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# Adolescent Overweight and Obesity in Ireland—Trends and Sociodemographic Associations Between 1990 and 2020

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# Adolescent overweight and obesity in Ireland—Trends and sociodemographic associations between 1990 and 2020

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## Summary

**Background:** Overweight and obesity in adolescence is a growing issue and can have a range of both short- and long-term consequences on health.

**Objectives:** To analyse trends in adolescent weight status in Ireland across a 30-year period and to examine the influence of sociodemographic factors on overweight/obesity in Irish adolescents over time.

**Methods:** Body composition and body mass index weight status of Irish adolescents were compared using data from three nationally representative, cross-sectional Irish national food consumption surveys from 1990, 2006 and 2020. Adjusted analysis of associations between socio-demographic factors with the risk of adolescent overweight/obesity at each time point were examined.

**Results:** The prevalence of Irish adolescents with overweight/obesity has increased significantly in recent years, with 24% of adolescents living with overweight/obesity in 2020 compared to 18% in 2006 and 13% in 1990 ($p < 0.001$). Of note is a substantial increase in the prevalence of obesity, with 8% of adolescents living with obesity in 2020 compared to 3% in 2006 and 0.5% in 1990 ($p < 0.001$). A lower affluence social class was associated with 3.95 increased odds of adolescent overweight/obesity (95%CI 2.06–7.61) ($p < 0.001$) in 2020 only, with 41% of adolescents from the lowest affluence social class affected by overweight/obesity. Parental education level was inversely associated with the risk of adolescent overweight/obesity in 2006 and 2020, with a stronger effect in 2020.

**Conclusion:** There is an increasing prevalence of adolescents living with overweight/obesity in Ireland, with evidence of a growing socioeconomic gradient of overweight/obesity where adolescents affected by socioeconomic disadvantage are most at risk.

KEYWORDS
adolescent, obesity, overweight, social class, socioeconomic gradient, trends

## 1 | INTRODUCTION

Obesity and overweight in adolescence are associated with a range of both short- and long-term consequences, including immediate unfavourable effects on physical and psychological health and a significantly increased risk of obesity and adverse health outcomes in adulthood,[1] including cardiovascular disease, type 2 diabetes, and cancer.[2] The development of an unhealthy weight status and obesity-related behaviours during adolescence strongly persists into adulthood,[3] posing this time point as a key stage for intervention for the treatment and prevention of overweight and obesity.

Efforts in childhood obesity prevention have increased exponentially in recent years and appear to be relatively successful in their efforts, with rates amongst children appearing to be approaching a plateau in Ireland[4] and across certain developed countries.[5] However, these plateaus appear to be rare and temporary, with overall exponential increases in overweight and obesity amongst youth observed globally.[6] A rapidly increasing prevalence of adolescents living with obesity has become very apparent in recent years, with one in four adolescents in Europe identified as living with overweight/obesity in 2022,[6] increased from one in five in 2019 and one in six in 2010.[7] Similar rising trends have been observed across several high-income countries, including the US[8] and much of Europe,[9] with adolescent obesity identified by the World Health Organization (WHO) as a serious public health challenge facing the European Region.[10] Overweight and obesity amongst Irish adolescents is a growing cause for concern, with data from the Global Burden of Disease Study 2016 identifying Ireland as having the 10th highest level of adolescent obesity in the developed world in 2016.[9] Surveillance of adolescent weight status in Ireland has been particularly lacking in recent years, highlighting the need for an updated depiction of the weight status of Irish adolescents.

