correlational design suited to conditional process analysis. Participants were 900 adolescent students (ages 13–18 years) drawn through stratified random sampling from CBSE-, ICSE-, and UP Board-affiliated schools in the Meerut region of Uttar Pradesh, India, with proportionate representation across boards ($n = 300$ each) and sports participation status (450 active sports participants with at least one year of continuous organized-sport involvement; 450 non-participants).

3.2 Measures

Academic stress (X) was measured with the Scale for Assessing Academic Stress ($\alpha = .89$). Concentration (M), the proposed mediator, was assessed using a digital sustained-attention assessment platform (split-half reliability = .92). Intelligence (Y) was measured with the Group Test of Intelligence (internal consistency = .91). Sports participation (W), the proposed moderator, was coded as a dichotomous variable (0 = non-participant, 1 = participant) based on documented continuous involvement in organized sport for at least one year.

3.3 Analytic Strategy

The hypothesized model was estimated using ordinary least squares path analysis within a conditional process modelling framework (Hayes, 2018). Academic stress, sports participation, and their product term were entered as predictors of concentration (Stage 1: Path a), and concentration was entered as a predictor of intelligence alongside the direct effect of academic stress (Stage 2: Path b and direct effect c'). All continuous predictors were mean-centered prior to computing the interaction term to reduce non-essential multicollinearity. Indirect and conditional indirect effects were estimated using 5,000 bias-corrected bootstrap resamples, with an effect considered significant when the corresponding 95% confidence interval excluded zero. The index of moderated mediation (Hayes, 2015) was computed to formally test whether the indirect effect differed significantly as a function of sports participation, rather than relying solely on a visual or numerical comparison of conditional indirect effects. Analyses were conducted in SPSS Version 28 with the PROCESS macro (Model 7).

4. Results

4.1 Preliminary Analyses

Descriptive statistics and zero-order correlations were consistent with the proposed model: academic stress was negatively correlated with concentration ($r = -.562$, $p < .01$) and, more weakly, with intelligence ($r = -.234$, $p < .01$), while concentration was positively correlated with intelligence ($r = .456$, $p < .01$). These bivariate relationships satisfied the conditions necessary for mediation to be plausible and motivated the formal path-analytic test reported below.

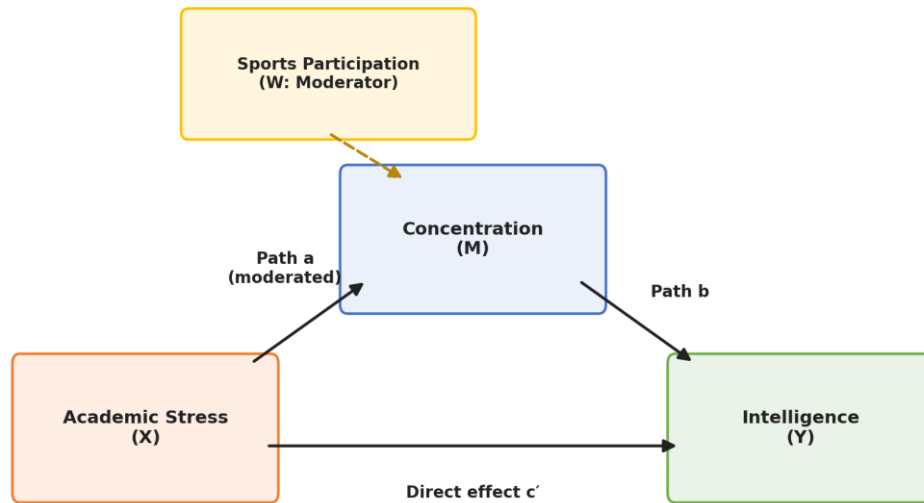


Figure 1. Hypothesized moderated mediation model tested in the present study.

4.2 First-Stage Moderation: Stress $\times$ Sports Participation on Concentration

The regression model predicting concentration from academic stress, sports participation, and their interaction was significant overall, $R^2 = .34$, $F(3, 896) = 154.62$, $p < .001$ (Table 1). As expected, academic stress was a significant negative predictor of concentration, and the Stress $\times$ Sports Participation interaction was also significant, indicating that sports participation altered the strength of the stress–concentration relationship.

