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SSM - Mental Health 8 (2025) 100535

Contents lists available at ScienceDirect

SSM - Mental Health

journal homepage: www.journals.elsevier.com/ssm-mental-health

Ethnic inequalities in adolescent mental wellbeing: An interaction analysis of social identity markers, risk and protective factors

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ARTICLE INFO

Handling Editor: Dr A C Tsai

1. Introduction

Inequalities are systematic, preventable and unfair disparities in outcomes between different populations or groups (McCartney et al., 2019). This paper focuses on ethnic inequalities in adolescent mental wellbeing, defined as feeling good (hedonia) and functioning well (eudaimonia) (Ryff et al., 2021). Wellbeing is a critical indicator in population health research (Thapar et al., 2021), given its predictive utility (in terms of future adult physical health, labour market/-socioeconomic, and relational outcomes) (Goodman et al., 2015), the fact that most adolescents do not meet diagnostic criteria for mental disorder (Newlove-Delgado et al., 2022), and the longstanding recognition that health is about more than the mere absence of illness (Schramme, 2023). Garnering an improved understanding of inequalities in adolescent mental wellbeing and the factors that may explain these is therefore a key research and public health priority.

Our focus on ethnic inequalities specifically is motivated by an apparent paradox. In the United Kingdom (UK), children and young people from minoritised ethnic groups[1] are significantly more likely than their White British peers to be exposed to established risk factors such as interpersonal racial discrimination and socio-economic disadvantage, which are fundamentally driven by entrenched structural and institutional racism (Nazroo et al., 2020). However, research routinely finds that they experience equivalent or in some cases better mental health outcomes (Ahmad et al., 2021). An early systematic review (Goodman et al., 2008) found consistent evidence of better mental health outcomes among Black African and Indian children and adolescents than their White British peers, but no (or mixed) evidence of disparities for other minoritised ethnic groups. With one notable exception (Bains and Gutman, 2021), recent work has replicated these effects (Ahmad et al., 2021; Jun et al., 2020; Patalay and Fitzsimons, 2016; Deighton et al., 2019; Marcheselli et al., 2018). This trend is also seen internationally, including for example the United States (Merikangas et al., 2010) and Norway (Noam et al., 2014). Where there are exceptions, these often relate to *indigenous* minoritised ethnic groups such as Aboriginal and Torres Strait Islander people in Australia (Dray et al., 2016) and Maori people in New Zealand (Sutcliffe et al., 2023).

1.1. Explanatory theoretical perspectives: racism, intersectionality, and resilience

Existing theoretical frameworks propose that structural, interpersonal and institutional racism contribute to ethnic inequalities in mental health and wellbeing (Nazroo et al., 2020; Nazroo, 2003). The interconnected dimensions of racism produce and reinforce inequalities in accessing resources (economic, social, physical), which results in disadvantage for minoritised ethnic groups across a range of socioeconomic indicators, including education, employment, income and housing. In turn, the accumulation of these disadvantages contributes to ethnic inequalities in mental health (Nazroo et al., 2020). Indeed, a

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[1] We use the term 'minoritised ethnic groups' throughout this paper as it acknowledges that individuals have been minoritised via social processes of power and domination rather than them simply belonging to groups who are statistical minorities (Law Society, 2025).

https://doi.org/10.1016/j.ssmmh.2025.100535
Received 8 April 2025; Received in revised form 23 September 2025; Accepted 23 September 2025
Available online 24 September 2025

recent study of adolescent mental health difficulties found substantive differences between unadjusted models and those adjusting for household income (e.g., significantly reduced odds-ratios for probable mental health disorders among Pakistani adolescents compared to their White peers in adjusted, but not unadjusted models) (Ahmad et al., 2021). Interpersonal racial discrimination is also well documented as being adversely associated with adolescent mental health outcomes (Cave et al., 2020; Priest et al., 2013). One study showed that experiences of interpersonal racial discrimination were of greater importance in explaining mental health difficulties than socioeconomic deprivation (Astell-Burt et al., 2012).

However, it is important to note that structures of disadvantage do not operate in isolation. Intersectionality theory proposes that individual experiences are shaped by multiple, intersecting social structures that produce unique exposure to discrimination, privilege and marginalisation (Crenshaw, 1991). Social positions intersect at the individual level (e.g., race, gender, socioeconomic position), yet experiences at those intersections are influenced by systems of oppression, such as racism, sexism, and classism (Bowleg, 2012). For example, the social position of a young Pakistani girl living in a deprived neighbourhood is influenced by racism, sexism and classism, whereas the social position of a White British girl living in the same area may only be influenced by sexism and classism. However, it is important to note that intersectional theory posits a constitutive approach, whereby experiences at an intersection must be considered jointly, rather than considering the additive effects of multiple social identities (Hancock, 2007). Here we focus our analysis on ethnicity, theorising this as a proxy measure of racism, and we explore the statistical interactions with gender and socioeconomic deprivation (happiness with material possessions, free school meal eligibility and Index of Multiple Deprivation) as proxy measures of sexism and classism (Else-Quest and Hyde, 2016). Whilst we are testing interactions across intersections, we do not necessarily hypothesise that the poorest outcomes will be observed amongst those at multiple marginalised intersections, as social identities interact in a synergistic way (Purdie-Vaughns and Eibach, 2008).

Why then might minoritised ethnic groups report equivalent or better mental health than their White British peers during adolescence, when they are demonstrably subjected to systemic disadvantage and discrimination, and may be more vulnerable to exposure to such influences? Here, theoretical perspectives on resilience, defined as positive adaptation in the context of exposure to adversity (Masten, 2014) are useful. In particular, the protective factor model of adolescent resiliency posits that access to assets or resources can moderate or reduce the harmful effects of risk exposure (Fergus and Zimmerman, 2005). In the context of investigating ethnic inequalities, factors such as close family bonds (i.e., strong family structures that engender a sense of support) (Ahmad et al., 2021), high neighbourhood ethnic density (i.e., living in areas with higher proportions of people from the same ethnic group, or more generally, in areas of higher ethnic diversity, can mitigate the deleterious effects of discrimination and other stressors through enhanced social support) (Jun et al., 2020), positive cultural identity (i.e., one's sense of belonging to a particular culture or group as a source of pride) (Ahmad et al., 2021), and religious service attendance (i.e. faith in religion and interaction with faith communities (Chen et al., 2020)) may confer protective effects among minoritised youth. However, it is also important to note that there may be cultural differences in how individuals perceive and report on their mental health and wellbeing (i.e., apparent disparities in outcomes may at least in part be due to variance in measurement) (Ahmad et al., 2021; Goodman et al., 2008), which was also explored in this study.

1.2. The current study

Existing studies have provided useful preliminary insights into the extent of ethnic inequalities in adolescent mental health, and the factors that might explain these. However, research to date has focused almost exclusively on mental health difficulties. We found only one study that examined ethnic disparities in adolescent mental *wellbeing*, reporting significantly better outcomes for Asian young people compared with their White British counterparts (Patalay and Fitzsimons, 2016). Granularity of ethnic classification data is also a concern, with most studies using between five and eight 'major' ethnic categories (Ahmad et al., 2021; Goodman et al., 2008; Bains and Gutman, 2021; Patalay and Fitzsimons, 2016; Deighton et al., 2019; Marcheselli et al., 2018), and one only using two (i.e., White vs other) (Jun et al., 2020). How ethnicity is classified is important as higher level categories (e.g., Black) could mask conflicting or differential outcomes between constituent groups (e.g., Black Caribbean, Black African), thereby impacting substantive findings (Yao et al., 2022). Furthermore, of those studies that aggregate ethnicity, fewer than half provide a justification for doing so (Lam et al., 2023). One common reason is to preserve statistical power (Lam et al., 2023), which speaks to the need for larger samples, so that more granular groupings can be used. An additional concern, possibly also related to statistical power concerns, is the general failure to consider the impact of intersectional systems of oppression, as indicated by social identity markers, e.g., sexism (gender identities) and classism (socioeconomic position, measured through happiness with material possessions, free school meal eligibility and Index of Multiple Deprivation), as well as racism (ethnicity) (Bauer et al., 2021). A recent, notable exception demonstrates the importance of intersectional analysis, finding clear evidence in support of effect modification (Ahmad et al., 2021). We also seek to explore the synergistic or antagonistic effects of interpersonal racism discrimination, bullying, parent/carer support, peer support religious service attendance and neighbourhood own-ethnic density on ethnic differences in wellbeing, as relatively few studies have examined *how* and *why* ethnic differences in outcomes such as mental wellbeing can be explained (Lam et al., 2023).

The current study is designed to address the above-noted concerns. It is driven by the following Research Questions (RQs).

1. Are there ethnic inequalities in mental wellbeing in early-to-mid adolescence?
2. To what extent do intersectional systems of oppression (measured by different social identity markers i.e., gender, socioeconomic position)) and/or exposures (e.g., risk factors, such as discrimination; protective factors, such as parent/carer support) interact with ethnicity to explain mental wellbeing?

2. Method

2.1. Design

We undertook cross-sectional, secondary analysis of the #BeeWell dataset (The, 2025). #BeeWell is a very large UK cohort study focusing on the development and drivers of adolescent wellbeing (see www.beewellprogramme/research for further information). The analysis plan was pre-registered prior to the lead author accessing the data (https://osf.io/xd89k/). The following are deviations from the pre-registered analysis plan: the inclusion of measurement invariance analysis to assess whether individuals from different ethnic groups interpreted the wellbeing items in a conceptually similar way; year of survey completion and area; and RQs 2 and 3 were combined to form RQ2, as these questions had similar aims and methodology (i.e. moderation analysis). To optimise sample size, we used the first annual survey responses from participants in the two current #BeeWell regions (Greater Manchester; and, Hampshire, Isle of Wight, Portsmouth and Southampton) from Year 8, 9 and 10 pupils (aged 12–15) during the period 2021–2023.

2.2. Participants

Following the application of analytical sample inclusion criteria

detailed in the preregistration, an initial sample of N = 84,774 was derived. The sample size for individual models depended on the imputation strategy (see Supplementary Materials A) and is depicted in Fig. 1. Demographic characteristics of the samples for the models are shown in Table 1. For descriptive statistics for categorical and continuous variables for both individual ethnic groups (including missing) and the total sample, see Supplementary Materials B.

