



Gender diversity and daily steps: Findings from the Adolescent Brain Cognitive Development Study

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ABSTRACT

Purpose: To examine the association between multiple dimensions of gender diversity and physical activity (daily steps) in a diverse national sample of early adolescents in the United States.

Methods: This study analyzed Year 2 data from the Adolescent Brain Cognitive Development (ABCD) Study ($N = 6038$, $M_{age} = 12.0$ years). Linear regression models were used to estimate the associations of gender diversity across multiple measures (transgender identity, felt gender, gender expression, gender non-contentedness) with daily step count measured by wrist-worn Fitbit devices.

Results: In this sample of early adolescents, 49.7 % were assigned female at birth, 39.4 % were from racial/ethnic minority groups, and 1 % to 16.9 % identified as gender diverse, depending on the measure used. Transgender identity was associated with 1394 (95 % confidence interval 284–2504) fewer steps per day compared to cisgender identity after adjusting for all covariates. Greater gender diversity, as measured by felt gender and gender non-contentedness, was also associated with lower daily steps.

Conclusions: Transgender and gender-diverse adolescents engage in less physical activity than their cisgender peers. This research has important implications for public health and policies focused on supporting physical activity among transgender and gender-diverse early adolescents.

Introduction

Biological sex and sociodemographic factors such as race/ethnicity, household income, and parental marital status have shown to be important factors relevant to physical activity participation and level of engagement among adolescents [1]. We previously found that sexual

minority (e.g., lesbian, gay, bisexual) early adolescents ages 10–14 years had significantly fewer accumulated daily steps than their heterosexual peers [2]. However, similar research among transgender and gender-diverse individuals in early adolescence has not yet been conducted. Furthermore, the existing literature tends to use binary measures of gender (e.g., girl or boy) that may not fully capture adolescents'

Abbreviations: ABCD, Adolescent Brain Cognitive Development; IRB, Institutional Review Board; KSADS-5, Kiddie Schedule for Affective Disorders and Schizophrenia; UCSD, University of California San Diego; SCFG, Sex congruent felt gender.

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complex experiences with gender. As such, a comprehensive assessment of gender diversity is needed to examine if gender identity is an additional sociodemographic factor that influences early adolescent physical activity.

Previous literature has shown that LGBTQ+ older adolescents and college students participate in fewer sports and physical activities than their cisgender peers [3–5]. Lightner et al. (2024) found that compared to transgender students, cisgender students were twice as likely to participate in sports and engaged in one more full day of physical activity per week, on average [6]. Another study found that LGBTQ+ college students engaged in 17 % less aerobic physical activity and 42 % less resistance training than their counterparts [7]. However, this study combined sexual orientation and gender identity in their analysis due to the low numbers of LGBTQ+ participants, an issue often encountered when studying this marginalized population. Possible reasons for these disparities between transgender and gender-diverse and cisgender individuals are stigma, transphobic discrimination, and structural barriers to access [8].

Prior studies examining transgender and gender-diverse individuals and physical activity include older adolescents and young adult populations [7,9], leaving early adolescents (defined as 10–15 years) a relatively understudied population subgroup [10]. In addition, these prior studies have almost exclusively assessed physical activity via self-report methods, which are prone to information and prevarication biases. Further, these surveys may not have queried physical activity types that are most relevant to transgender and gender-diverse early adolescents, resulting in incomplete assessment. These limitations can be addressed using device-based measures that quantify accumulated physical activity (e.g., daily steps) across extended wear periods in naturalistic settings.

To address these research gaps, the current study leveraged the Adolescent Brain Cognitive Development (ABCD) Study with comprehensive gender diversity and device-based physical activity measures to estimate the association of gender diversity with daily physical activity among early adolescents across the United States (U.S.). We hypothesized that adolescents experiencing greater gender diversity would have fewer daily steps than their cisgender (non-transgender) counterparts.

Methods

Study Population

Since 2016–2018, the ABCD longitudinal cohort study has followed 11,875 adolescents (baseline 2016–2018, ages 9–10 years) across 21 U.S.-based research sites. Adolescents provided assent along with their caregivers' consent for participation. The University of California, San Diego (UCSD) institutional review board (IRB) provided approval for the study, with each participating study site also obtaining approval through their local IRB. Further study and recruitment details have been outlined previously [11].