Obesity is a multifactorial chronic disease, influenced by a complex interplay of biological, genetic, environmental, social, and behavioural factors. Socio-ecological models of obesity demonstrate the multiple distinct yet related factors that contribute to the risk of obesity, with overarching social elements such as household and neighbourhood characteristics identified as significant influential factors in the risk of overweight/obesity amongst youth.[11] The growth and development of the "social brain" in adolescence results in increased social cognition and awareness of norms, making adolescents particularly attuned to the influences of the family, community, physical environment, and socioeconomic resources on their decision-making.[12] Existing research has indicated that adolescents are particularly susceptible to the effects of social and environmental determinants of obesity, such as level of parental educational attainment, family structure, and neighbourhood amenities.[13]

The "socioeconomic gradient of obesity" describes the inverse relationship between obesity and social class, with both the incidence and the severity of obesity tending to increase as social class decreases and vice versa. Socioeconomic disadvantage has been consistently associated with an increased risk of adolescent overweight and obesity across many high-income countries,[14] with evidence indicating an increased prevalence of obesity risk factors including reduced physical activity and less healthful food choices amongst adolescents from a lower socioeconomic position.[15] According to WHO estimates, 27% of adolescent obesity in Europe was associated with socioeconomic differences in 2014, a rise from 18% in 2002, which has been attributed, at least in part, to increases in income inequality in more recent years.[10]

The aim of this research was to depict trends and changes in adolescent weight status across three different time points from 1990, 2006 and 2020 using data from nationally representative Irish National Nutrition Surveys. These analyses aimed to examine the prevalence of adolescents living with overweight and obesity across gender and social class groups at each of these time points, with a focus on assessing the association of sociodemographic factors on adolescent weight status over time.

## 2 | METHODS

### 2.1 | Study design and participants

The data in this analysis are derived from the Irish National Nutrition Survey 1990 (INNS 1990), the National Teens' Food Survey 2005–2006 (NTFS 2006) and the National Teens' Food Survey II 2019–2020 (NTFS II 2020). Each cross-sectional food consumption survey encompassed a nationally representative sample of school-going adolescents in the Republic of Ireland at each time point. The INNS 1990 was conducted in 1990 and contained a sample of 390 school-going adolescents aged between 13 and 18 years (43% male), who were recruited from a sample of post-primary schools stratified by county.[16] The NTFS 2006 was conducted between 2005 and 2006 amongst a representative sample of adolescents aged 13 to 17 years ($n = 441$, 51% male) recruited from post-primary schools.[17] The NTFS II 2020 conducted between 2019-2020 recruited school-aged adolescents aged 13 to 18 years ($n = 428$, 49% male) from post-primary schools to provide a demographically balanced sample when compared to data from the 2016 National Census of Ireland.[18]

### 2.2 | Assessment of body composition

Each of these cross-sectional national dietary surveys obtained anthropometric measurements from adolescents through a similar protocol, thereby providing comparable datasets. Anthropometric assessments of participants were conducted by trained researchers (qualified dietitians or nutritionists) in all three surveys using standardized techniques. Height was measured by a stadiometer to the nearest 0.1 cm with the participant standing barefoot in an upright position with their heels, buttocks and back to the backboard of the stadiometer and their head positioned in the Frankfurt Plane for all three surveys. Body weight (kg) was measured in duplicate for all three surveys, with calibrated digital personal weighing scales used in INNS 1990 and NTFS 2006 and a Tanita® Body Composition Analyser (BC-420MA, Tanita LTD, GB) used for NTFSII 2020, with all devices placed on a hard level surface. Adolescents were measured barefoot,

in light clothing with pockets emptied and after voiding. Waist and hip circumference measurements were measured by trained researchers in both the NTFS 2006 and the NTFS II 2020 only, with measurements taken in duplicate to the nearest 0.1 cm using a Seca 201 Measuring Tape (Seca, Birmingham, UK). Waist circumference (WC) was measured on the bare skin where possible, with the waist defined as the halfway point between the bottom of the rib cage and the supra-iliac crest. Hip circumference (HC) measurements were taken over light clothing around the greater trochanter, with measurements conducted in duplicate to the nearest 0.1 cm. Percentage body fat (% BF) was assessed in the NTFS II 2020 only, with % BF estimated via tetrapolar bioelectrical impedance using the Tanita® Body Composition Analyser (BC-420MA, Tanita LTD, GB). All measurements were taken in duplicate to the nearest 0.1%, with the device calibrated in line with the manufacturer's instructions and placed on a hard level surface and the adolescent was measured barefoot, wearing light clothing and after voiding.