2.3. Measures

Measures used in the current study are outlined in Table 2.

2.4. Analytical strategy

Given the potential for cultural differences in how young people perceive and report on their wellbeing (Ahmad et al., 2021; Goodman et al., 2008), our starting point was to assess measurement invariance by ethnicity, following best practice guidance (Panayiotou et al., 2023). This involved: (i) Creating 100 random datasets with balanced groups determined by the size of the smallest granular ethnic group; (ii) Conducting measurement invariance (MI) testing using multi-group models across the 100 datasets following a four-step procedure (baseline, configural, metric, and scalar); and, (iii) Inspecting absolute and comparative fit indices, using the following criteria as model fit indicators: CFI of $\geq$ .95, SRMR $\leq$.08, RMSEA $\leq$.08 (<.10 for baseline and configural model), and CFI difference of .01 to compare fit of nested models. Invariance was assumed if all four models demonstrated good fit with no significant degradation in nested model comparisons. As a robustness check, MI testing was also conducted on the full sample without balanced groups.

To assess disparities in adolescent mental wellbeing between ethnic groups (RQ1), model 1 was a multiple regression model fitted with dummy-coded ethnicity (reference group = White British) as the predictor variable and the continuous transformed SWEMWBS score as the outcome variable. Datapoint (i.e., year and region of survey completion: 2021 GM, 2022 GM, 2023 GM, 2023 HIPS), year group (8, 9 or 10), and gender (cisgender boy, cisgender girl, trans and gender diverse) were included as covariates.

For RQ2, building on model 1, separate multiple regression models were fitted for each of the social identity markers and exposures, with an interaction term included with the specified variables and dummy-coded ethnicity, including the corresponding simple effects. The following interaction terms were included to form models 2a-2i: 2a = gender, 2b = IMD quintile, 2c = FSM eligibility, 2d = happiness with material possessions, 2e = experiences of racial or religious discrimination, 2f = bullying, 2g = parent/carer support, 2h = religious service attendance, 2i = Middle Super Output Area (MSOA)-level own ethnic density. For all models, false discovery rate multiple comparison correction was applied using the p.adjust function (method = 'fdr') in R, and standardised beta coefficients were used to assess the magnitude of the associations, together with 95 % confidence intervals (CIs) for all parameters of interest.

The missing data analysis and imputation strategy is presented in Supplementary Materials A. The approach that we have taken - namely, investigate the scale of missingness (i.e. how much data are missing?); examine the nature of missingness (e.g. is the assumption of MAR supported?) and then, adopt an appropriate method to deal with missingness (in this case, MI) - follows recommended practice in studies with missing data (Runarsdottir and Vilhjalmsson, 2019) and we also note the evidence that our chosen approach (MI) has been shown to be robust under conditions with much higher rates of missing data than that of the current study (Lee et al., 2021). In brief, missing data analysis found that missingness was conditional on other observed variables, making a Missing Completely at Random (MCAR) mechanism unlikely. Data with more than 5 % missing (apart from the outcome variable (SWEMWBS), ethnicity, and MSOA-level own ethnic density) were imputed using the package *mice* in R (pooled estimates derived from 100 imputed datasets).

3. Results

Results of the measurement invariance analyses can be found in Supplementary Materials C. In brief, fit statistics were largely indicative of measurement invariance by ethnicity, indicating that any differences observed across ethnic groups in the analyses reported below appear to be valid and not due to differences in how young people perceive and report on their wellbeing.

1 Are there ethnic inequalities in mental wellbeing in early-to-mid adolescence?

Our analysis for RQ1 is detailed in Table 3 and depicted visually in Fig. 2. We found that compared to the reference group of White British young people, those who identified as Asian Other, Bangladeshi, Black African, Black Other, Indian, Mixed Other, Other Ethnic Group, Pakistani, White Irish, and White Other reported significantly better mental wellbeing. No minoritised ethnic groups reported significantly worse mental wellbeing than White British young people.

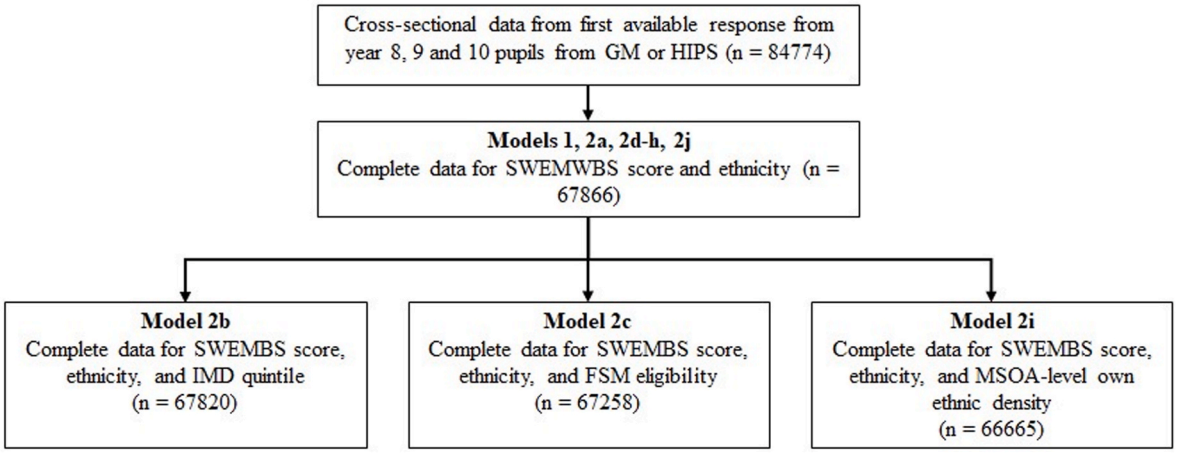

Fig. 1. STROBE Diagram to Show Sample Sizes of the Initial Sample and Subsequent Model Samples
Note. FSM = free school meal; GM = Greater Manchester; HIPS = Hampshire, Isle of Weight, Portsmouth and Southampton; IMD = Indices of Multiple Deprivation; MSOA = Middle Super Output Area; SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

Table 1
Demographic characteristics of the sample (ethnicity, gender, year group and free school meal (FSM) eligibility) for all models.

	Models 1, 2a, 2d-h, 2j (n = 67866)		Model 2b (n = 67820)		Model 2c (n = 67258)		Model 2i (n = 66665)	
Variable	n	%	n	%	n	%	n	%
Ethnicity								
Asian Other	990	1.46	990	1.46	969	1.44	981	1.47
Bangladeshi	1487	2.19	1487	2.19	1480	2.20	1487	2.23
Black African	2414	3.56	2412	3.56	2379	3.54	2405	3.61
Black Caribbean	256	.38	255	.38	254	.38	253	.38
Black Other	537	.79	534	.79	531	.79	533	.80
Chinese	522	.77	521	.77	486	.72	516	.77
Indian	1525	2.25	1524	2.25	1515	2.25	1511	2.27
Mixed Other	1490	2.20	1490	2.20	1481	2.20	1474	2.21
Mixed White & Asian	957	1.41	957	1.41	953	1.42	948	1.42
Mixed White & Black African	576	.85	575	.85	572	.85	572	.86
Mixed White & Black Caribbean	798	1.18	797	1.18	794	1.18	792	1.19
Other Ethnic Group	1290	1.90	1290	1.90	1270	1.89	1288	1.93
Pakistani	5213	7.68	5208	7.68	5102	7.59	5201	7.80
White British	46620	68.69	46591	68.70	46313	68.86	45547	68.32
White Gypsy, Roma or Irish Traveller	114	.17	114	.17	112	.17	111	.17
White Irish	160	.24	160	.24	159	.24	157	.24
White Other	2917	4.30	2915	4.30	2888	4.29	2889	4.33
Gender								
Cisgender Girl	28604	42.15	28595	42.16	28401	42.23	28116	42.18
Cisgender Boy	28592	42.13	28568	42.12	28369	42.18	28056	42.09
Trans and Gender Diverse	4276	6.30	4271	6.30	4227	6.28	4210	6.32
Missing (imputed)	6394	9.42	6386	9.42	6261	9.31	6283	9.42
Year Group								
8	25669	37.82	25652	37.82	25480	37.88	25301	37.95
9	4643	6.84	4639	6.84	4478	6.66	4546	6.82
10	37554	55.34	37529	55.34	37300	55.46	36818	55.23
FSM Eligibility								
No	51046	75.22	51021	75.23	51046	75.90	50058	75.09
Yes	16212	23.89	16195	23.88	16212	24.10	16031	24.05
Missing (not imputed)	608	.90	604	.89	0	0	576	.86

Note. Model 1 = model including ethnicity, datapoint, year group and gender as predictors of SWEMWBS score; for models 2a-i, the following interaction terms were included in the models: 2a = gender, 2b = IMD quintile, 2c = FSM eligibility, 2d = happiness with material possessions, 2e = experiences of racial or religious discrimination, 2f = bullying, 2g = parent/carer support, 2h = religious service attendance, 2i = Middle Super Output Area (MSOA)-level own ethnic density, 2j = peer support.

2 To what extent do intersectional systems of oppression (measured by different social identity markers i.e., gender, socioeconomic position) and/or exposures (e.g., risk factors, such as discrimination; protective factors, such as parent/carer support) interact with ethnicity to explain mental wellbeing?

Regarding gender (model 2a), within the reference group of White British adolescents, cisgender girls reported significantly lower wellbeing (β = -.40, $p < .001$), as did trans and gender diverse adolescents (trans or gender diverse $\beta = -.687$, $p < .001$) compared to cisgender boys. All simple effects are interpreted relative to both the reference gender and the reference ethnicity group; this applies to all subsequent models involving interactions between ethnicity and other variables. There were positive interaction effects with ethnicity for trans and gender diverse Black Caribbean ($\beta = .587$, $p = .027$) and Pakistani ($\beta = .262$, $p < .001$) adolescents in explaining mental wellbeing. These are depicted visually in Fig. 3, and indicate that disparities in mental wellbeing between cisgender boys and trans and gender diverse young people from these minoritised ethnic groups are significantly less pronounced than for their White British counterparts. All other unmentioned interaction effects were not statistically significant. For full regression output, see Supplementary Materials D.

