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Abstract

Introduction. The World Health Organisation recommends that children and adolescents engage in at least 60 minutes of moderate-to-vigorous physical activity per day. Previous research has shown that physical activity is related to other constructs such as, mental well-being, and self-rated health. This study examined the inter-relatedness of these constructs in Northern Irish school children. **Methods.** This study was a secondary analysis of data gathered as part of a longitudinal study. Participants were *n* = 1,791 adolescents in their final years of secondary (high) school (age range 15-18; Female = 64.6%). Data were gathered on three occasions over a two-year period on: self-rated health; physical activity; mental well-being; heavy episodic drinking; lifetime smoking; psychological and somatic symptoms; as well as a range of socio-demographic measures. **Results.** Descriptive results showed extremely low levels of self-reported physical activity within the past week, with < 6% of the sample attaining the WHO guidelines at each wave of data collection. There were significant gender differences on all variables assessed. Results further showed a small-sized relationship (statistically significant for girls only) between physical activity and mental well-being. There was also a small-sized relationship between physical activity and self-rated health. Notably, effect sizes for the relationship between self-rated health and both physical activity and mental well-being were higher. In terms of socio-demographic predictors of lower physical activity, being female, lifetime cigarette smoking, and higher somatic and psychological symptoms, were all statistically significant factors. **Conclusion.** Self-rated health emerged as the most important predictor of physical activity among adolescents.

Keywords: physical activity, self-rated health; mental well-being; secondary school age

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Physical activity (PA) plays a critical role in the normal growth and healthy development of young people, and can be a predictor of their continued well-being through to adulthood (Tremblay et al., 2021). The World Health Organisation (WHO) has recommended that children ought to engage in a minimum of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day, in order to maintain health benefits (WHO, 2010). It is therefore of concern to note recent findings from the Health Behaviour in School-aged Children study, which reveal that globally, fewer than one in five adolescents achieve the daily recommended levels of MVPA (Inchley et al., 2020).

In keeping with trends observed internationally (Inchley et al., 2020), the majority of young people in Northern Ireland (NI) are not meeting these MVPA targets as recommended both by the WHO, and by the Chief Medical Officers of the four United Kingdom (UK) Nations (Davies et al., 2019). Relatedly, fewer than half of all children and adolescents across the island of Ireland are meeting this MPVA target (Harrington et al., 2016). Comparing data from all UK countries, children living in NI appear to be least likely to meet the WHO target compared to their peers across the UK (Griffiths et al., 2013), and Europe (van Hecke et al., 2016). More recent findings suggest that PA levels continue to remain chronically low in NI, with a minority of children (only 13% overall) currently meeting the recommended PA target (primary pupils 20%, post-primary pupils 11%; Connolly et al., 2020). Understanding the predictors of PA, and the relationship between PA and other variables of consequence in adolescence, seems a particularly important research question in the NI context.

Additional to physical health benefits (e.g., Boreham et al., 1999), PA has been recognised as an accessible, cost-effective way to support mental health by reducing symptoms of common mental disorders and improving well-being (Dishman et al., 2021). The relationship between PA and mental well-being in adults has been widely researched, with some studies suggesting that 12% of future cases of depression in adults can be offset by participation in just one hour of PA per week in youth (Harvey et al., 2017).

Arguably then, those whose mental health would benefit most from regular PA are children and adolescents (Biddle & Asare, 2011). In addition to the problem of relative physical inactivity, it has also been reported that cases of anxiety and depression are 25% more common in children and young people in NI compared to the rest of the UK (Bunting et al., 2020). Although the literature examining the relationship between PA and mental well-being is not as advanced in children and young people as it is in adults, some studies have shown interesting findings. In a scoping review, Hagell (2016) identified a positive relationship between participation in organised PA and reduced anxiety and depression, improved well-being, and improved self-esteem. Further, data from the Avon Longitudinal Study of Parents and Children birth cohort study (ALSPAC) showed a positive relationship between regular PA and lower levels of depression in 14-year-olds (Wiles et al., 2012).

Conversely, other studies have reported a positive relationship between increased sedentary behaviour and an increased risk for symptoms of depression and psychological distress (Hoare et al., 2016). A recent systematic review and meta-analysis (Zhang et al., 2020) identified that PA was positively associated with self-rated health (SRH), while sedentary behaviour was associated with lower SRH among both children and adolescents. Furthermore, this positive

dose-response relationship between PA and SRH was observed in both boys and girls, with no significant gender differences.

Research into determinants and correlates of PA in adolescents is particularly important due to the potential duration of positive effect which regular PA might have on and current, and future health outcomes. Adolescent experiences are often cited as having a profound effect on mental health outcomes across the life span (Chapman et al., 2004). Moreover, it has been suggested that at an individual level, the most reliable predictor of future PA is past PA (Bauman et al., 2012). Accordingly, PA in adolescence could influence well-being not only in youth but across the lifespan through two pathways. Firstly, early exposure, sampling of activity, and continuity of activity in youth may help to create an environment wherein active children/adolescents are likely to have a continuous source of support for their well-being over time. Secondly, potential residual effects of adolescent PA can extend beyond those associated with activity levels over time.

The theory of expanded, extended, and enhanced opportunities (TEO; Beets et al., 2016), underpins the present study. Individuals exist in specific contexts and environments, and the TEO moves away from solely considering interpersonal and intrapersonal factors for PA engagement (such as motivation and capability), and instead focuses more attention on the environment and what is available (or absent) therein. Accordingly, the very contexts in which individuals live, learn, and play, may themselves be determinants of PA (Rosenkranz et al., 2021). According to TEO, PA can be enhanced in three main ways: 1) through the expansion of opportunities by creating a new occasion(s) to be active, 2) through the extension of existing PA opportunities (for example, through increased duration of such opportunities, and 3) by enhancing the quality of available PA opportunities (Rosenkranz et al., 2021). In the present

study, attention is focused on availability of PA opportunities within an environment (e.g., schools and community settings [rural and urban] in Northern Ireland) as opposed to just motivation and capability of the youth.

In summary, the present study sought to examine the inter-relatedness of three main variables of consequence for adolescent PA, and potentially for future health. It did so in a geographical context characterised by relatively low levels of adolescent PA, and relatively high levels of psychiatric morbidity. It involved an analysis of longitudinal data gathered in the final three years of secondary school, when adolescents are beginning to transition towards adulthood. The initial aim of the overall research project in which these data were collected had been to assess the effectiveness of a classroom-based alcohol education programme in a randomised controlled trial (RCT; McKay et al., 2018). The data used herein did not form part of the trial and were gathered in the three academic years after the reporting on the trial primary outcomes. Data were gathered on PA levels, SRH, mental well-being, as well as other health variables. The study had three main aims: 1) To examine levels of self-reported PA, mental well-being, and SRH (descriptive data) in this population. 2) To identify socio-demographic variables that most strongly influenced both PA, and SRH, cross-sectionally, and over time. 3) To examine the bi-directional relationship between SRH, PA, and mental well-being. We examined whether changes in perceived SRH and PA had an effect on mental well-being over time. It was hypothesized that sociodemographic variables would influence PA and SRH and mental well-being. It was also hypothesized that changes in SRH and PA would have an effect on mental well-being over time, more specifically, that increases in SRH and PA would predict better mental well-being over time.