Year 2 data (2018–2020, mostly ages 11–12 years) from the ABCD 5.1 data release was utilized as this was the most recent year with Fitbit and gender data. Adolescents without gender diversity or Fitbit data at Year 2 ($n = 5835$) were excluded, along with those without ABCD study sampling weight information ($n = 2$), leaving 6038 eligible individuals included in the final analysis (see [Appendix](#)).

Independent variables

Gender diversity

Responses to Year 2 gender identity questions from the core ABCD study were used to create multiple gender diversity measures for this study. All measures were coded in the order of increasing gender diversity or non-conformity.

Transgender identity was a categorical measure based on the Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-5)

background item asked of all participating adolescents at baseline (“Are you transgender?”) [12]. Responses of “Yes,” “Maybe,” and “No” were directly translated to the three categories used for this measure, while “I do not understand” and “Refuse to answer” were coded as missing.

Felt gender was created both as a categorical measure (felt gender groups) based on definitions provided by Potter et al., 2021 (Cisgender, 1-STEP, 2-STEP, Minority gender) [13] and as an ordinal measure (felt gender), with higher scores indicating greater incongruence between the adolescent's felt gender identity and their sex assigned at birth. To create the ordinal measure, we averaged the reverse-coded responses to the questions “How much do you feel like a boy?” and “How much do you feel like a girl?” such that responses ranged from 1 (“Totally”) to 5 (“Not at all”) for the question referring to the adolescent's sex assigned at birth and the opposite (1 = “Not at all” to 5 = “Totally”) for the other question.

Gender non-contentedness, an ordinal measure representing the degree of satisfaction the adolescent felt with their assigned sex at birth, was created by reverse-coding the adolescent's Likert-scale responses to the question “How much have you had the wish to be a <opposite sex>?” such that the re-coded responses ranged from 1 (“Never”) to 5 (“Always”).

Gender expression was an ordinal measure of the adolescent's expression of gender norms. This measure used the reverse-coded Likert-scale responses to the question, “How much have you dressed or acted as a <opposite sex> during play?” such that the final responses ranged from 1 (“Never”) to 5 (“Always”).

Dependent variable

Physical activity

We utilized the steps per day measure from Year 2 Fitbit data collected using Fitbit Charge 2 devices (Fitbit Inc., San Francisco, CA) as a reliable estimate of accumulated adolescent physical activity [14,15]. Data were collected over a 3-week (21-day) period from November 2018 to November 2020 and were extracted, filtered, and processed following best practices established by the ABCD study [14,15]. We included all days with > 599 min of wear time per day and at least 1000 steps per day to compute the average daily step estimate used in analyses [16–18].

Covariates

Eight covariates were included in our analysis as potential confounders, with parental baseline survey responses utilized to determine adolescents' age at Year 2, sex assigned at birth (male or female), race and ethnicity (categorized as Asian, Black, Latino, Native American, Other, and White), parental education level (coded as “high school or less” and “more than high school”), and household income level (coded as six categories ranging from an annual income of less than \$25,000 to more than \$200,000). Data collection period (before, before and during, and during the COVID-19 pandemic) [19] and season (spring, summer, winter, and fall) were included to reduce variance by accounting for pandemic and seasonal effects on physical activity. Previous research has demonstrated the effect of regional factors on study outcomes [20]. As these factors may also affect physical activity and gender expression, our analysis also adjusts for study site location. All categorical covariates were dummy-coded for regression.

Statistical analysis

All statistical analyses were performed using R version 4.4.1 and incorporated the ABCD study propensity weights based on the American Community Survey from the U.S. Census to improve the generalizability of study results [21]. Regression using survey-weighted generalized linear models (*survey* package version 4.4–2) [22] assessed the associations between the five gender diversity measures and daily step counts (continuous outcome) while adjusting for the previously mentioned

covariates, with Model 2 adjusting for all but race/ethnicity and Model 3 adjusting for all eight covariates.