Regarding neighbourhood deprivation (IMD quintile; model 2b), there were positive simple effects observed for most quintiles when compared to the reference of quintile 1, within the reference group of White British young people (quintile 2 $\beta = .031$, $p = .077$; quintile 3 $\beta = .076$, $p < .001$; quintile 4 $\beta = .122$, $p < .001$; quintile 5 $\beta = .152$, $p < .001$). Furthermore, there were negative interaction effects with ethnicity and IMD quintile for Black African (quintile 2 $\beta = -.149$, $p = .043$; quintile 3 $\beta = -.235$, $p = .043$; quintile 4 $\beta = -.311$, $p = .044$; compared to quintile 1) and Mixed Other (quintile 3 $\beta = -.227$, $p = .037$; compared to quintile 1) adolescents in explaining mental wellbeing. These are depicted visually in Fig. 4, and indicate that in contrast to White British young people (for whom there is a clear, positive association between neighbourhood affluence and mental wellbeing), adolescents in these minoritised ethnic groups living in more deprived neighbourhoods actually report better mental wellbeing than their peers living in some of the more affluent neighbourhoods. For full regression output, see Supplementary Materials E.

Regarding familial deprivation (model 2c), within the reference group of White British young people, there was a negative simple effect of FSM eligibility on wellbeing (β = -.168, $p < .001$). To add, there were statistically significant positive interaction effects with ethnicity for FSM eligible young people who were from Black African ($\beta = .135$, $p = .003$), Black Other ($\beta = .316$, $p < .001$), Indian ($\beta = .255$, $p = .003$), Other Ethnic Group ($\beta = .127$, $p = .041$), Pakistani ($\beta = .076$, $p = .038$) or White Other ($\beta = .142$, $p = .007$) backgrounds. These are depicted visually in Fig. 5, and indicate that disparities in mental wellbeing between FSM eligible and non-eligible adolescents from these minoritised ethnic groups are less pronounced than for their White British counterparts (and, indeed, for adolescents from Indian and Black Other backgrounds, those eligible for FSM report *better* mental wellbeing than their non-eligible peers). For full regression output, see Supplementary Materials F.

For happiness with material possessions (model 2d), within the reference group of White British young people, there was a statistically significant positive simple effect ($\beta = .335$, $p < .001$). Futhermore, there was a negative interaction effect with ethnicity for Black Caribbean ($\beta = -.135$, $p = .042$) and a positive effect for Indian ($\beta = .092$, $p = .003$) young people in explaining mental wellbeing. This is depicted in Fig. 6

Table 2
Measures used in the current study.

Variable	Measure	Sample item	Response format/categories	Score range and interpretation
Mental wellbeing	Short Warwick Edinburgh Mental Wellbeing Scale (Stewart-Brown et al., 2009)	I've been feeling useful	None of the time; rarely; some of the time; often; always	Continuous transformed score from 7 to 35 (higher score = better mental wellbeing)
Ethnicity	Administrative data provided by Local Authorities or schools	N/A	National Health Service (NHS) classifications: White British; White Irish; Any other White background; White Gypsy, Roma, or traveller of Irish Heritage; Bangladeshi; Indian; Pakistani; Chinese; Any other Asian background; Black African; Black Caribbean; Any other Black background; White and Asian; White and Black African; White and Black Caribbean; and, Any other mixed background; Any other ethnic background. NB: White Gypsy/Roma and White traveller of Irish Heritage combined to increase group size.	N/A
Gender identity	Administrative data on sex provided by Local Authorities or schools, combined with self-reported gender identity	N/A	Cisgender boy; cisgender girl; trans and gender diverse NB: Determination of the above categories based on congruence between data on sex and self-reported gender identity (Marquez et al., 2023)	N/A
Year group	Administrative data provided by Local Authorities or schools	N/A	8; 9; 10	N/A
Datapoint	Year and region of survey completion	N/A	2021 Greater Manchester (GM); 2022 GM; 2023 GM; 2023 Hampshire, Isle of Wight, Portsmouth and Southampton (HIPS)	N/A
Happiness with material possessions	Good Childhood Index (The Children's Society, 2021)	How happy are you with the things that have (like money and the things that you own)?	0-10 scale, where 0 = "very unhappy" to 10 = "very happy"	0-10, higher score = greater levels of happiness with material possessions
Experiences of racial or religious discrimination	Harvard Measuring Discrimination Resource (Williams, 2016)	How often do people make you feel bad because of your race, skin colour or where you were born? How often do people make you feel bad because of your religion or faith?	Never; hardly ever; occasionally; some of the time; often or always	Binary yes/no: responses of 'never' to both items were coded as 'no' and any other response coded as 'yes'
Bullying victimisation	Understanding Society Youth Questionnaire (Institute for Social and Economic Research, 2021); Health Behaviours in Schools Checklist (Inchley et al., 2018)	How often do you get physically bullied at school? By this we mean getting hit, pushed around, threatened, or having belongings stolen?	Not bullied at all; not much (0–3 times in the last 6 months); quite a lot (more than 4 times in the last 6 months); a lot (a few times every week)	Total score across all three items (0–9); higher scores = more frequent experiences of bullying victimisation
Peer support	Child and Youth Resilience Measure (Jefferies et al., 2019)	I feel supported by my friends	Not at all; a little; somewhat; quite a bit; a lot	4 to 20, higher scores = higher levels of peer support
Parent/carer support	Student Resilience Survey (Sun and Stewart, 2007)	At home there is an adult who believes that I will be a success	Often or always; some of the time; occasionally; hardly ever; never	4 to 20, higher scores = higher levels of parent/carer support
Religious service attendance	Millennium Cohort Study (Connelly and Platt, 2014)	How often do you attend a religious service when not at school?	Never or almost never; once a year or less; several times a year; at least once a month; at least once a week; most days	0 to 5; higher scores = more frequent religious service attendance
Familial socio-economic deprivation (Free school meal eligibility)	Administrative data on free school meal eligibility in last 6 years provided by Local Authorities or schools	N/A	0 = no; 1 = yes	N/A
Neighbourhood socio-economic deprivation (Indices of Multiple Deprivation; IMD)	IMD (Noble et al., 2019) data linked to residential postcode provided by Local Authorities or schools	N/A	Quintile 5 (least deprived) to Quintile 1 (most deprived)	1 to 5, with higher score = less deprivation
Neighbourhood own ethnic density	Neighbourhood ethnic composition data (Office for National Statistics, 2021) linked to residential postcode provided by Local Authorities or schools	N/A	0–100 %	0-100, higher score = higher % of neighbourhood population at the middle super output area (MSOA) level is same ethnicity as the young person

and indicates that, compared to White British young people, happiness with material possessions has a more pronounced effect on the mental wellbeing of Indian young people and less pronounced effect on the mental wellbeing of Black Caribbean young people. For full regression output, see Supplementary Materials G.

For experiences of racial or religious discrimination (model 2e), within the reference group of White British young people, there was a statistically significant simple effect ($\beta = -.312$, $p < .001$). There were negative interaction effects with ethnicity for Indian ($\beta = -.123$, $p = .041$) and Pakistani adolescents ($\beta = -.107$, $p = .002$), and a positive

Table 3
Regression results for research question 1 (n = 67866).

Term	Estimate	*SE*	Statistic	95 % CI		Std. Beta	p-value*
				2.50 %	97.50 %		
(Intercept)	22.262	.055	403.294	22.154	22.370	.218	<.001
Datapoint (ref = 2021 GM)							
2022 GM	.101	.050	2.013	.003	.200	.021	.059
2023 GM	.457	.061	7.446	.337	.577	.094	<.001
2023 HIPS	−.267	.052	−5.097	−.369	−.164	−.055	<.001
Year group (ref = Year 8)							
Year 9	−.568	.078	−7.279	−.721	−.415	−.117	<.001
Year 10	−.436	.043	−1.048	−.521	−.351	−.090	<.001
Gender (ref = Cisgender boy)							
Cisgender girl	−1.893	.040	−47.905	−1.970	−1.815	−.391	<.001
Trans and gender diverse	−3.176	.077	−41.516	−3.326	−3.026	−.656	<.001
Ethnicity (ref = White British)							
Asian Other	1.005	.151	6.637	.708	1.302	.207	<.001
Bangladeshi	.484	.125	3.871	.239	.728	.100	<.001
Black African	1.139	.099	11.509	.945	1.333	.235	<.001
Black Caribbean	.280	.296	.949	−.299	.860	.058	.343
Black Other	1.360	.205	6.641	.958	1.761	.281	<.001
Chinese	−.264	.208	−1.270	−.671	.143	−.054	.233
Indian	1.585	.123	12.902	1.344	1.826	.327	<.001
Mixed Other	.468	.124	3.770	.225	.711	.097	<.001
Mixed White Asian	.275	.154	1.786	−.027	.576	.057	.091
Mixed White & Black African	.189	.198	.958	−.198	.576	.039	.343
Mixed White & Black Caribbean	.299	.168	1.778	−.031	.629	.062	.091
Other Ethnic Group	1.000	.133	7.491	.738	1.261	.206	<.001
Pakistani	1.060	.070	15.101	.923	1.198	.219	<.001
White Gypsy, Roma or Irish Traveller	−.503	.443	−1.136	−1.370	.364	−.104	.279
White Irish	.994	.373	2.667	.263	1.724	.205	.011
White Other	.480	.090	5.333	.304	.657	.099	<.001

Note. *p-values were adjusted by false discovery rate. CI = confidence interval; GM = Greater Manchester; HIPS = Hampshire, Isle of Wight, Portsmouth, Southampton; Ref = reference, Std = standardised.