Method

Participants

Participants were 1,791 school children attending 54 secondary schools (high schools) in NI, and who participated in three waves of data collection in their final three years of statutory schooling (T1 – T3; *N* = 1,791; Female [64.6%]; lived in a rural setting [52.1%], entitled to a free school meal [78.2%]). The 54 secondary schools in the current study represented 32% (54/167) of the total possible number of secondary schools in NI. Schools had previously been among those involved in a randomised controlled trial and had agreed to allow on-going data collection following the cessation of the trial. Paper-and-pencil surveys were administered under examination-like conditions in each individual school by one of three different researchers. Both pupil assent and parental consent were obtained before the data were collected. Ethical approval was given by the ethics committee at the University of Liverpool. Data collection occurred in the first term of each school year (October-November) in order to avoid clashes with statutory examinations later in the school year. School year 12 (T1) is the last year of statutory education in NI. Therefore, in the overall sample there was large attrition between T1 and T2 (46.9% from T1 completed T2), with much less between T2 and T3 (83% at T2 completed T3). Data from only those who completed questionnaires at all time points (39.0% from T1) were used in analyses.

Measures

Main variables of interest

The main variables of interest in the present study were *SRH*, and *PA frequency*. Both variables were assessed using single questions as administered in the Health Behaviour in School-Aged Children symptom checklist (Currie et al., 2008).

Physical activity frequency. The context for enquiring about PA was set as follows: *Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. Physical activity can be done in sports, school activities, playing with friends, or walking to school. Some examples of physical activity are running, walking quickly, cycling, dancing, skateboarding, swimming, football, and gymnastics*. Participants were then asked, "*Over the past 7 days, on how many days were you physically active for a total of at least 60 min per day*?" Responses options ranged from 0 - 7.

Self-rated health. SRH was assessed by asking, "*In general, how would you rate your health?*" Response options were as follows: 1) Poor; 2) Fair; 3) Good; 4) Very Good; 5) Excellent.

Demographic variables influencing SRH and PA

Data were also collected on gender, home location, and free school meals (FSM) entitlement, a proxy measure for socioeconomic status (SES; Hobbs & Vignoles, 2010), with entitlement to FSM indicative of lower SES. Additional to individual-level FSM entitlement, deprivation quintiles, and categorization by Urban/Rural were determined using the Central Postcode Directory (Northern Ireland Statistics and Research Agency (NISRA, 2019). For those participants who had provided a postcode, these were matched with deprivation deciles and the urban/rural label. Quintiles were then derived by collapsing deciles. Data were also collected on family size (number of siblings), and place within the family (number of older siblings).

Outcome variables of interest

Mental well-being. The Warwick-Edinburgh Mental Well-being Scale (WEMWBS) was used to measure positive mental well-being. This is a 14-item scale assessing positive affect, satisfying interpersonal relationships, and positive functioning (e.g., "*I have been feeling useful*";

Tennant et al., 2007). Items are anchored at the extremes of 1 ("*none of the time*"), and 5 ("*all of the time*") and scores on items are summed to provide a single score ranging from 14 to 70 with higher scores reflecting greater well-being. The WEMWBS has displayed content and criterion validity, and acceptable test–retest reliability over one week (Tennant et al., 2007). Internal consistency for the subscales was acceptable in the present study ($\alpha = 0.91$). The psychometric validity of the WEMWBS has previously been demonstrated in this geographical context (McKay & Andretta, 2017).

Health Symptoms. Psychological and somatic symptoms were measured using the HBSC symptom checklist (Currie et al., 2008), which includes eight common symptoms: Headache, stomach-ache, dizziness, backache, feeling low, irritability/bad temper, difficulty sleeping, and nervousness. These symptoms can be thought of as constituting two dimensions that differ qualitatively; somatic and psychological symptoms (Haugland et al., 2001). Children were asked how often in the last six months they had felt any of the symptoms with the following response categories: 1) 'about every day', 2) 'more than once a week', 3) 'about every week', 4) 'about every month', and 5) 'rarely or never'. Items within the scale have shown adequate content validity and test–retest reliability (Haugland & Wold, 2001). Internal consistency for psychological and somatic subscales respectively were acceptable in the present study ($\alpha = 0.74$, $\alpha = 0.72$).

Drinking. The number of self-reported heavy episodic (binge) drinking (HED) episodes in the previous 30 days (defined as the consumption of ≥6 units of alcohol [males]/ ≥4.5 units [females]) was assessed. HED was reported as 0, 1…, 6 or more episodes. To help assess HED, participants were presented with pictorial prompts of how much alcohol ≥6/≥4.5 UK units represents. Pictures presented the most popular drinks typically consumed by adolescents, and

participants were asked to report the frequency of consuming this amount of alcohol over the previous month (Blinded for review).

Smoking. Lifetime use of cannabis or cigarettes was assessed with two single-item questions: '*Have you ever smoked a cigarette/used cannabis in your life?*' Response options were yes/no.

Statistical analyses

Given the large attrition between T1 and T2 (attributable to the cessation of compulsory school attendance at the end of the T1 school year) we conducted preliminary analyses, examining differences between those leaving education after year 12 (T1) and those remaining in education after year 12.

Basic demographic information and descriptive statistics were collected to characterise the sample. All additional statistical analyses were limited to those participants who took part in all three waves of the study. Linear regression analyses were used to investigate the bi-directional relationship between PA, SRH, and mental well-being. Outcomes were measured at T3. Exposures were measured at T2, and change scores were created capturing the time period between T2 and T3. All analysis were adjusted for previously defined confounders including prior (T1) PA, SRH, and mental well-being as well as the outcome at T2. Additionally, each analysis was stratified by gender to examine where these effects were observed in boys and girls.

To assess change over time, linear regression was used to investigate which variables were associated with PA at T2 and change in PA between T2 and T3. All predictors were measured at T1, and analyses adjusted for T1 score. Predictors included gender, free school meals (FSM) entitlement (proxy SES), urbanicity, smoking, binge drinking status, psychological

symptoms, somatic symptoms, and past PA. Univariate and multivariate analysis were both investigated. All analyses were computed using Stata v.17.

Results

Demographic results

Preliminary analyses (Odds ratios [OR], 95% confidence intervals [CI]I) comparing those participating at T1 only, with those transitioning on into sixth form schooling, revealed that those remaining in education were more likely to be female (OR = 2.15, 1.90 - 2.43), to live rurally (OR = 1.12, 1.01 - 1.24), to report higher mental well-being (OR = 1.12, 1.01 – 1.24), but less likely to be entitled to a free school meal (OR = 0.52, 0.44 – 0.60), less likely to meet WHO PA guidelines (OR = 0.96, 0.93 – 0.99), less likely to report lifetime smoking (OR = 0.44, 0.37 – 0.52), or lifetime HED (OR = 0.52, 0.45 – 0.59).