Results

Overall, 50.3 % of the adolescents ($M_{age}=12.0$, $SD_{age}=0.69$) were assigned male at birth, 39.4 % were racial or ethnic minorities, 1.0 % identified as transgender or maybe transgender, and 16.9 % were non-cisgender/sex-congruent based on the felt gender categorization (Table 1). The average daily step count for the study population was 9188.

Table 2 shows unadjusted and adjusted associations between gender diversity variables and average daily steps. In general, greater gender diversity across multiple measures was associated with fewer steps per day. Except for the 2-STEP felt gender category, greater levels of gender diversity within both categorical gender measures were associated with larger decreases in daily steps (e.g., “Yes” transgender responses were associated with fewer daily steps than “Maybe” responses, which were associated with fewer steps than “No” responses); this pattern was seen in all three models. Likewise, greater gender diversity within the felt gender (mean score) and gender non-contentedness measures were also significantly associated with fewer daily steps, with $p < 0.001$ for these measures in all models. All associations between gender diversity variables and daily steps were maintained in adjusted models, except for the significant association between gender expression and daily steps, which was only seen in the unadjusted model.

Discussion

In this diverse national sample of 6038 adolescents ages 11–12 years, the principal findings of this study support the role of gender identity as another key sociodemographic variable to consider when examining physical activity levels among early adolescents. Specifically, adolescents identifying as transgender took 1394 fewer daily steps than their cisgender peers. As prior research has identified 12,000 daily steps as a lower threshold of satisfying the 60 min of moderate-to-vigorous intensity physical activity recommended for adolescents [23], this difference approximates 12 % of the daily physical activity recommended for their age group. Furthermore, when compared to cisgender participants, those with greater incongruence between felt gender identity and sex assigned at birth also had lower daily steps, a finding that was robust when operationalizing felt gender as an ordinal measure. Finally, every one-increment increase in gender non-contentedness was associated with lower daily steps. These findings, within the context of prior research, are described below.

Our finding of a lower average daily step count among those identifying as transgender is consistent with those of previous studies such as Kaja & McGuire (2024) and Frederick et al. (2022) [7,9]. However, these prior studies assessed the physical activity of high school and college-age transgender students, who are at different developmental stages from our study’s cohort of early adolescents. Our findings build on these previous studies by showing that physical activity disparities by gender diversity are evident even earlier in the lifespan, among early adolescents 11–12 years old. For transgender adolescents, physical activity may be replaced with more time spent online, where they might find more accepting and supportive environments [24]. Furthermore, transgender adolescents may be discouraged from participating in team sports or physical activity due to bullying, school/district- or state-level policies, and political tension [9,25]. Gender minority stress at the interpersonal and structural levels has noted effects on the mental health of LGBT adolescents [26,27]. Transphobic school environments may worsen gender dysphoria and leave adolescents more vulnerable to harassment from peers and parents alike [25]. With sports, changing rooms, and some physical education classes being segregated by gender from a young age, transgender and gender-diverse adolescents may not be able to participate with the group most aligned with their gender or

Table 1
Sociodemographic, gender diversity, and physical activity characteristics of Adolescent Brain Cognitive Development (ABCD) study participants at Year 2 (N = 6038).

Sociodemographic characteristics	Mean (SD) / %*
Age at Year 2 (years)	11.98 (0.69)
Sex (%)	
Male	50.3 %
Female	49.7 %
Race/ethnicity (%)	
Asian	5.1 %
Black	12.2 %
Latino	17.6 %
Native American	3.2 %
White	60.6 %
Other	1.3 %
Household income (%)	
Less than \$25,000	13.0 %
\$25,000 to <\$50,000	20.1 %
\$50,000 to <\$75,000	18.5 %
\$75,000 to <\$100,000	15.3 %
\$100,000 to <\$200,000	25.2 %
\$200,000 or higher	7.8 %
Parents’ highest education (%)	
More than high school	86.0 %
High school or less	14.0 %
Data collection period (%)	
Before COVID–19 pandemic†	93.9 %
Before and during COVID–19 pandemic‡	3.0 %
During COVID–19 pandemic§	3.0 %
Season (%)	
Spring	20.0 %
Summer	24.5 %
Fall	23.5 %
Winter	32.0 %
Gender Diversity Measure	
Are you transgender? (categories)¶	
No	99.0 %
Maybe	0.7 %
Yes	0.3 %
Felt gender group (categories)¶	
Cisgender/SCFG	83.1 %
1-STEP	8.2 %
2-STEP	4.1 %
Minority group	4.6 %
Felt gender (mean [SD])¶	1.17 (0.49)
Gender non-contentedness (median [min, max])¶	1 (1, 5)
Gender expression (median [min, max])¶	1 (1, 5)
Total step count, mean (SD), steps/d	9188 (3182)