## 2.3 | Defining weight status

Body mass index (BMI) was calculated (weight (kg)/height ($m^2$)) and age and gender adjusted BMI *z*-scores were computed using the "LMSGrowth" Microsoft Excel Add-in, which uses the LMS method to derive standard deviation score (SDS) based on method-specific reference values of height and weight.[19] BMI z-scores were converted to percentiles using IBM SPSS statistics software package version 27. Adolescents were then classed according to BMI percentile-derived weight status as determined using three established methods: the International Obesity Task Force (IOTF) BMI thresholds,[20] the UK90 BMI population level reference curves[21] and the WHO growth reference curves,[22] with morbid obesity defined using the IOTF and the UK90 cut-offs. Age and gender-adjusted % body fat z-scores were calculated using the "LMSgrowth" Microsoft Excel Add-in, with %BF percentiles subsequently computed. Classification of adolescents as having under fat, normal %BF, overfat and obesity was determined based on age and gender-specific %BF reference curves.[23] Central obesity was assessed for adolescents from NTFS 2006 and NTFS II 2020 only as WC was not available in INNS 1990. Age- and gender-standardized WC and waist-to-height ratio (WHtR) *z*-scores were computed using NHANES LMS tables for 5 to 19 years,[24] with central obesity defined as a WC ≥90th centile as per the established international WC cut-offs for central obesity in children and adolescents.[25] WHtR was computed for NTFS 2006 and NTFS II 2020, with abdominal overweight/obesity defined as a WHtR ≥0.50.[26] Waist-to-hip circumference ratio was calculated by dividing the mean of the duplicate WC measurements (cm) by the mean of the duplicate HC measurements (cm).

## 2.4 | Sociodemographic classification

Family sociodemographic information, including social class and education level, was collected via Health and Lifestyle questionnaires completed by the participant and both of their parents/guardians where possible. Household location was recorded for each participant and was classified as urban or rural based on the definitions provided by the Irish Central Statistics Office (CSO), which classifies an urban area as a town with a total population ≥1500 and rural areas as those with a population <1500.[18] Adolescent social class was assessed via the current or previous occupation type of the adolescents' parents/guardians. Social class groups were allocated based on the defined social class groups from the Irish CSO (listed in descending order): professional, managerial, and technical workers, non-manual workers, skilled manual workers, and semi-skilled and unskilled workers (including students).[18] The current or previous occupation of both parents/ guardians was assessed whenever possible, and in cases where the occupations provided resulted in two different social class codes, the participant was allocated to the higher social class group. The NTFS II 2020 cohort contained a higher proportion of adolescents of professional workers and a lower proportion of adolescents of semi-skilled and unskilled workers than the national population. Therefore, a statistical weighting factor was applied to the data from NTFS II 2020 to adjust and account for the under-representation of adolescents from the lower social class groups. Parental education level was assessed via the same Health and Lifestyle questionnaire, with parents/guardians stratified according to their level of educational attainment using categories defined by the Irish CSO: primary/intermediate education, secondary education, or tertiary education.[18] In cases where two different levels of parental educational attainment were present within the same household, the participant was allocated to the higher education level group.

## 2.5 | Statistical analysis

All statistical analysis was performed using the IBM SPSS Statistics software package version 27. Differences in the prevalence of BMI and WC-derived adolescent overweight and obesity over time and across social class status were assessed using the $\chi^2$ test. Significance across all tests was defined as $p < 0.05$, with Bonferroni correction for multiple comparisons applied by multiplying each $p$ value by the number of traits in each table, with those that exceeded 1.0 marked down to 1.00. Effect sizes are presented for statistically significant results as partial eta squared ($\eta^2$), with 0:01 $\eta^2$ < 0:06 deemed as a small effect, 0:06 $\eta^2$ < 0:14 classed as a medium effect and $\eta^2$ ≥ 0:14 classed as a large effect. Trends and differences in adolescent height, weight, BMI, WC, HC, waist to hip ratio and weight to height ratio across surveys were assessed using a general linear model adjusted for age and gender where applicable. Age and gender-adjusted binary logistic regression were applied to assess the influence of sociodemographic factors on the risk of adolescent overweight/obesity, with an adjusted odds ratio and 95% confidence intervals presented for having overweight/obesity.