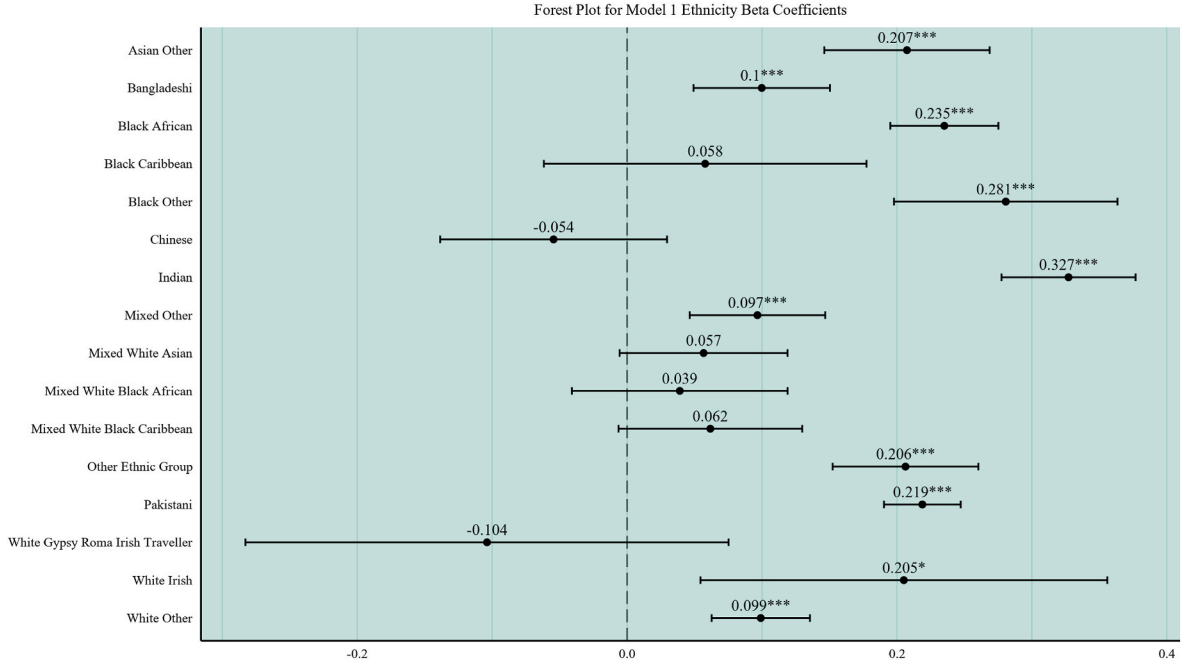

Fig. 2. Forest Plot Depicting Model 1 Beta Coefficients for Ethnic Inequalities in Adolescent Mental Wellbeing
Note. Reference category is White British (coefficient of 0). *$p < .05$. **$p < .01$, ***$p < .001$.

interaction effect for White Other (β = .084, p = .045) adolescents. These are depicted visually in Fig. 7, and indicate that the effects of exposure to racial or religious discrimination on mental wellbeing are more pronounced among Indian and Pakistani young people, and less pronounced among White Other young people, than their White British peers. For full regression output, see Supplementary Materials H.

For bullying (model 2f), within the reference group of White British young people, there was a statistically significant simple effect (β = −.250, p < .001). To add, there was a negative interaction effect with ethnicity for Pakistani (β = −.044, p = .019) compared to White British adolescents. This is depicted visually in Fig. 8, and indicates that the deleterious effects of more frequent exposure to bullying on mental

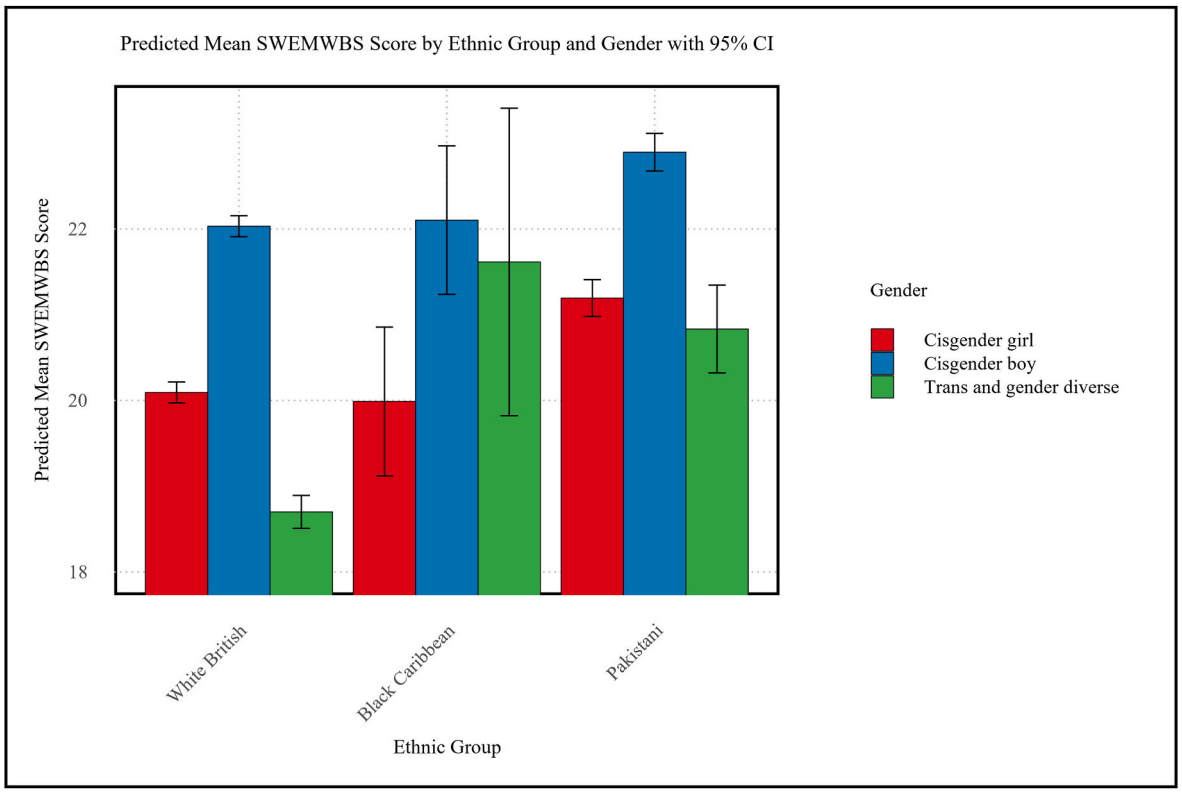

Fig. 3. Predicted Mean SWEMWBS Score by Ethnicity and Gender for White British, Black Caribbean and Pakistani Young People
Note. Y-axis starts at 18. SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

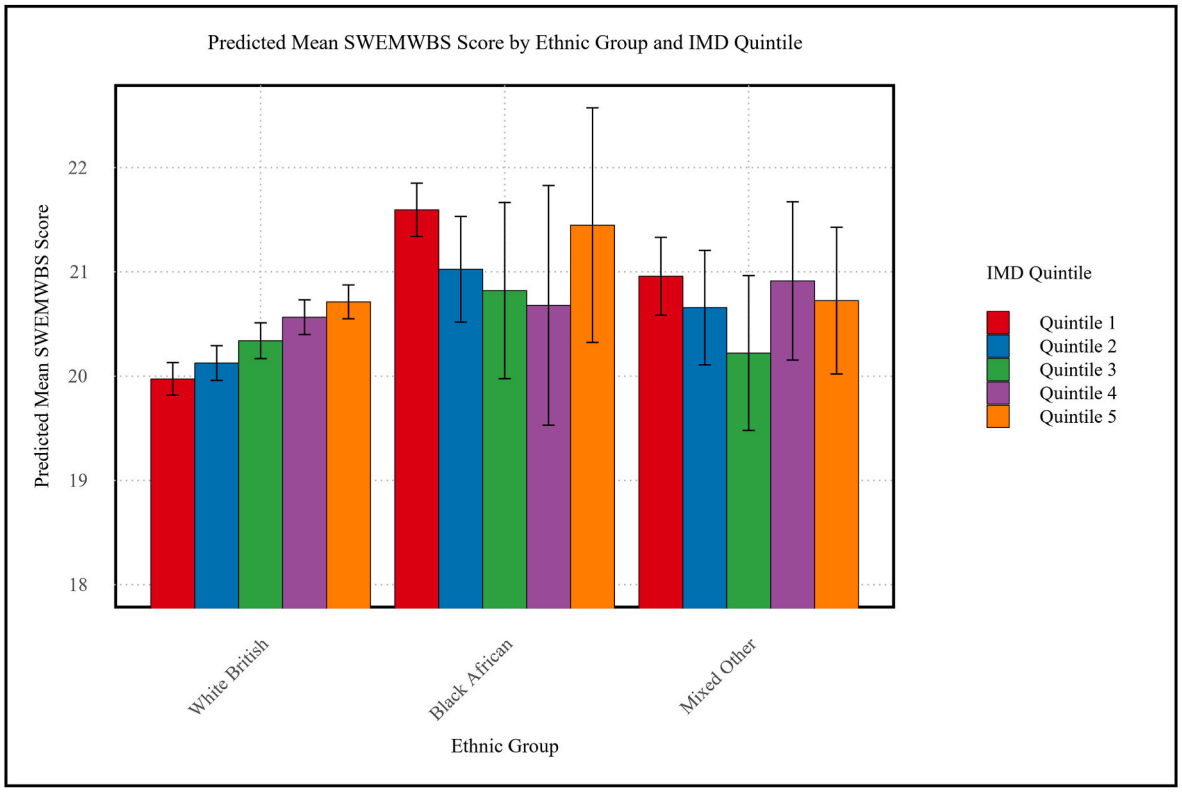

Fig. 4. Predicted Mean SWEMWBS Score by Ethnicity and IMD Quintile for White British, Black African and Mixed Other Young People
Note. Y-axis starts at 18. IMD = Indices of Multiple Deprivation; SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