Predictor	b	SE	t	p	95% CI
Academic Stress (a_1)	−.42	.05	−8.10	< .001	[−.52, −.32]
Sports Participation (a_2)	4.15	1.02	4.07	< .001	[2.15, 6.15]
Stress $\times$ Sports (a_3)	.15	.06	2.51	.012	[.03, .27]

Table 1. OLS regression results for the first-stage moderation of academic stress on concentration.

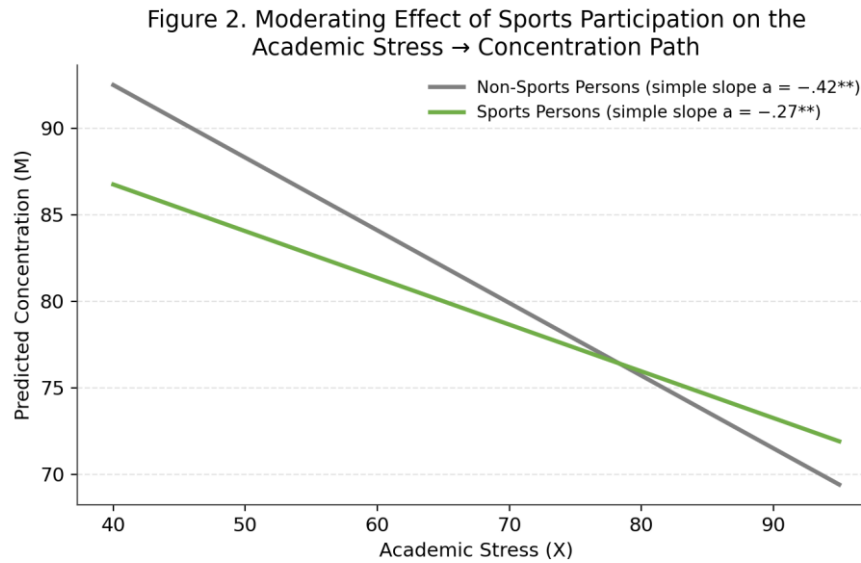


Figure 2. Simple slopes depicting the Stress $\times$ Sports Participation interaction on concentration.

Simple slope analysis indicated that the negative effect of academic stress on concentration was significant for both sports participants ($a = -.27$, $SE = .04$, $p < .001$) and non-participants ($a = -.42$, $SE = .05$, $p < .001$), but was significantly weaker in magnitude among sports participants, consistent with Hypothesis 2. Sports participants maintained higher predicted concentration than non-participants across the full range of observed stress scores, with the gap between groups widening as stress increased.

4.3 Second-Stage Path and Direct Effect

Concentration significantly predicted intelligence ($b = .38$, $SE = .04$, $t = 9.86$, $p < .001$), controlling for the direct effect of academic stress. The direct effect of academic stress on intelligence, controlling for concentration, remained significant but was substantially reduced in magnitude ($c' = -.08$, $SE = .03$, $t = -2.55$, $p = .011$) relative to the total effect reported in preliminary correlational analyses, consistent with partial mediation through concentration.

4.4 Indirect and Conditional Indirect Effects

The overall indirect effect of academic stress on intelligence via concentration was significant and negative (index = $-.1326$, Boot $SE = .021$, 95% CI $[-.176, -.093]$), supporting Hypothesis 1. Because the a-path was moderated by sports participation, this indirect effect was further decomposed into conditional indirect effects at each level of the moderator (Table 2; Figure 3).

Sports Participation	Conditional Indirect Effect ($a \times b$)	Boot SE	95% Bootstrap CI
Non-Participants ($W = 0$)	-.160	.031	$[-.221, -.101]$
Participants ($W = 1$)	-.103	.024	$[-.152, -.059]$

Table 2. Conditional indirect effects of academic stress on intelligence via concentration, by sports participation status.