Table 1 depicts the percentage of boys and girls who took part at each wave and met the closest approximation to the WHOs recommended daily PA for this age group. Additionally, the table contains the percentage who perceived their health as “poor”, the average of the well-being scores, and the number of those who report “Low” (score < 41) mental well-being. Full proportions for the two main variables of interest (PA & SRH) are displayed in Supplementary Table S1. Less than 6% of the sample neared the WHOs recommended PA guidelines at each of the three waves. At each wave, at least twice the proportion of boys met these criteria than girls. A small proportion (less than 2% at each wave) reported their health as ‘poor’, with a greater proportion of boys than girls doing so at each wave. Between 9-15% of the overall sample met criteria for low mental well-being and girls were more likely to meet this threshold than boys. At all waves of the study, we observed that a significantly higher proportion of boys, than girls, met the WHOs recommend threshold for weekly PA. There was no significant difference between

boys and girls in the percentage reporting poor SRH. Mental well-being, when measured both categorically and as a continuous measure, was significantly lower in girls than boys but with small effect sizes.

Table 1 about here

Fisher's exact test results (Supplementary Table S1) revealed significant gender differences for all variables, at each wave of data collection. However, in all cases, Cramer's *V* effect size values were in the small range (< .30). For example, results show that more than twice the proportion of boys than girls self-rated their health as 'excellent' at all times points. In terms of WHO guidelines for PA, approximately three times the proportion of males reported at least 60 minutes of PA on every day of the previous week than females. Of note, the overall proportion of participants meeting the WHO guidelines was low: 5.6% at T1; 5.4% at T2; and 4% at T3.

Aim 1: *To examine the degree of self-reported PA, the level of mental well-being, and SRH (descriptive data) in this population (Table 1).*

Physical activity longitudinal association with mental well-being

Higher PA at T2 and increases in PA between T2 and T3 (hereafter 'over time') were associated with a small improvement in mental well-being at T3 (β = 0.03 [95% CI = 0.02, 0.05]); and change (β = 0.03 [95% CI = 0.01, 0.05]). These relationships were observed after stringent adjusting for demographic characteristics, prior PA, SRH, and mental well-being (all at T1) as well as current (T2) mental well-being. Stratified analysis revealed that the effects of PA and changes in PA over time were small-sized both at T3 (β = 0.04 [95% CI = 0.02, 0.06]), and over time (β = 0.04 [95% CI = 0.02, 0.06]). The effects in boys were not statistically significant

at T3 (β = 0.02 [95% CI = -0.01, 0.05]) nor over time (β = 0.01 [95% CI = -0.01, 0.04]). Strong auto-regressive effects of mental well-being were observed in all models.

PA longitudinal association with SRH

Higher PA at T2 and increases in PA between T2 and T3 were associated with better SRH at T3 (β = 0.06 [95% CI = 0.03, 0.08]); and change over time (β = 0.08 [95% CI = 0.06, 0.10]). Again, these effects were observed after adjusting for demographic characteristics, prior PA, SRH, and mental well-being (all at T1) as well as current (T2) SRH. Stratified analysis revealed that the effects of PA and changes in PA on SRH for boys were small-sized at T3 (β = 0.10 [95% CI = 0.06, 0.14]), and over time (β = 0.12 [95% CI = 0.08, 0.16]). Small-sized effects were also observed in analyses restricted to girls for T3 (β = 0.02 [95% CI = 0.01, 0.05]) and over time (β = 0.06 [95% CI = 0.03, 0.08]). Strong auto-regressive effects of self-rated health were observed in all models.

Longitudinal association of SRH and mental well-being with PA

SRH (β = 0.29 [95% CI = 0.18, 0.41]), changes in SRH (β = 0.34 [95% CI = 0.24, 0.44]) changes in mental well-being (β = 0.18 [95% CI = 0.04, 0.32]) but not current (T2) mental well-being (β = -0.03 [95% CI = -0.19, -0.13]) were associated with PA at follow-up (T3). These effects were observed after adjusting for demographic characteristics, prior PA, SRH, and mental well-being (all at T1) as well as current (T2) SRH. Stratified analysis revealed moderate-sized effects of SRH and changes in SRH on PA for boys at T3 (β = 0.48 [95% CI = 0.29, 0.68], and over time (β = 0.49 [95% CI = 0.33, 0.65), whereas the effect sizes in analyses restricted to girls were small-sized at T3 (β = 0.14 [95% CI = -0.01, 0.30]), and over time (β = 0.23 [95% CI = 0.10, 0.36]). In girls, increases in mental well-being were associated with significantly higher PA at T3 (β = 0.31 [95% CI = 0.13, 0.49]) although current mental well-being score (T2) was not

significantly associated with PA at T3 (β = 0.18 [95% CI = -0.02, 0.38). In boys there was no effect of change in mental well-being on PA (β = 0.01 [95% CI = -0.24, 0.23) but those with lower mental well-being at T2 reported higher levels of PA at T3 (β = -0.36 [95% CI = -0.62, -0.09). Strong auto-regressive effects of PA were observed in all models.

Table 2 about here

Aim 2: *To identify socio-demographic and health variables that most strongly influenced both PA, and SRH (Table 2).*

The predictive effects of a number of demographic variables were considered including, risk-taking behaviours, psychological and somatic well-being on PA, and changes in PA. Table 2 displays the beta coefficients for univariate and multivariate analyses. Being female, lifetime smoking, higher psychological, and higher somatic symptomatology scores, were all associated with a lower level of PA at T3. Multivariate analyses indicated that being female, being a lifetime smoker, and higher psychological symptoms remained significantly related to T2 PA after adjustment for all variables in the model. Analyses showed that these variables accounted for 6.59% of the variance in PA at T3. However, none of the demographic variables were significantly associated with a change in PA between T2 and T3.

Aim 3: *To examine the bi-directional relationship between SRH, PA, and mental wellbeing; examine whether changes in perceived SRH and PA had an effect on mental well-being over time; examine the social and demographic variables that influenced SRH, PA, and changes in SRH and PA.*

Within Table 3 and Table 4, the results of the bi-directional relationships between PA, mental well-being, and SRH are presented. Overall, the results suggest that PA was significantly but weakly related to mental well-being (β values all $\leq$ .06). Larger effect sizes were observed in

the relationship between PA and SRH. As in the case of mental well-being, the relationship between self-reported PA at T1 and T2, and SRH at T3 were similar in magnitude (beta values). As would be expected, with increasing levels of statistical adjustment, the beta values decreased, however, all remained statistically significant. Said another way, T1 self-reported PA levels predicted both T3 SRH, and changes in SRH with time, even after adjusting considerably for socio-demographic and health-related variables.

Tables 3 and 4 about here

There was a notable difference in results when SRH, and mental well-being were operationalised as predictors of PA (Table 4). Looking firstly at SRH, results revealed that overall, higher SRH at both T1 and T2 (adjusted for socio-demographic variables) was associated with greater self-reported PA at T3. Of note, results suggested that this relationship was stronger in males than in females. Results remained statistically significant with increased statistical adjustment (models 3 and 4), and the same gender patterning of results was observed. Results for SRH predicting changes in PA followed a similar pattern, albeit with beta values smaller in magnitude. For both males and females, higher SRH status was significantly related to increased PA with time, with the effect sizes higher in males than in females. Again, results remained statistically significant in fully adjusted models.