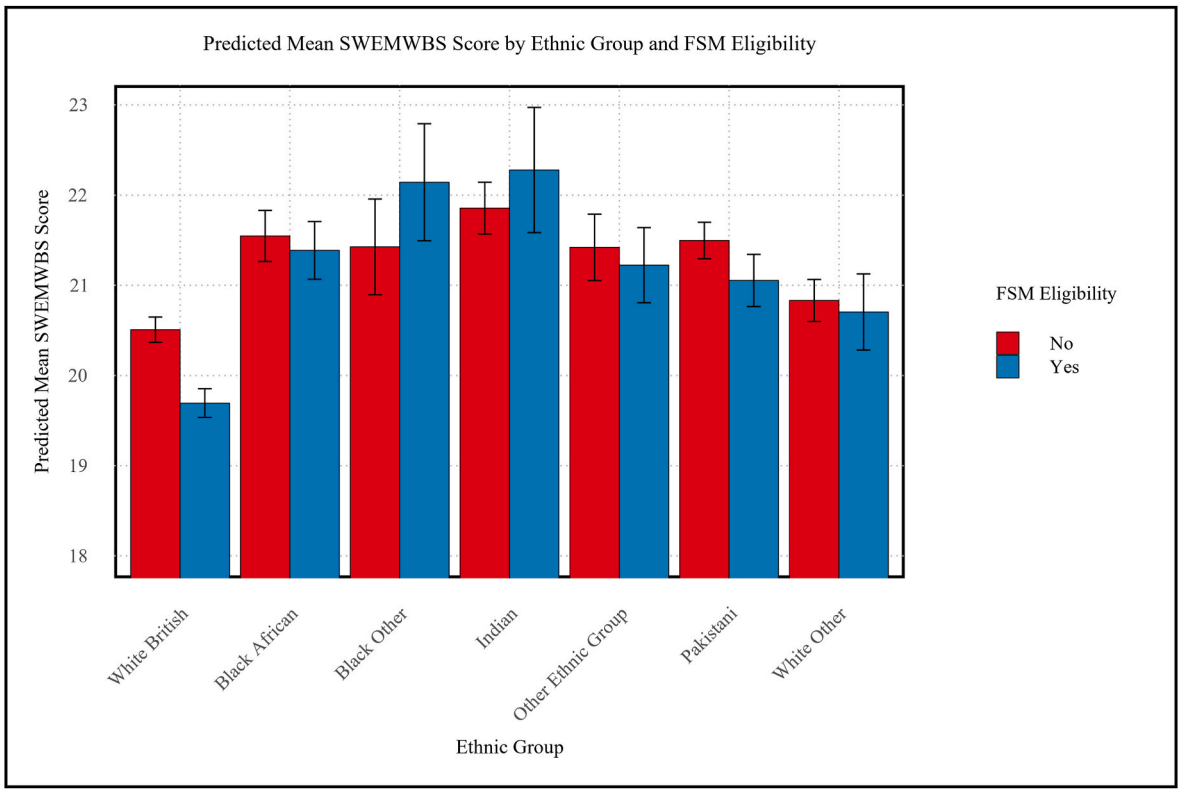

Fig. 5. Predicted Mean SWEMWBS Score by Ethnicity and FSM Eligibility for White British, Black African, Black Other, Indian, Other Ethnic Group, Pakistani, and White Other Young People
Note. Y-axis starts at 18. SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

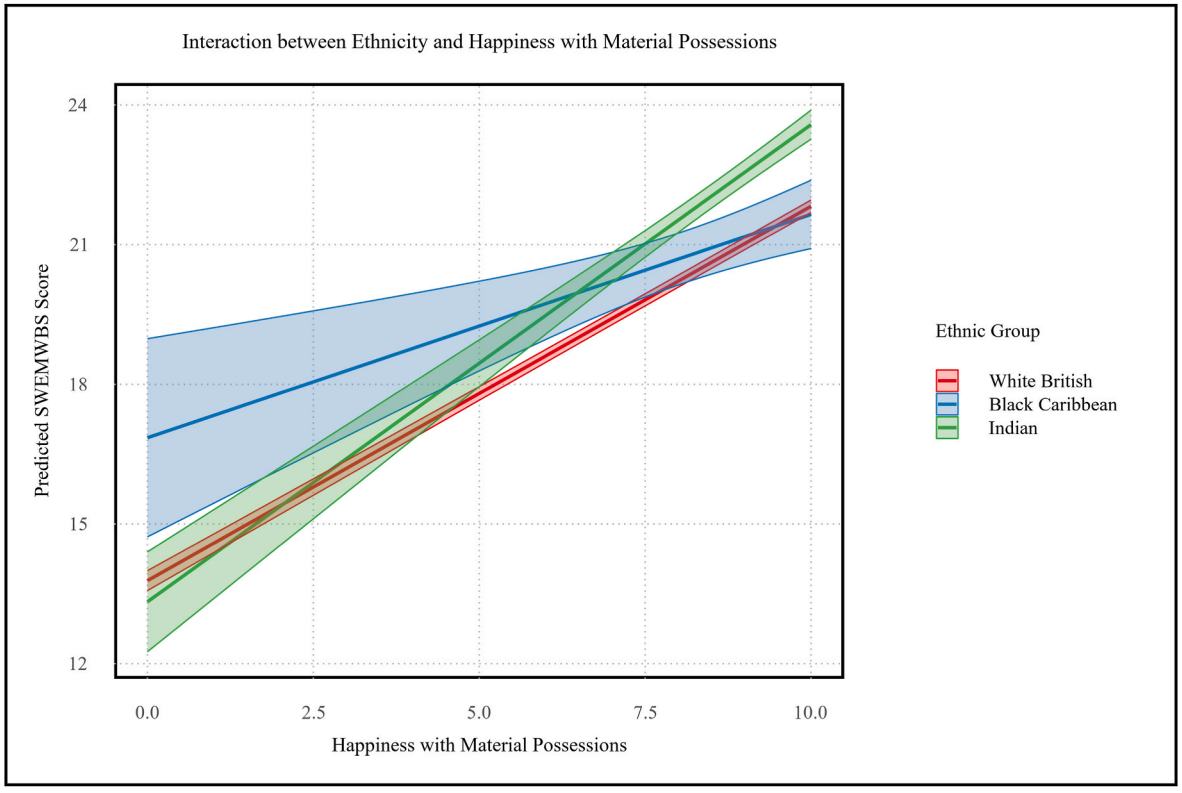

Fig. 6. Interaction between Ethnicity and Happiness with Material Possessions to Predict SWEMWBS Score for White British, Black Caribbean and Indian Young People
Note. Higher scores indicate greater happiness with material possessions. SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

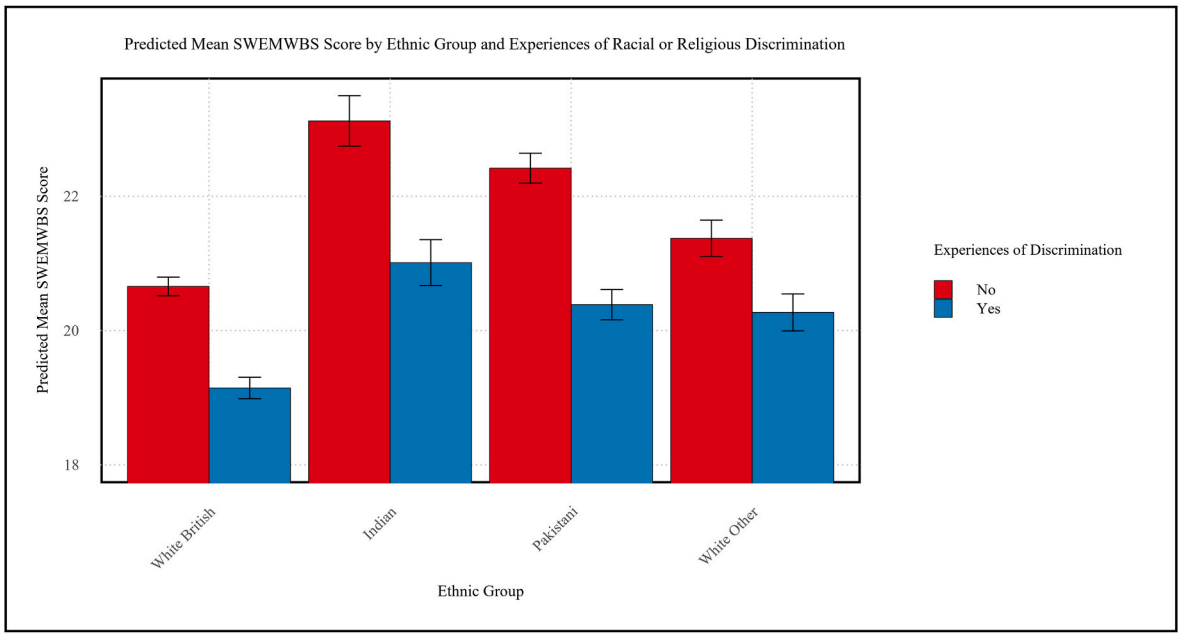

Fig. 7. Predicted Mean SWEMWBS Score by Ethnicity and Experiences of Racial or Religious Discrimination for White British, Indian, Pakistani, and White Other Young People
Note. Y-axis starts at 18. SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