* ABCD Study sample weights were applied based on the American Community Survey from the US Census

† All physical activity data collected before March 13, 2020

‡ Physical activity data collection started before March 13, 2020 but ended on or after March 13, 2020

§ All physical activity data collected on or after March 13, 2020

¶ Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-5)

¶ From Potter et al., 2021; Categories represent increasing gender diverse identities based on questions of adolescents’ felt gender. In increasing order, categories are cisgender, 1-STEP, 2-STEP, and minority group. SCFG = sex congruent felt gender (e.g., female feels ‘totally’ like a girl and ‘not at all’ like a boy). 1-STEP = sex-congruent on one item and the response option 1-step away from the anchor on the other item (e.g., female feels ‘totally’ like a girl and ‘a little’ like a boy; or ‘mostly’ like a girl and ‘not at all’ like a boy). 2-STEP = 1-step from the sex-congruent anchor on both felt-gender items (e.g., female feels ‘mostly’ like a girl and ‘a little’ like a boy). All other responses comprised the minority felt-gender group.

Scored from 1 (gender conforming) to 5 (gender diverse)

may be excluded from participation entirely [25]. With 62.6 % of children ages 6 to 12 years participating in some sport in 2022, banning transgender adolescents from playing may have serious effects on their social, physical, and psychological development [28]. Some recommendations for making athletics inclusive include allowing transgender students to use the locker rooms, showers, and restrooms where they feel

Table 2

Unadjusted and adjusted associations between gender diversity and physical activity in the Adolescent Brain Cognitive Development Study.

Linear Regression	Model 1: Unadjusted		Model 2: Adjusted Except Race*		Model 3: Fully Adjusted [†]	
	B (95 % CI)	p	B (95 % CI)	p	B (95 % CI)	p
Gender Diversity Measure						
Are you transgender? (categories) [‡]						
No	[reference]	—	[reference]	—	[reference]	—
Maybe	−1910 (−2969, −852)	p < 0.001	−1296 (−2229, −364)	0.006	−1304 (−2242, −365)	0.006
Yes	−1771 (−2939, −602)	0.003	−1416 (−2523, −310)	0.012	−1394 (−2504, −284)	0.014
Felt gender group (categories) [§]						
Cisgender/SCFG	[reference]	—	[reference]	—	[reference]	—
1-STEP	−1011 (−1318, −703)	p < 0.001	−650 (−945, −354)	p < 0.001	−658 (−953, −363)	p < 0.001
2-STEP	−1135 (−1572, −699)	p < 0.001	−550 (−960, −140)	0.009	−552 (−962, −143)	0.008
Minority group	−1408 (−1807, −1009)	p < 0.001	−698 (−1079, −316)	p < 0.001	−722 (−1105, −339)	p < 0.001
Felt gender (mean score)	−765 (−953, −577)	p < 0.001	−402 (−576, −228)	p < 0.001	−411 (−585, −237)	p < 0.001
Gender non-contentedness	−596 (−771, −422)	p < 0.001	−371 (−537, −206)	p < 0.001	−375 (−540, −211)	p < 0.001
Gender expression	−244 (−370, −119)	p < 0.001	−10 (−134, 113)	0.868	−14 (−138, 110)	0.827

ABCD Study sample weights were applied based on the American Community Survey from the US Census; bold indicates $p < 0.05$

* Adjusted for age, sex at birth, household income, parental education, data collection period, season, and research site location

† Adjusted for age, sex at birth, race/ethnicity, household income, parental education, data collection period, season, and research site location

‡ Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-5)