Results for the relationship between mental well-being and PA were less substantial, less consistent, and more difficult to interpret. Only in more fully adjusted models was the relationship between mental well-being and PA statistically significant, where higher mental well-being at T2 was significantly associated with greater PA for females at T3, but less PA for males at T3. In terms of changes in PA between T2 and T3, higher mental well-being was significantly related to increased levels of PA, but only for females.

Finally, any significant interaction effects between any of the categorical measures on PA and SRH were explored. Tables (Tables S2 and S3), and figures (Figures SF1 to SF6) are displayed in Supplementary Materials. For gender and FSM entitlement, results showed that compared to boys entitled to FSM (reference group), girls entitled to FSM (β = -0.90), and girls not entitled to FSM (β = -0.98), reported significantly less PA. There were no significant interaction effects for change in PA between T2 and T3. Regarding the interaction between gender and urbanicity, results show that compared to males living in an urban setting (reference group), females living in an urban setting (β = -1.04), and females living in a rural setting (β = -0.86) reported significantly less PA. There were no significant interaction effects for change in PA between T2 and T3. Finally, with regard to the interaction effect of FSM entitlement and urbanicity, there were no significant effects on PA observed.

For gender and FSM entitlement, results showed that compared to boys entitled to FSM (reference group), girls entitled to FSM (β = -0.20), boys not entitled to FSM (β = -0.28), and girls not entitled to FSM (β = -0.44), reported significantly lower levels of SRH. In terms of change in SRH between T2 and T3, results showed that relative to boys entitled to FSM, girls entitled to FSM had significant increases in their SRH. Regarding the interaction of gender and urbanicity, compared to boys living in an urban setting (reference group), girls living in an urban setting reported significantly lower SRH (β = -0.27). All other interaction effects were non-significant. Finally, with regard to the interaction between FSM entitlement and urbanicity, compared to those entitled to FSM and living in an urban setting (reference), those not entitled to FSM and living in an urban (β = -0.21), and those not entitled to FSM and living in a rural setting (β = -0.20) reported significantly lower SRH. Conversely, compared to those entitled to

FSM and living in an urban setting (reference), those entitled to FSM and living in a rural context reported significantly higher SRH ($\beta = 0.11$).

In terms of the effect of PA on both mental well-being, and SRH, while there were some small sized effects (all beta values $\leq .12$), it must be remembered that these beta coefficients were adjusted for a range of confounding variables and are therefore indicative of some meaningful relationship. There were notable gender differences in these results, with more frequent PA significantly related to mental well-being in girls (but not boys), and more frequent PA related to SRH to a greater degree in boys than in girls. In terms of what actually predicted levels of PA, there were again, notable gender differences. There were further notable differential results (by gender) for the effect of both SRH and mental well-being, on PA. Overall, there was a significant and substantive ($.29 \leq \beta \leq .34$) effect of T2 SRH and change in SRH (T2 to T3), on PA at T3, however, results stratified by gender demonstrated that this effect was observed predominantly in males ($\beta_{T2} = .48$; $\beta_{T2\text{-}T3} = .49$) with corresponding values for girls being much lower ($\beta_{T2} = .14$; $\beta_{T2-T3} = .23$). Results for the effect of mental well-being on physical activity were complex, and to some degree, counter intuitive.

Increased levels of mental well-being between T2 and T3 for girls, was associated with an increased level of PA at T3, although there was no significant relationship between T2 mental well-being itself, and T3 PA. A completely different result was observed for boys, where there was no significant effect of changes in mental well-being on PA at T3, however, reduced levels of mental well-being at T2 were significantly associated with a greater amount of PA at T3. These results tentatively suggest that the motivation for PA is different between girls and boys, and that while in boys higher SRH predicts future (+12 month) PA, so too does lower mental well-being predict greater levels of PA (+12 months). In girls, higher levels of T3 PA were

observed when they became better, in terms of mental well-being between T2 and T3 (+12 months), with results robust to increased statistical adjustment for potential confounders.

Discussion

The present study used three waves of data, covering a 24-month period in middle to late adolescence, to examine the cross-sectional, longitudinal, and developmental inter-relatedness between PA, SRH, and a number of demographic variables. Overall, results show the inter-relatedness of SRH and levels of past week PA, with in particular, SRH, and changes in SRH predicting levels of PA in both boys and girls. In other words, those most likely to meet the WHO guidelines for MVPA were those who already rated their health highly. The idea that already healthy, or health-aware individuals are more likely to participate in PA is not new in the NI context. For example, using data from the Northern Ireland Young Hearts Study (NIYHS; McCourt et al., 2014) reported that participants with a higher 'healthy' (derived) score had a higher PA score, and also that participants with a higher Mediterranean Diet Score had a higher PA score. SRH has been shown to be a good predictor of objective health outcomes (e.g., Cislaghi & Cislaghi, 2019), and a recent meta-analysis demonstrated the strong inter-relatedness of SRH and PA. However, the relatively simplistic assessment of it herein does not allow us to disentangle self-rated physical health from self-rated mental health. In other words, it is not apparent whether high self-rated mental health, physical health, or a combination of both was the active ingredient in this relationship.

Despite this, the present study suggests that increased self-esteem about health is more likely to result in increased PA engagement. This finding, although seemingly simplistic, links to perhaps satisfaction of basic psychological needs derived from PA engagement (Gunnell et al., 2016; Paradis et al., 2014) and feelings of competence (Agans et al., 2017; Bedard et al., 2020)

and feelings of self-efficacy (Neissar & Raudsepp, 2011) and self-esteem (Ekeland et al., 2005). Previous research has also found a link to increased self-esteem and positive self-concept from sport/PA engagement (Kołoło et al., 2012; Rodgers & Sullivan, 2001; Slutzky & Simkins, 2009). However, Rodgers and Sullivan (2001) demonstrated a domain-specific effect for self-efficacy, with coping, and scheduling self-efficacy reported as variables of consequence, but task self-efficacy was not. Regarding the question of which comes first (physical activity increase leads to self-esteem, or self-esteem leads to PA increase), the relationship is likely reciprocal. Thus, one area to target for intervention may in fact be self-concept, as one way to increase PA engagement in adolescents.

Results for the relationship between mental well-being and PA at T3 (Table 4) suggested a gender effect where (counterintuitively) there was a negative relationship between mental well-being and PA for boys, but a positive relationship between mental well-being and PA for girls, with an overall non-significant effect. This firstly points to the importance of examining gender-specific effects in this relationship. Without a qualitative element to the study this finding is not easily explained. It is possible that boys use PA to ameliorate the negative effects of low mental well-being, or that lower mental well-being is not as keenly felt in young males. In terms of the change over time in PA, the overall positive effect of mental well-being on increasing PA is clearly driven by this effect in females. The results as a whole speak to the important role that mental well-being has in female PA.