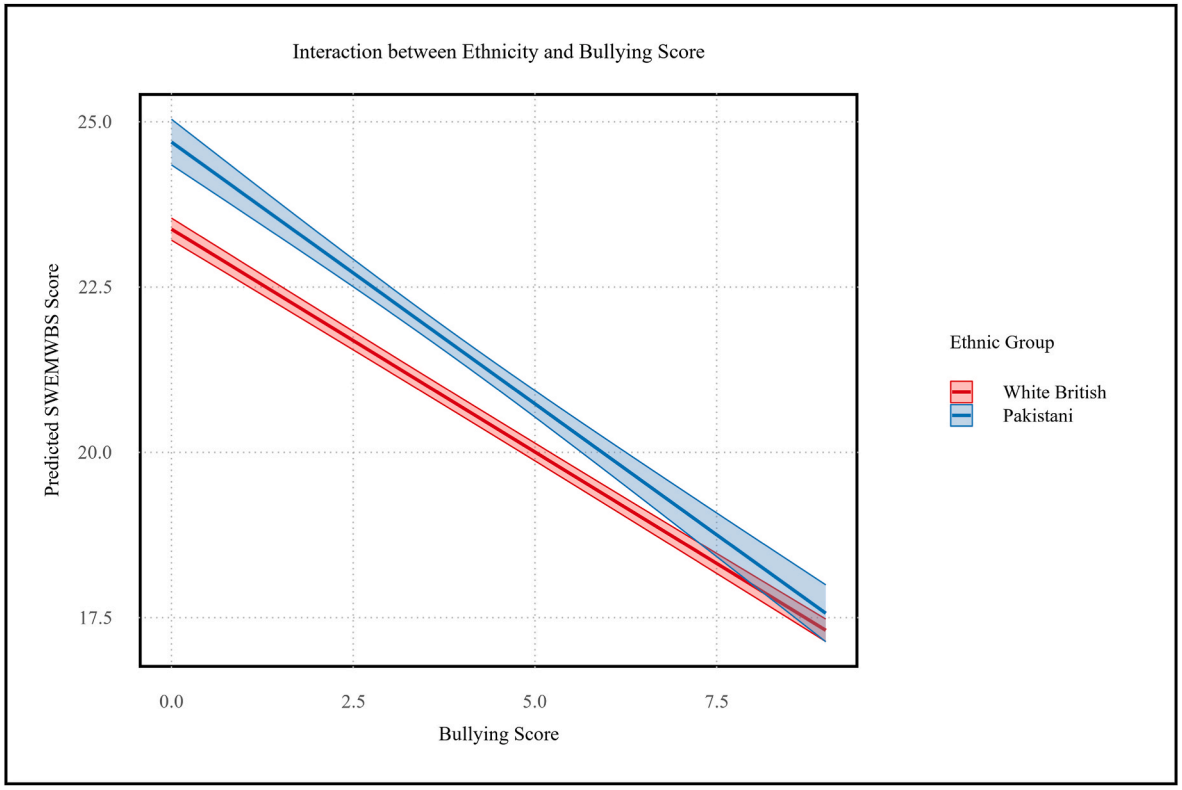

Fig. 8. Interaction between ethnicity and bullying to predict SWEMWBS score white British and pakistani young People
Note. Swemwbs = short Warwick Edinburgh Mental wellbeing scale.

wellbeing are more pronounced among Pakistani young people than their White British peers. For full regression output, see Supplementary Materials I.

For parent/carer support (model 2g), within the reference group of White British young people, there was a statistically significant positive simple effect ($\beta = .357$, $p < .001$). There were positive interaction effects with ethnicity for Indian ($\beta = .103$, $p = .001$) and Pakistani ($\beta = .051$, $p = .001$) adolescents. These are depicted visually in Fig. 9, and indicate that the protective effects of increased levels of parent/carer support on mental wellbeing are more pronounced among Indian and Pakistani

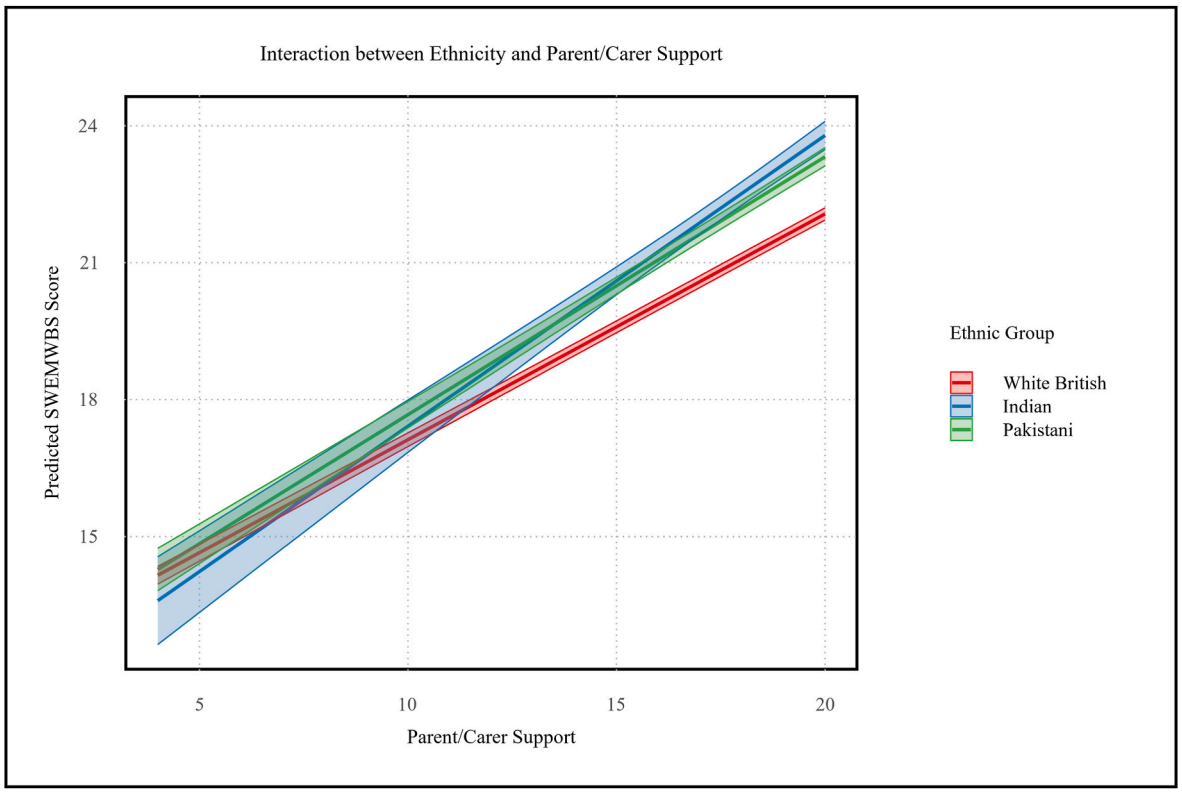

Fig. 9. Interaction between ethnicity and parent/carer support to predict SWEMWBS score for white British, Indian and pakistani young People
Note. Swemwbs = short Warwick Edinburgh Mental wellbeing scale.

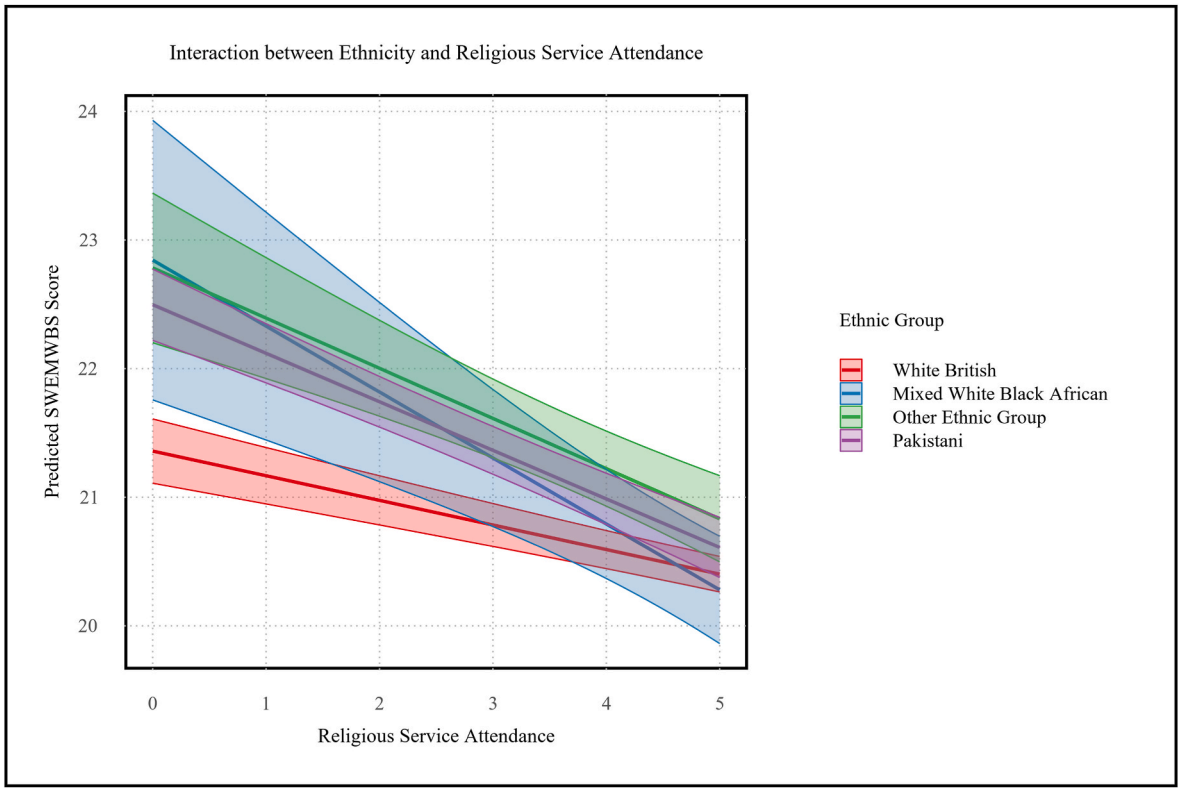

Fig. 10. Interaction between ethnicity and frequency of religious service attendance to predict SWEMWBS score for white British, mixed white Black African, other ethnic group and pakistani young People
Note. Swemwbs = short Warwick Edinburgh Mental wellbeing scale.

young people than their White British peers. For full regression output, see Supplementary Materials J.

For religious service attendance (model 2h), within the reference group of White British young people, there was a statistically significant negative simple effect (β = −.066, p < .001). There were negative interaction effects with ethnicity for adolescents from Mixed White and Black African (β = −.111, p = .023), Other Ethnic Group (β = −.069, p = .027), and Pakistani (β = −.064, p < .001) backgrounds. These are depicted visually in Fig. 10, and indicate that the deleterious effect of more frequent religious service participation on mental wellbeing are more pronounced among young people from Mixed White and Black African, Other Ethnic and Pakistani backgrounds than their White British peers. For full regression output, see Supplementary Materials K.

For neighbourhood own ethnic density (model 2i), within the reference group of White British young people, there was a statistically significant positive simple effect (β = .001, p = .021). There there were positive interaction effects with ethnicity for adolescents from Black African (β = .006, p = .033), Black Caribbean (β = .060, p = .020) and White Other (β = .013, p = .031) backgrounds. These are depicted visually in Fig. 11, and indicate that the protective effects of higher neighbourhood own ethnic density on mental wellbeing are more pronounced among young people from Black African, Black Caribbean and White Other backgrounds than their White British peers. For full regression output, see Supplementary Materials L.