§ From Potter et al., 2021; Categories represent increasing gender diverse identities based on questions of adolescents' felt gender. In increasing order, categories are cisgender, 1-STEP, 2-STEP, and minority group. SCFG = sex congruent felt gender (e.g., female feels 'totally' like a girl and 'not at all' like a boy). 1-STEP = sex-congruent on one item and the response option 1-step away from the anchor on the other item (e.g., female feels 'totally' like a girl and 'a little' like a boy; or 'mostly' like a girl and 'not at all' like a boy). 2-STEP = 1-step from the sex-congruent anchor on both felt-gender items (e.g., female feels 'mostly' like a girl and 'a little' like a boy). All other responses comprised the minority felt-gender group.

|| Scores rated on a scale from 1 (most gender conforming) to 5 (most gender diverse)

the safest, offering more private changing areas, promptly updating students' names on team rosters, and making sure that all individuals involved in that sport (i.e., coaches, referees, and announcers) are informed of changes in students' names or pronouns [29]. While many studies have assessed the effects of social exclusion and transphobia on mental health of transgender adolescents, relatively few have looked at the impacts on physical health, which this study provides.

Strengths of this study include its use of Fitbit data and a large sample of early adolescents. Regarding potential limitations, there is a possibility of reporting, response, or information bias affecting the data given the sensitive nature of this topic and the self-reported format of the study; adolescents may not have answered truthfully or fully understood the questions. If some transgender adolescents are not yet "out" or cisgender adolescents are misclassified as transgender, this would likely bias findings toward the null hypothesis. Furthermore, the cross-sectional study design does not provide the opportunity to establish temporality between gender diversity and physical activity among this early adolescent population and bidirectional relationships may exist. In addition, step-based estimates do not provide time-based estimates of physical activity intensity.

Conclusion

Transgender and gender-diverse early adolescents in this diverse national sample were found to take significantly fewer steps daily compared to cisgender adolescents, as measured by Fitbit. Transgender and gender-diverse adolescents may face a higher risk for subsequent disease due to reduced physical activity. Given the lifetime benefits of physical activity, a concerted effort should be made to promote physical activity, exercise, and sports among transgender and gender-diverse adolescents.

Ethics approval

The University of California, San Diego provided centralized institutional review board (IRB) approval and each participating site received local IRB approval.

CRedit authorship contribution statement

Jason M. Nagata: Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization. **Shirley Sui:** Writing – review & editing, Writing – original draft, Formal analysis. **Angela Kim:** Writing – review & editing. **Iris Yuefan Shao:** Writing – review & editing. **Christopher Otmar:** Writing – review & editing, Writing – original draft, Formal analysis. **Kyle T. Ganson:** Writing – review & editing. **Alexander Testa:** Writing – review & editing. **Erin E. Dooley:** Writing – review & editing. **Holly C. Gooding:** Writing – review & editing. **Fiona C. Baker:** Writing – review & editing, Formal analysis, Data curation. **Kelley Pettee Gabriel:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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report.

Sociodemographic characteristics of adolescents included vs. excluded in the analysis

Sociodemographic characteristics	Excluded* (N = 5837)	Included* (N = 6038)	p-value [†]
Age (years)	12.04 (1.42)	11.98 (0.69)	< 0.001
Sex (%)			0.071
Male	52.1%	50.3%	
Female	47.9%	49.7%	
Race/ethnicity (%)			<0.001
Asian	5.9%	5.1%	
Black	22.6%	12.2%	
Latino	22.7%	17.6%	
Native American	3.1%	3.2%	
White	44.0%	60.6%	
Other	1.6%	1.3%	
Household income (%)			<0.001
Less than \$25,000	25.6%	13.0%	
\$25,000 to <\$50,000	20.8%	20.1%	
\$50,000 to <\$75,000	16.2%	18.5%	
\$75,000 to <\$100,000	11.0%	15.3%	
\$100,000 to <\$200,000	19.5%	25.2%	
\$200,000 or higher	6.9%	7.8%	
Parents' highest education (%)			<0.001
More than high school	73.5%	86.0%	
High school or less	26.5%	14.0%	

Adolescent Brain Cognitive Development Study sample weights were applied based on the American Community Survey from the US Census

* Mean (SD) or %

[†] Wilcoxon rank-sum test for complex survey samples; chi-squared test with Rao & Scott's second-order correction

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