There is international consensus on the validity of SRH as a good predictor of both morbidity and mortality (e.g., Burström & Fredlund; 2001; Cislaghi & Cislaghi, 2019), and the findings of the present study support this association in adolescents with respect to past week levels of PA. Elsewhere in adolescent studies, SRH has been shown to capture a person's

perception of their overall health status, physical and mental, and has been used as an indicator of health-related quality of life (Breidablik et al., 2009; Herman et al., 2015). These singular considerations do not really explain why higher SRH, but not higher mental well-being, predict PA in the present study. Perhaps a more nuanced assessment of PA may have produced more enlightening results. For example, sports-related PA can be individual (e.g., tennis, or swimming), or team (e.g., rugby or cricket) pursuits. Whereas low mental well-being (or low sense of self generally) may be a barrier to involvement in team sports, this may be reduced in the context of individual sports where a sense of physiological competence (SRH) might be sufficient, where less inter-personal engagement is necessary. These are matters which should be considered in studies going forward.

Another concerning finding from the current study is the overall low levels of PA reported (~5% of sample meeting guidelines), and the year-on-year reduction in the proportion of those engaging in 60 minutes of intense PA, something previously reported in the NI context in the NIYHS study, where Boreham et al. (1999) reported decreasing levels in PA between the ages of 12 and 15 years. Contemporary research has advocated for the importance of creating enjoyable and fun PA experiences (Adachi & Willoughby, 2014; Creighton et al., 2022; Ekkakakis & Zenko, 2016; Visek et al., 2021). Sport participation in school is the most common method in which adolescents may obtain PA engagement and has links to increased well-being and reduced depression and anxiety (Jewett et al., 2014; Kort-Butler & Hagewan, 2011).

In terms of the demographic variables that may moderate the relationship of PA and wellbeing, it was interesting to note that urbanicity and FSM entitlement (proxy SES) were not factors in lower PA or well-being. Likewise, smoking and alcohol use were also not factors in lower PA or mental well-being. Previous research has found that urbanicity can lead to barriers

in PA with lack of parks or green spaces (e.g., Mitra et al., 2020). However, the current sample had low PA levels overall, thus a number of factors may be contributing to not meeting the guidelines.

Attending to the descriptive data, some of the results are potentially concerning from the perspective of public health. The proportion of boys (10.6% - 7.2%) and girls (3.0% - 2.3%) which reported attaining the WHO PA target in the previous week were low, and decreased with each wave of data collection, while substantial proportions of both boys (24.4% - 31.0%) and girls (47.5% - 53.7%) reported taking 60 minutes of PA on two or less days in the previous week. Again, these proportions increased with each data collection wave. In short, as they approach late adolescence/early adulthood, almost half of the girls in this study undertook a substantial amount of PA on two or less days in the previous week. Results for self-rated health were not so stark (relatively speaking), where around 90% of both boys (90.0%, 90.5%, 88.6% respectively for T1 to T3), and girls (88.5%, 87.6%, 89.9% respectively) reported their health to be ‘good’ or above.

The present study is not without limitations. In the first instance, two of the main measures were assessed using single items. Secondly, because transition beyond statutory education (beyond the first wave of data collection in the present study) is over-represented by those in higher SES, the population-wide representativeness of the present results remains uncertain. However, this limitation is somewhat offset by adjustment for SES in the analyses. However, to counterbalance these limitations, strengths of the study include the relatively large sample size, the fact that data were collected at three time points over a two-year period, and that analyses were adjusted for a range of important socio-demographic and psycho-social measures.

A main takeaway of the current study is that positive self-assessments of one's health led to a greater likelihood of meeting the WHO PA guidelines. This leaves the ongoing challenge of reaching those who might view their health poorly, or even relatively poorly, to encourage them to engage in physical activity. This challenge has plagued the field of exercise and health psychology. Previous research has suggested that offering a variety of PA options may allow individuals to engage in activities that may suit their own perceived health status and thus increase feelings of competence and self-esteem. For example, encouraging a variety of PA options (Sylvester et al., 2014) and multi-sport sampling in youth (Sylvester et al., 2020) in addition to facilitating enjoyable PA experiences (Creighton et al., 2022; Ekkakakis & Zenko, 2016) can perhaps offer more appealing entry avenues for individuals to become physically active and result in longer term PA engagement across the lifespan.

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Table 1

Physical activity and mental well-being scores for the overall sample and boys and girls separately.

	Overall *N* (%)	Boys *N* (%)	Girls *N* (%)
60 minutes of physical activity every day in the past week %			
Wave 1***	101 (5.6)	67 (10.6)	34 (3.0)
Wave 2***	96 (5.4)	57 (9.0)	39 (3.4)
Wave 3***	73 (4.3)	46 (7.2)	27 (2.3)
Self-rated health as "Poor" %			
Wave 1	19 (1.1)	10 (1.6)	9 (0.8)
Wave 2	29 (1.7)	12 (1.9)	17 (1.5)
Wave 3	30 (1.8)	15 (2.4)	15 (1.3)
"Low" mental well-being %			
Wave 1***	167 (9.3)	37 (5.8)	130 (11.2)
Wave 2***	284 (15.9)	76 (12.0)	208 (18.0)
Wave 3***	241 (13.5)	70 (11.0)	171 (14.8)
Average mental well-being *Mean* (SD)			
Wave 1***[1]	50.7 (7.7)	52.3 (7.4)	49.7 (7.7)
Wave 2***[2]	48.7 (8.7)	50.4 (8.6)	48.8 (8.6)
Wave 3***[3]	49.2 (8.6)	50.5 (9.0)	48.5 (8.2)

Note: ***Statistically significant gender differences, $p < .001$. [1]Cohen's $d = 0.34$; [2]Cohen's $d = 0.29$; [3]Cohen's $d = 0.23$.

Table 2

Beta coefficients for the predictors of Physical Activity and changes in Physical Activity, and beta coefficient for the interactions of predictors with of Physical Activity and changes in Physical Activity.

Predictors (reference category)	**Physical Activity (T2)**		**Change in Physical Actively (T2 to T3)**
	Uni-variable	Multi-variable	Uni-variable
Gender (Male)	**-0.91** (-1.07, -0.74)	**-0.85** (-1.02, -0.68)	0.01 (-0.17, 0.17)
Free School Meals (FSM; Yes)	-0.10 (-0.32, 0.11)	-0.04 (-0.26, 0.17)	0.05 (-0.18, 0.27)
Urbanicity (Urban)	0.09 (-0.06, 0.25)	0.01 (-0.15, 0.18)	-0.06 (-0.22, 0.10)
Lifetime Smoking (T1 - Never)	**-0.53** (-0.77, -0.30)	**-0.45** (-0.73, -0.18)	**0.26** (0.18, 0.52)
Lifetime Cannabis Use (T1 - Never)	-0.37 (-0.76, -0.01)	-0.18 (-0.60, -0.23)	-0.11 (-0.53, 0.31)
Binge Drinking Status (T1 No)	-0.05 (-0.24, 0.14)	0.13 (-0.07, 0.34)	0.12 (-0.08, 0.31)
Somatic Symptoms (T1 continuous)	**-0.20** (-0.3, -0.10)	0.04 (-0.09, 0.17)	-0.06 (-0.18, 0.05)
Psychological Symptoms (T1 continuous)	**-0.25** (-0.34, -0.16)	**-0.15** (-0.26, -0.05)	0.08 (-0.02, 0.17)

Predictors (reference category)	**Physical Activity (T2)**	**Change in Physical Actively (T2 to T3)**
	Uni-variable	Uni-variable
Female*No FSM (Male*Yes FSM)	-0.06 (-0.30, 0.17)	-0.01 (-0.50, 0.49)
Female*Rural (Male*Urban)	0.28 (-0.05, 0.59)	0.15 (-0.20, 0.50)
Rural*No FSM (Urban* Yes FSM)	-0.27 (-0.71, 0.16)	-0.18 (-0.64, 0.27)

Note. FSM = free school meals entitlement. Bolded values indicate statistically significant results (confidence intervals not overlapping zero).