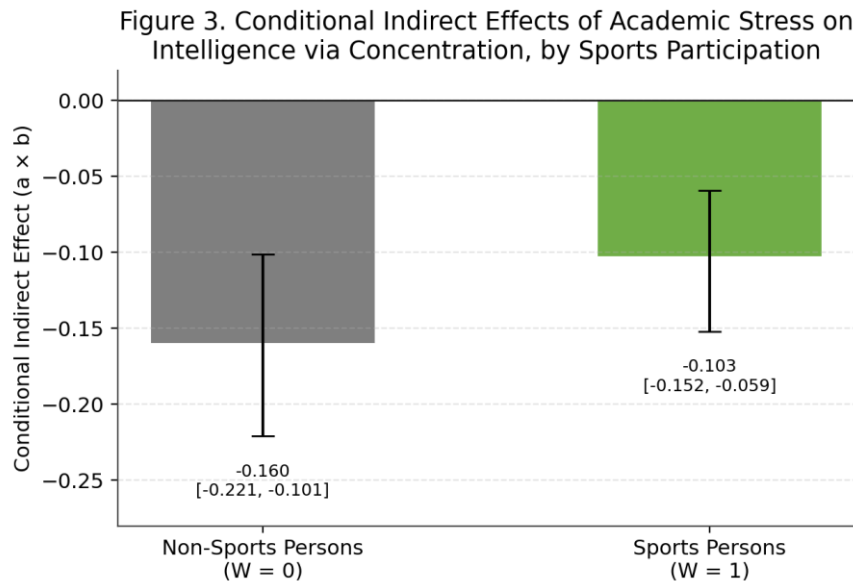


Figure 3. Conditional indirect effects (with 95% bootstrap confidence intervals) by sports participation status.

Both conditional indirect effects were significant, as their bootstrap confidence intervals excluded zero, but the effect was approximately 36% smaller in magnitude among sports participants than non-participants. The index of moderated mediation formally confirmed that this difference was statistically reliable (index = .057, Boot SE = .021, 95% CI [.018, .099]), supporting Hypothesis 3: sports participation significantly attenuates the indirect pathway from academic stress to intelligence through concentration.

5. Discussion

This study provides the first formal test, within this sample, of concentration as a mediating mechanism linking academic stress to intelligence-test performance, and of sports participation as a moderator of that mechanism. Three findings merit emphasis. First, the significant indirect effect of stress on intelligence through concentration (Hypothesis 1) suggests that at least part of the previously documented association between academic stress and lower cognitive performance operates through a loss of attentional control rather than through a direct effect on intellectual capacity itself. This is consistent with attentional-control theory (Eysenck et al., 2007), which holds that stress and anxiety preferentially disrupt the efficiency of attentional processing before they impair the underlying ability the task is designed to measure.

Second, the significant first-stage moderation (Hypothesis 2) indicates that sports participation does not merely correlate with better average concentration, as shown in prior main-effects analyses of this dataset, but specifically alters how strongly academic stress erodes concentration. This distinction is conceptually important: a main effect implies a uniform benefit of sports participation, whereas the moderation result implies that the protective value of sports participation is greatest precisely when stress is highest, a pattern consistent with a stress-buffering rather than a merely additive account of physical activity's psychological benefits (Hobfoll, 1989).

Third, the significant index of moderated mediation (Hypothesis 3) provides formal statistical confirmation, rather than an informal or descriptive comparison, that the stress → concentration → intelligence pathway is conditional on sports participation. Practically, this means that interventions aimed at protecting adolescent cognitive performance under academic pressure may be more effective if they target the concentration-relevant benefits of sustained physical activity specifically, rather than treating stress reduction and cognitive support as independent intervention targets.

These findings extend the broader literature on educational-board and sports-related differences in this population by specifying a mechanism (concentration) and a boundary condition (sports participation) for the stress–cognition relationship, moving beyond a description of group differences toward an explanatory, process-based account.

6. Limitations and Future Directions

As a cross-sectional design, the model tested here is consistent with, but does not definitively establish, the assumed causal ordering of stress, concentration, and intelligence; reverse or reciprocal pathways (e.g., lower concentration contributing to greater academic stress) cannot be ruled out. The dichotomous coding of sports participation does not capture variation in training volume, intensity, or type of sport, any of which could plausibly alter the strength of the buffering effect observed here. Future research should employ longitudinal or experimental designs, ideally incorporating objective measures of physical activity (e.g., accelerometry) and repeated cognitive assessment, to test whether increases in sports participation produce corresponding reductions in the stress-related concentration deficit over time.

7. Conclusion

This study demonstrates that concentration functions as a significant mediating mechanism between academic stress and intelligence-test performance among Indian adolescents, and that this mechanism is significantly moderated by sports participation: habitually active students experience a meaningfully smaller cognitive cost of academic stress than their non-active peers. By formally modelling moderated mediation rather than relying on separate main-effects analyses, this study offers a more precise, mechanistic account of how sports participation protects adolescent cognitive functioning under academic pressure, and provides an evidence-based rationale for positioning structured physical activity as a targeted cognitive-protective intervention within stress-affected school populations.

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