Finally, regarding peer support (model 2j), within the reference group of White British young people, there was a statistically significant positive simple effect (β = 464, p < .001), but there there were no statistically significant interaction effects with ethnicity in predicting adolescent mental wellbeing (i.e., the promotive effects of peer support were effectively uniform across ethnic groups; see Supplementary Materials M).

To identify the social identity markers and exposures that explain ethnic inequalities in adolescent mental wellbeing, the adjusted models for RQ2 were inspected to determine where the statistically significant simple effects of ethnicity on wellbeing became non-significant upon accounting for these markers and exposures. When parent/carer support was included, all main ethnic group effects ceased to be statistically significant (model 2g; Supplementary Material J). Peer support accounted for the simple effect of ethnicity for eight ethnic groups (model 2j; Supplementary Materials M) and happiness with material possessions explained the simple effect of ethnicity for seven ethnic groups (models 2d; Supplementary Materials G). Finally, in the bullying model, the simple effect of ethnicity was explained for five ethnic groups (model 2f; Supplementary Materials I).

4. Discussion

The aims of this study were to (1) determine the nature and magnitude of ethnic inequalities in adolescent wellbeing; and, (2) assess the extent to which intersectional systems of oppression (as indicated by social identity markers) and various exposures interact with ethnicity to explain adolescent wellbeing. Our findings provide new insights through our focus on mental wellbeing; increased precision and power via high granularity ethnicity data and a very large sample; and improved understanding of how social identity markers and exposures interact with ethnicity to produce synergistic or antagonistic effects on mental wellbeing.

1 Are there ethnic inequalities in mental wellbeing in early-to-mid adolescence?

We found that compared to White British young people, 10 of 16 minoritised ethnic groups reported significantly better mental wellbeing, and none reported signficantly worse mental wellbeing. Our measurement invariance analysis indicated that these differences are likely genuine, and not due to differences in how young people perceive

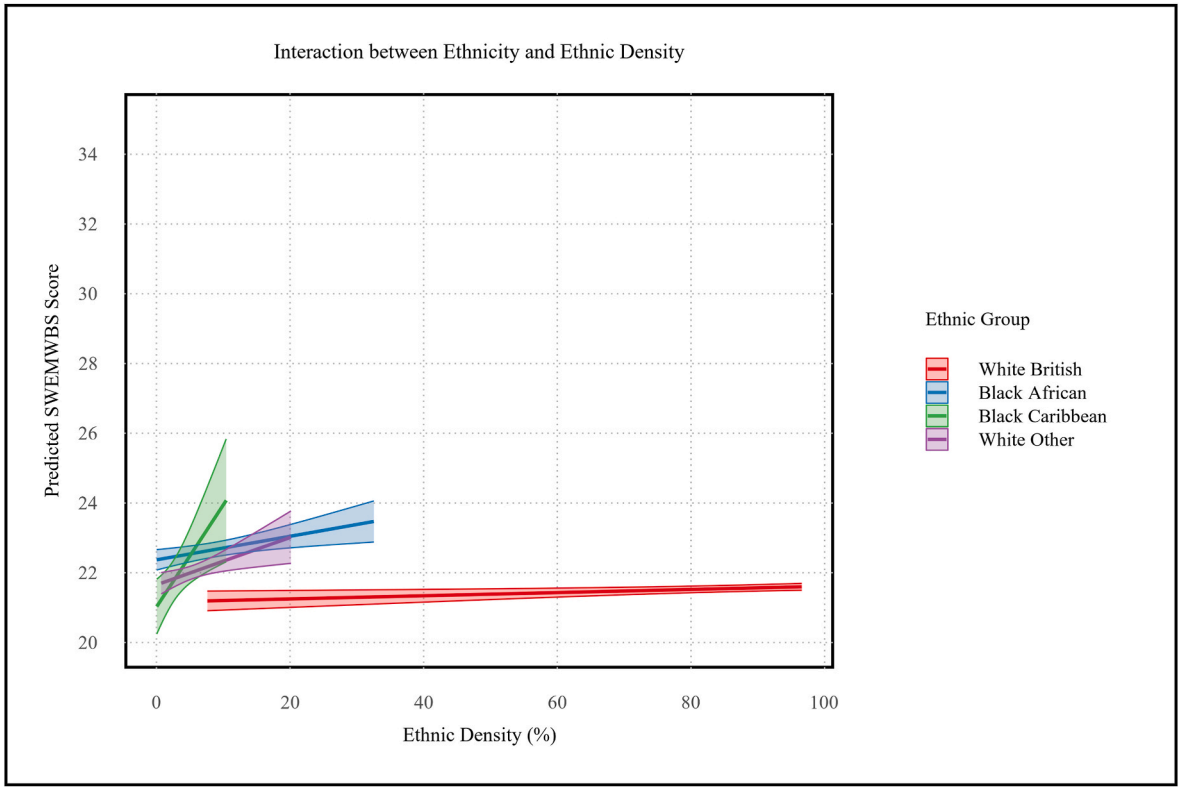

Fig. 11. Interaction Between Ethnicity and Neighbourhood Own Ethnic Density to Predict SWEMWBS Score for White British, Black African, Black Caribbean and White Other Young People

Note. Regression line and confidence intervals are within the limits of the data. SWEMWBS = Short Warwick Edinburgh Mental Wellbeing Scale.

and report on their wellbeing.

These findings align with the existing evidence base in the broadest sense (Ahmad et al., 2021; Goodman et al., 2008; Jun et al., 2020; Patalay and Fitzsimons, 2016; Deighton et al., 2019; Marcheselli et al., 2018) indicating that, for adolescents, many minoritised ethnic groups report better wellbeing. This contrasts the stark ethnic inequalities in a range of physical and mental health outcomes, including wellbeing, amongst older age groups (Pampaka et al., 2016; Watkinson et al., 2021). One theory which may explain these findings is the weathering hypothesis, whereby chronic exposure to social and economic disadvantage contributes to an accelerated decline in health (Aksoy et al., 2022), and therefore, the effects of such disadvantage may not be apparent in children and young people. Alternatively, these patterns may also reflect cohort effects, whereby generational differences in exposure to social, cultural, or environmental factors shape wellbeing outcomes. Nevertheless, the current study provides some important new insights. The most analagous study to our own found significantly higher wellbeing among only Asian (compared to White) young people (Patalay and Fitzsimons, 2016). In the current study, the methodological improvements noted above enabled us to pinpoint signficant differentiation *within* the Asian category (i.e., effect sizes ranging from $\beta = .10$ (Bangladeshi), $\beta = .22$ (Pakistani) to $\beta = .33$ (Indian), and no significant difference in mental wellbeing between Chinese young people and their White British peers). They also enabled us to identify ethnic disparities in mental wellbeing that went undetected in previous studies due to conflation of distinct groups (e.g., White Irish included in overall White reference group (Ahmad et al., 2021); Black African, Black Caribbean and Black Other included in higher level Black category (Patalay and Fitzsimons, 2016)). In sum, our findings underscore the importance of granular ethnic classification for substantive findings in adolescent wellbeing research (Yao et al., 2022).

The adjusted models used to address RQ2 indicate that the relationship between ethnicity and mental wellbeing was significantly moderated by several factors. The inclusion of interaction terms for parent/carer support (model 2g), peer support (model 2j), happiness with material possessions (model 2d), and bullying (model 2f) notably attenuated most statistically significant ethnic group coefficients, suggesting that ethnic disparities in mental wellbeing are contingent on specific levels of these moderating factors. While other interaction effects were also significant, they did not reduce the magnitude or statistical significance of ethnic group differences to the same degree. These findings are consistent with prior work which has focused on parent/carer support, peer support, and socio-economic disadvantage (Ahmad et al., 2021; Jun et al., 2020; Forde et al., 2019), with new insight offered here in relation to the additional role of bullying.

2. To what extent do intersectional systems of oppression (measured by different social identity markers i.e., gender, socioeconomic position) and/or exposures (e.g., risk factors, such as discrimination; protective factors, such as parent/carer support) interact with ethnicity to explain mental wellbeing?

Our gender identity analyses revealed two important findings. First, in contrast to prior research (Ahmad et al., 2021), there were no interaction effects with ethnicity for cisgender girls (compared to the reference group of cisgender boys), indicating that the well-established gender gap (using the traditional binary) in adolescent mental wellbeing (with girls consistently reporting worse outcomes than boys) (Campbell et al., 2021) is uniform across ethnic groups, perhaps reflecting gender socialisation and intensification practices that are ubiquitous and culturally invariant. Second, the substantial mental wellbeing disadvantages previously reported for trans and gender diverse youth (compared to the reference group of cisgender boys) (Black et al., 2023) are significantly attenuated among those from Black Caribbean and Pakistani backgrounds (compared to their White British peers). Although research in this space is very sparse, there is some limited evidence to support our findings, including a recent analysis that revealed fewer depressive symptoms and self-injurious thoughts and behaviors among Black gender minority adolescents (Fox et al., 2020). Our other findings may signify a potential protective mechanism, since a recent study found that family support buffers the association between peer victimisation and suicide attempts among transgender youth (Holt et al., 2023), and we found that increased parent-carer support yielded stronger effects on mental wellbeing among one of the two minoritised ethnic groups noted above (Pakistani young people).

Patterns of interaction between ethnicity and our three measures of socio-economic deprivation (familial, neighbourhood, subjective) revealed a common trend aligning with previous research (Jun et al., 2020) that disparities between the most and least deprived were less pronounced, or in some cases reversed, among certain minoritised ethnic groups (e.g., Black Caribbean, Pakistani) compared to their White British peers. However, *which* minoritised ethnic groups this trend applied to varied somewhat by deprivation measure (e.g., neighbourhood deprivation versus familial deprivation for Black Caribbean young people), potentially indicating different underpinning mechanisms, and reinforcing the importance of a multifaceted approach to assessment of socio-economic status (Zaneva et al., 2024). One possible general explanation is the role of stigma. It has been argued that cultural values can increase feelings of shame of individuals experiencing socio-economic disadvantage (Sutton et al., 2014; Addis and Murphy, 2018). For example, increased stigma among White British young people experiencing familial deprivation, compared to their peers in minoritised ethnic groups, may counteract the documented financial health, nutritional and wellbeing benefits of receiving free school meals (McKelvie-Sebileau et al., 2023).