Table 3

Stepwise comparison of the coefficient betas for physical activity (baseline and change score) predicting mental well-being and self-rated health with increasingly stringent adjustment in the overall sample and stratified by gender.

	Model 1 T1->T3	**Model 2 T2->T3**	**Model 3 T2->T3 adjust T1**	**Model 4 T2->T3 Adjust T1+**
Physical Activity Predicting T3 Mental Well-being				
Baseline Score				
Overall	**0.04** (0.02, 0.05)	**0.04** (0.03, 0.06)	**0.04** (0.02, 0.06)	**0.04** (0.02, 0.06)
Boys	**0.04** (0.02, 0.06)	0.03 (-0.01, 0.06)	0.01 (-0.02, 0.05)	0.02 (-0.02, 0.05)
Girls	**0.04** (0.02, 0.06)	**0.05** (0.03, 0.07)	**0.06** (0.03, 0.08)	**0.06** (0.03, 0.08)
Change Score *(T3 minus Baseline, T1)*				
Overall	**0.03** (0.02, 0.05)	**0.03** (0.01, 0.05)	**0.03** (0.01, 0.04)	**0.03** (0.01, 0.04)
Boys	0.02 (-0.01, 0.04)	0.01 (-0.02, 0.04)	0.01 (-0.03, 0.03)	0.01 (-0.03, 0.03)
Girls	**0.04** (0.02, 0.06)	**0.04** (0.02, 0.06)	**0.04** (0.02, 0.06)	**0.04** (0.02, 0.06)
Physical Activity Predicting T3 Self-rated Health				
Baseline Score				
Overall	**0.17** (0.15, 0.19)	**0.14** (0.12, 0.17)	**0.10** (0.07, 0.12)	**0.10** (0.07, 0.13)
Boys	**0.23** (0.19, 0.26)	**0.21** (0.17, 0.25)	**0.15** (0.10, 0.19)	**0.15** (0.10, 0.19)
Girls	**0.13** (0.10, 0.16)	**0.10** (0.07, 0.13)	**0.07** (0.04, 0.10)	**0.08** (0.05, 0.11)
Change Score *(T3 minus Baseline, T1)*				
Overall	**0.12** (0.10, 0.14)	**0.11** (0.08, 0.13)	**0.09** (0.06, 0.11)	**0.09** (0.06, 0.11)
Boys	**0.16** (0.13, 0.19)	**0.16** (0.12, 0.20)	**0.13** (0.09, 0.17)	**0.12** (0.08, 0.17)
Girls	**0.09** (0.06, 0.12)	**0.07** (0.04, 0.11)	**0.06** (0.03, 0.09)	**0.06** (0.03, 0.09)

Note. Model 1: T1, Time 1 Exposure adjusted for Gender, Free School Meals, and Urbanicity.
Model 2: T2, Time 2 Exposure adjusted for Gender, Free School Meals, and Urbanicity.
Model 3: T2, Time 2 Exposure adjusted for Gender, Free School Meals, Urbanicity, T1 Outcome scores, T1 Exposure.
Model 4: T2 Exposure adjusted for Gender, Free School Meals, Urbanicity T1 Outcome scores, T1 Exposure, T1 Mental Well-being Score, Lifetime Cannabis Use by T1, Lifetime Smoking by T1 and Binge Drinking Status at T1.
Emboldened value denote value with $p < .05$.

Table 4

Stepwise Comparison of the coefficient betas for mental well-being and self-rated health (baseline and change score) predicting physical activity with increasingly stringent adjustment in the overall sample and stratified by gender.

	Model 1 T1->T3	**Model 2 T2->T3**	**Model 3 T2->T3 adjust T1**	**Model 4 T2->T3 Adjust T1+**
Self-rated health predicting T3 Physical Activity				
Baseline Score				
Overall	**0.81** (0.70, 0.91)	**0.73** (0.62, 0.85)	**0.49** (0.37, 0.62)	**0.50** (0.38, 0.64)
Boys	**1.00** (0.84, 1.15)	**1.02** (0.84, 1.20)	**0.70** (0.50, 0.90)	**0.69** (0.48, 0.90)
Girls	**0.65** (0.52, 0.79)	**0.51** (0.35, 0.66)	**0.33** (0.17, 0.49)	**0.36** (0.19, 0.52)
Change Score *(T6 minus Baseline)*				
Overall	**0.50** (0.41,0.59)	**0.42** (0.30, 0.53)	**0.34** (0.23, 0.45)	**0.35** (0.24, 0.46)
Boys	**0.69** (0.55,0.83)	**0.62** (0.44, 0.79)	**0.53** (0.36, 0.70)	**0.51** (0.33, 0.68)
Girls	**0.36** (0.23,0.48)	**0.26** (0.11, 0.40)	**0.21** (0.07, 0.35)	**0.23** (0.06, 0.38)
Mental Well-being predicting T3 Physical Activity				
Baseline Score				
Overall	-0.04 (-0.19, -0.11)	-0.02 (-0.18, 0.14)	0.01 (-0.16, 0.19)	0.03 (-0.15, 0.20)
Boys	0.01 (-0.25, -0.26)	-0.25 (-0.52, 0.02)	**-0.35** (-0.64, -0.06)	**-0.36** (-0.66, -0.07)
Girls	-0.03 (-0.22, -0.16)	0.14 (-0.06, 0.35)	**0.24** (0.03, 0.46)	**0.28** (0.06, 0.50)
Change Score *(T3 minus Baseline, T1)*				
Overall	0.09 (-0.04, 0.22)	**0.18** (0.01, 0.34)	**0.23** (0.07, 0.38)	**0.23** (0.07, 0.38)
Boys	-0.12 (-0.33, 0.09)	0.01 (-0.24, 0.27)	0.01 (-0.24, 0.26)	0.01 (-0.24, 0.26)
Girls	**0.23** (0.06, 0.40)	**0.31** (0.10, 0.52)	**0.37** (0.18, 0.57)	**0.38** (0.18, 0.58)

Note. Model 1: T1, Time 1 Exposure adjusted for Gender, Free School Meals and Urbanicity.
Model 2: T2, Time 2 Exposure adjusted for Gender, Free School Meals and Urbanicity.
Model 3: T2, Time 2 Exposure adjusted for Gender, Free School Meals, Urbanicity, T1 Outcome scores, T1 Exposure.
Model 4: T2 Exposure adjusted for Gender, Free School Meals, Urbanicity T1 Outcome scores, T1 Exposure, T1 Mental Well-being Score, Lifetime Cannabis Use by T1, Lifetime Smoking by T1 and Binge Drinking Status at T1.
Emboldened value denote value with $p < .05$.

Supplementary Table S1

Percentage and raw number of participants in each outcome for self-rated health and physical activity when stratified by gender.

Self-rated Health						
Rating	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**	
Males T1 % (n)	1.6 (10)	8.4 (53)	31.0 (195)	42.3 (266)	16.7 (105)	Fisher's = < .001
Females T1 % (n)	0.8 (9)	10.8 (124)	36.9 (424)	43.3 (497)	8.3 (95)	Cramer's *V* = 0.14
Males T2 % (n)	1.9 (12)	7.6 (48)	33.4 (210)	41.5 (261)	15.6 (98)	Fisher's = <.001
Females T2 % (n)	1.5 (17)	11.0 (126)	40.0 (460)	41.2 (473)	6.4 (73)	Cramer's *V* = 0.16
Males T3 % (n)	2.4 (15)	9.1 (57)	31.3 (197)	43.1 (271)	14.2 (89)	Fisher's = <.001
Females T3 % (n)	1.3 (15)	8.9 (102)	41.0 (471)	41.8 (480)	7.1 (81)	Cramer's *V* = 0.14
Number of days in previous week when recommended levels of Physical Activity were attained						
Days	**0**	**1-2**	**3-4**	**5-6**	**7**	
Males T1 % (n)	4.6 (29)	19.8 (126)	39.2 (249)	25.8 (164)	10.6 (67)	Fisher's = <.001
Females T1 % (n)	6.9 (79)	40.6 (468)	32.9 (380)	16.7 (193)	3.0 (34)	Cramer's *V* = 0.26
Males T2 % (n)	5.7 (36)	23.5 (149)	40.5 (257)	21.4 (136)	9.0 (57)	Fisher's = <.001
Females T2 % (n)	12.7 (146)	37.2 (429)	33.0 (381)	13.8 (159)	3.4 (39)	Cramer's *V* = 0.22
Males T3 % (n)	7.1 (45)	23.9 (152)	38.4 (244)	23.3 (148)	7.2 (46)	Fisher's = <.001
Females T3 % (n)	12.5 (144)	41.2 (475)	31.8 (367)	12.2 (141)	2.3 (27)	Cramer's *V* = 0.24

Note. Results are based on the *n* = 1,789 individuals who have data at all-time points.

Supplementary Table S2

Margins plots and marginal effects of the interaction between Urbanicity, Gender and Free School Meals entitlement on Physical Activity.

Predictors	Physical Activity (T2) Uni-variable	Change in Physical Activity (T2 to T3) Uni-variable
FSM and Gender (Figure 1)		
Males with FSM	Ref	Ref
Females with FSM	**-0.90** (-1.09, -0.72)	0.02 (-0.18, 0.22)
Males with No FSM	-0.01 (-0.37, -0.35)	0.05 (-0.36, 0.46)
Females with No FSM	**-0.98** (-1.26, -0.71)	0.06 (-0.23, 0.35)
Urbanicity and Gender (Figure 2)		
Males with Urban	Ref	Ref
Females with Urban	**-1.04** (-1.28, -0.81)	0.04 (-0.30, 0.22)
Males with Rural	-0.05 (-0.31, 0.22)	0.05 (-0.34, 0.25)
Females with Rural	**-0.86** (-1.09, -0.63)	0.03 (-0.22, 0.28)
FSM and Urbanicity (Figure 3)		
FSM with Urban	Ref	Ref
No FSM with Urban	0.02 (-0.26, -0.31)	0.13 (-0.18, -0.44)
FSM with Rural	0.10 (-0.08, -0.29)	0.06 (-0.12, -0.25)
No FSM with Rural	-0.15 (-0.48, -0.18)	0.02 (-0.32, -0.35)

Note. Bolded values indicate statistically significant results (confidence intervals not overlapping zero).

Supplementary Table S3

Margins plots and marginal effects of the interaction between Urbanicity, Gender and Free School Meals entitlement on Self-rated Health.

Predictors	Self-rated Health (T2)	Change in Self-rated Health (T2 to T3)
	Uni-variable	Uni-variable
FSM and Gender (Figure 1)		
Males with FSM	Ref	Ref
Females with FSM	**-0.20** (-0.29, -0.11)	**0.11** (0.01, 0.20)
Males with No FSM	**-0.28** (-0.45, -0.11)	0.05 (-0.14, 0.25)
Females with No FSM	**-0.44** (-0.57, -0.31)	0.10 (-0.04, 0.24)
Urbanicity and Gender (Figure 2)		
Males with Urban	Ref	Ref
Females with Urban	**-0.27** (-0.38, -0.16)	0.11 (-0.01, 0.23)
Males with Rural	-0.04 (-0.09, 0.16)	0.03 (-0.11, 0.17)
Females with Rural	-0.11 (-0.22, 0.001)	0.11 (-0.01, 0.23)
FSM and Urbanicity (Figure 3)		
FSM with Urban	Ref	Ref
No FSM with Urban	**-0.21** (-0.34, -0.07)	0.06 (-0.09, 0.21)
FSM with Rural	**0.11** (0.03, 0.20)	0.04 (-0.05, 0.13)
No FSM with Rural	**-0.20** (-0.35, -0.05)	0.01 (-0.15, 0.17)

Note. Bolded values indicate statistically significant results (confidence intervals not overlapping zero).

Figure SF1. Physical activity (Left) and change in Physical activity (Right) by FSM and Gender

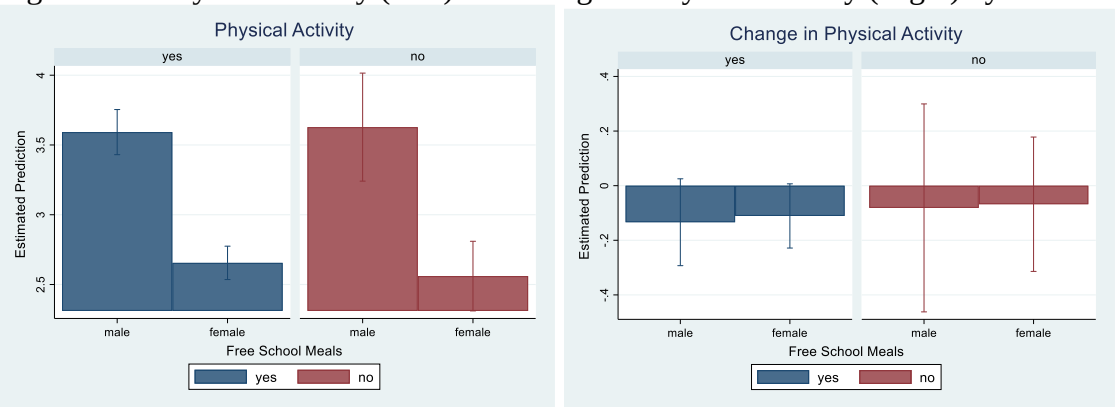

Figure SF2. Physical activity (Left) and change in Physical activity (Right) by Urbanicity and Gender