Regarding experiences of racial or religious discrimination, our findings align with a recent systematic review which found consistent evidence of adverse associations between discrimination and child and adolescent mental health (Cave et al., 2020), and earlier work which found that racism had an important impact on psychological wellbeing among adolescents from minoritised ethnic groups (Astell-Burt et al., 2012). However, our analyses revealed that the impact of racial and/or religious discrimination is not uniform across these groups. The impact of discrimination on wellbeing for Indian and Pakistani adolescents may be influenced by both increased frequency of exposure, compared to White British young people (indicated in Supplementary Materials B), *and* increased vulnerability to the effects of exposure (indicated in Supplementary Materials G), consistent with theories of health inequalities (Diderichsen et al., 2019). The fact that Bangladeshi adolescents are an exception despite similar levels of exposure could be a consequence of factors pertaining to socio-economic context, religious/cultural visibility, and/or social support that mitigate the effects of discrimination for these young people, relative to their Pakistani and Indian peers. In any event, the differential effects observed here again reinforce the importance of more granular ethnic classification to elucidate more nuanced effects. Relatedly, we note the amplified effects of bullying victimisation identified in relation to Pakistani adolescents compared to their White British peers. Earlier research reported that some minoritised ethnic groups (e.g. Black young people) may be protected against the negative consequences of bullying by protective factors such as strong ethnic identity and positive cultural and family values (Xu et al., 2020; Thornton et al., 2024); our analysis indicates that this is not the case for Pakistani adolescents.

Turning now to positive relationships with parent/carers, our analyses align with previous work demonstrating general mental wellbeing benefits (Butler et al., 2022) and build on earlier research demonstrating differential levels of perceived support (i.e., those from minoritised ethnic groups report closer relationships with parents and carers than their White peers) (Ahmad et al., 2021) to provide new evidence of an amplified protective effect for Indian and Pakistani young people. This effect mirrors that of a recent study of the wellbeing of Icelandic adolescents which reported that those born to foreign parents benefited

more from supportive parents than native Icelanders (Forde et al., 2019). Collectively, these findings are indicative of culturally-specific protective mechanisms for some minoritised ethnic groups that may reflect a heightened reliance on family as a source of support in contexts where other (e.g., institutional) sources may be less accessible and/or appealing.

Our analysis of frequency of religious service attendance yielded interesting new insights, given that most prior work has focused on adolescent religiosity (as opposed to specific practices) and mental health (Hardie et al., 2016). In addition to a simple effect indicating that more frequent religious service attendance was associated with lower levels of mental wellbeing for White British adolescents, we found amplified effects for Mixed White-Black African, Pakistani, and Other Ethnic Group adolescents. Such findings contrast with the evidence from adults, where positive associations are typically found (Chen et al., 2020; Watkinson et al., 2021). We therefore tentatively speculate that the effects found in the current study reflect tensions specific to the developmental phase of adolescence. More frequent adolescent religious service attendance is associated with higher levels of parental monitoring activities and normative regulations (Kim and Wilcox, 2014); thus, it may be a marker of reduced autonomy in a developmental phase characterised by the quest for independence.

Our findings support the ethnic density hypothesis, which proposes that members of minoritised ethnic groups experience greater wellbeing when they live in areas with higher proportions of people from the same ethnicity (or more generally, in areas of higher ethnic diversity), because this can mitigate the deleterious effects of discrimination and other minority stressors through enhanced social support and community cohesion (Jun et al., 2020). However, the protective (as opposed to promotive) effects of own area ethnic density were restricted to those of White Other, Black African, and Black Caribbean backgrounds, with the strongest effects observed for the latter group. As above, this is indicative of culturally-specific protective mechanisms for some minoritised ethnic groups. Given that a recent study of English adolescents that used a binary (i.e., White vs minority) classification approach found no support for the ethnic density hypothesis (Jun et al., 2020), our findings serve as yet another reminder of the need for more granular approaches to ethnic classification.

4.1. Strengths and limitations

The current study benefits from a number of strengths. First, it is, to the best of our knowledge, the largest ever study of ethnic differences and adolescent mental wellbeing, offering considerably increased statistical power to detect subtle but nonetheless meaningful disparities. Second, we used higher granularity ethnicity data than all previous studies, and this was vindicated across multiple analyses, particularly in relation to Asian young people, where differential effects were observed for both research questions across Bangladeshi, Indian and Pakistani groups. Third, we applied an intersectional approach, exploring the interactions between ethnicity and social identity markers of systems of oppression (gender identities and socioeconomic position), and exploring the interactions between ethnicity and a range of exposures to identify possible synergistic or antagonistic effects, thereby enabling a much more nuanced analysis than has been evident in most previous work. Finally, the analysis plan was pre-registered prior to the lead author accessing the study dataset, providing an additional layer of rigour.

There are also a range of limitations that should be borne in mind. First, the study was cross-sectional, limiting causal inference due to our inability to establish temporal precedence and rule out reverse causality (though, of course, this enabled us to maximise sample size, which conferred the significant advantages outlined above). Second, despite the very large sample and high granularity ethnic classification data, we had to combine those of White Gypsy, Roma or Irish Traveller heritage to increase group size. This methodological compromise speaks to the challenges of researching outcomes for such minoritised ethnic groups, even when using a very large sample; further research with booster samples is warranted. Third, despite the wide range of social identity markers and exposures included in the study, our secondary analysis was naturally restricted to measures available in the #BeeWell dataset. This meant that some potential important factors (e.g., substance use (Ahmad et al., 2021)) were omitted. Finally, although it provides a large and diverse sample drawn from 14 different Local Authorities in England, the #BeeWell dataset is not sampled to be nationally representative. In particular, despite one of the two project regions (Greater Manchester) being among the most ethnically diverse in the country, the overall sample composition over-represents White British pupils (69 %, compared to 64 % nationally) (UK Government, 2023), primarily due to the relative ethnic homogeneity of Hampshire (which makes up c.20 % of the overall sample). Caution is therefore required in terms of generalisation of the findings reported here. It is also noted that the data were collected during the COVID-19 pandemic, which may have influenced wellbeing alongside the other explanatory factors. Furthermore, the interaction between ethnicity groups and different variables were not accounted for in the imputation models, which meant that there was inconsistency between the imputation models and the substantive models. Incorporating all interaction terms involving ethnicity into the imputation model would have considerably increased its complexity and potentially compromised model stability. Future research should aim to address this to assess whether model estimates are impacted.

4.2. Implications

The findings of this study offer important insights into adolescent wellbeing, particularly in relation to ethnic disparities; however, given the cross-sectional design, specific outcome focus, and sample characteristics, any implications should be interpreted with caution. Recommendations offered here are intended to illustrate possible avenues for future inquiry and policy development rather than definitive solutions or causal conclusions. Beginning with schools, our findings imply the need to go beyond generalised support programmes and offer tailored, targeted support that reflects a more nuanced understanding of the needs of different ethnic groups. Given the differential impacts of bullying exposure we identified, this might include strengthening/augmenting anti-bullying interventions, with a particular focus on addressing potential ethnic or racial discrimination. There is also a clear need to engage parents and carers from diverse ethnic backgrounds, recognising the critical role their support plays in fostering adolescent wellbeing. Workshops and resources focused on fostering supportive home environments could be beneficial in this regard. Furthermore, schools can play an important role in addressing socioeconomic disparities among students, providing resources and support (e.g., access to extracurricular activities), particularly among those more acutely impacted by particular forms of disadvantage. Finally, our findings indicate that providing staff with training on cultural sensitivity and awareness to ensure they understand and respect the diverse backgrounds of their students will be beneficial.

Turning to healthcare providers, training on cultural competence to provide sensitive and effective care to adolescents from diverse ethnic backgrounds is an essential foundation.

Given the importance of parent/carer support, a family-centered approach, involving parents/carers in assessment and treatment relating to adolescent wellbeing is also essential. Additionally, healthcare providers should be aware of the socioeconomic factors that can affect mental wellbeing and connect adolescents and their families with relevant resources and support services. Finally, policymakers should prioritise and allocate funding to support initiatives that address the specific needs of adolescents from different ethnic backgrounds. Policy in this space should be informed by research that disaggregates data by ethnicity, recognising the within-group differences highlighted in the current study. These policies should aim to address the systemic,

structural inequalities that contribute to the socioeconomic disadvantage and discrimination that disproportionately impacts minoritised ethnic groups. By implementing these recommendations, schools, healthcare providers, and policymakers can work together to create a more equitable and supportive environment for adolescent mental wellbeing.

5. Conclusion

In sum, the current study has demonstrated that compared to White British young people, a number of minoritised ethnic groups reported significantly better mental wellbeing, and none reported signficantly worse mental wellbeing. These disparities were largely explained by factors including parent/carer support, bullying, socio-economic disadvantage, and peer support. Our interaction analyses revealed a complex picture. While some social identity markers and exposures yielded effects that appear to be ubiquitous and invariant across ethnic groups (e.g., the traditional gender gap in wellbeing and the promotive effects of peer support were uniform across ethnic groups), many interacted with ethnicity in explaining mental wellbeing (e.g., Indian and Pakistani youth particularly negatively impacted by racial or religious discrimination; protective ethnic density effects evident only for those of Black Caribbean, Black African and White Other origin). Collectively, these findings provide important new insights into the nature, magnitude and factors underpinning ethnic disparities in mental wellbeing.

CRediT authorship contribution statement

Jessica Stepanous: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Patricia Irizar:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Kathryn Mills-Webb:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Dharmi Kapadia:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Qiqi Cheng:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Jose Marquez:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Neil Humphrey:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, 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.

Acknowledgements

The authors gratefully acknowledge the efforts of participating young people and their schools in this research. The #BeeWell study is kindly funded by the University of Manchester, the Greater Manchester Combined Authority, The National Lottery Community Fund, BBC Children in Need, Big Change, the Gregson Family Foundation, the Paul Hamlyn Foundation, the Holroyd Foundation, the Oglesby Charitable Trust, and the Peter Cundill Foundation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmmh.2025.100535.

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