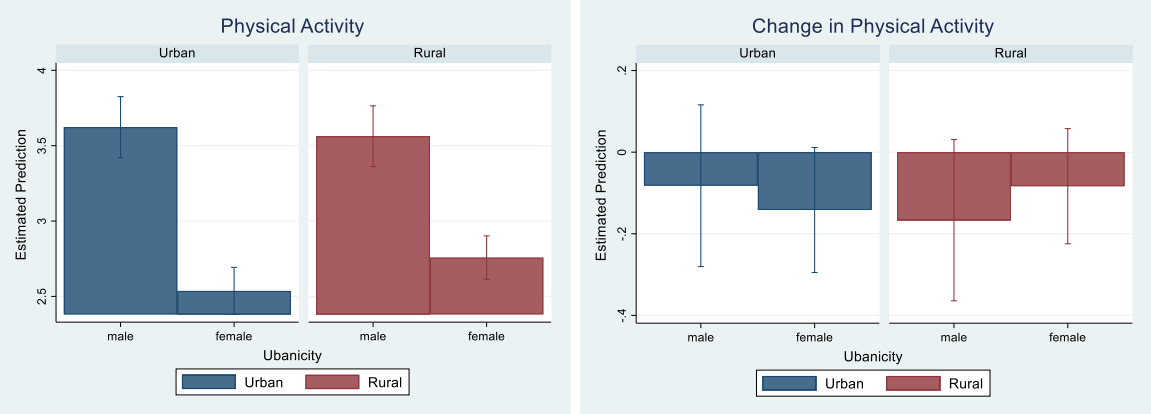

Figure SF3. Physical activity (Left) and change in Physical activity (Right) by Urbanicity and FSM

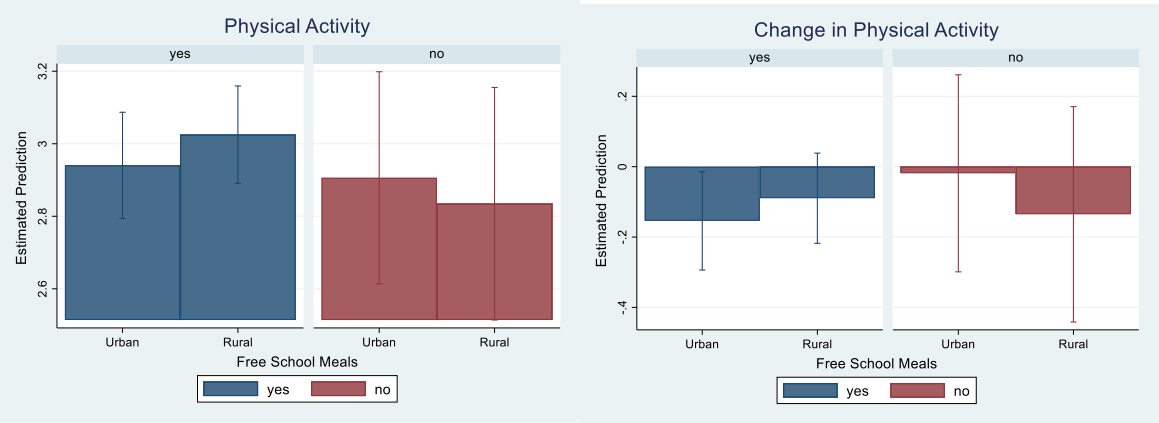

Figure SF4. Self-rated health (Left) and change in self-rated health (Right) by FSM and Gender

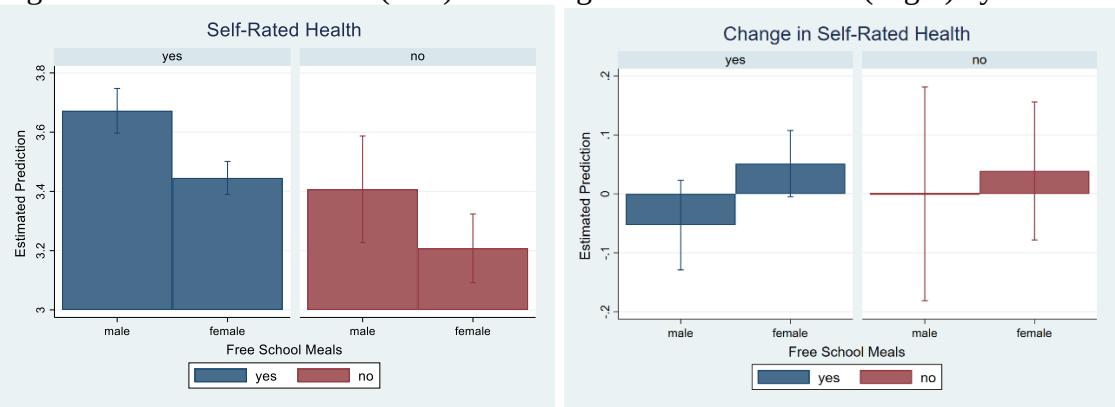

Figure SF5. Self-rated health (Left) and change in self-rated health (Right) by urbanicity and Gender

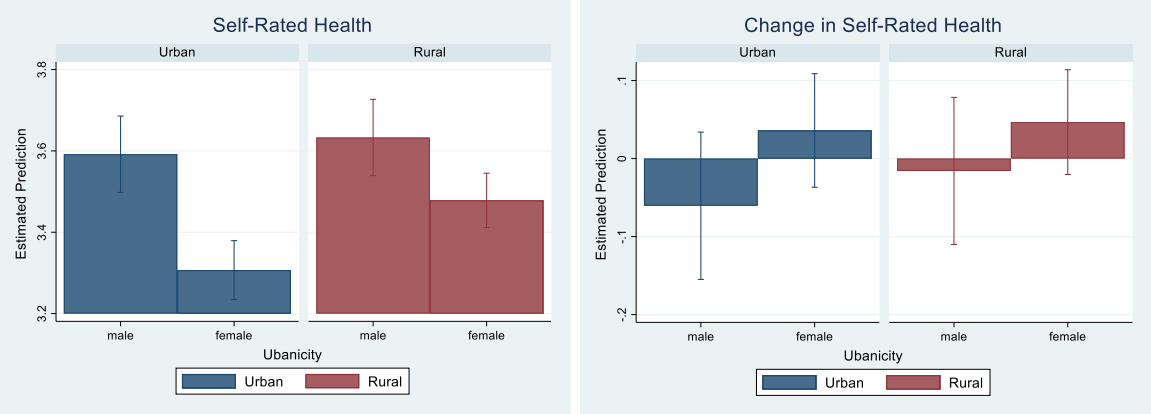

Figure SF6. Self-rated health (Left) and change in self-rated health (Right) by urbanicity and FSM