# 3 | RESULTS

Slight differences in the gender proportions of each survey were observed, with INNS 1990 containing a higher prevalence of females

**TABLE 1** Anthropometric and body composition measurements of adolescents in Ireland in 1990, 2006 and 2020

| | INNS 1990 | | | | | NTFS 2005–2006 | | | | | NTFS II 2019–2020* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 95% CI | | | | | 95% CI | | | | | 95% CI | | | |
| | *n* | Mean | SE | Lower | Upper | *n* | Mean | SE | Lower | Upper | *n* | Mean | SE | Lower | Upper | *p* | $n_p^2$ |
| *Total population* | | | | | | | | | | | | | | | | | |
| Weight (kg)† | 389 | **55.3**[a] | 0.6 | 54.2 | 56.3 | 440 | **60.02**[b] | 0.5 | 59.0 | 60.7 | 425 | **61.8**[b] | 0.5 | 60.7 | 62.8 | **<0.001** | **0.059** |
| Height (cm)† | 389 | **162.7**[a] | 0.4 | 161.9 | 163.5 | 441 | **166.5**[b] | 0.4 | 165.7 | 167.3 | 426 | **166.9**[b] | 0.4 | 166.1 | 167.7 | **<0.001** | **0.045** |
| BMI (kg/m$^2$)† | 389 | **20.7**[a] | 0.2 | 20.4 | 21.1 | 440 | **21.6**[b] | 0.2 | 21.3 | 21.9 | 425 | **22.1**[b] | 0.2 | 21.8 | 22.4 | **<0.001** | **0.027** |
| WC (cm)† | - | - | - | - | - | 437 | **75.0**[a] | 0.4 | 74.1 | 75.8 | 426 | **72.8**[b] | 0.4 | 71.9 | 73.7 | **<0.001** | **0.013** |
| HC (cm)† | - | - | - | - | - | 437 | 93.4 | 0.4 | 92.7 | 94.1 | 426 | 93.6 | 0.4 | 92.9 | 94.3 | 1.000 | - |
| Waist: hip ratio† | - | - | - | - | - | 436 | **0.8**[a] | 0.0 | 0.8 | 0.8 | 426 | **0.8**[b] | 0.0 | 0.8 | 0.8 | **<0.001** | **0.048** |
| Waist: height ratio† | - | - | - | - | - | 437 | **0.5**[a] | 0.0 | 0.4 | 0.5 | 426 | **0.4**[b] | 0.0 | 0.4 | 0.4 | **<0.001** | **0.020** |
| % Body Fat | - | - | - | - | - | - | - | - | - | - | 424 | 20.6 | 0.4 | 19.8 | 21.5 | - | - |
| *Males* | | | | | | | | | | | | | | | | | |
| Weight (kg)† | 165 | **56.4**[a] | 0.9 | 54.7 | 58.2 | 224 | **62.3**[b] | 0.8 | 60.8 | 63.9 | 211 | **64.0**[b] | 0.8 | 62.5 | 65.6 | **<0.001** | **0.077** |
| Height (cm)† | 165 | **166.1**[a] | 0.6 | 164.9 | 167.3 | 224 | **170.6**[b] | 0.5 | 169.6 | 171.6 | 211 | **171.3**[b] | 0.5 | 170.3 | 172.4 | **<0.001** | **0.076** |
| BMI (kg/m$^2$)† | 165 | **20.2**[a] | 0.3 | 19.7 | 20.7 | 224 | **21.3**[b] | 0.2 | 20.9 | 21.8 | 211 | **21.6**[b] | 0.2 | 21.2 | 22.1 | **<0.001** | **0.030** |
| WC (cm)† | - | - | - | - | - | 223 | 76.3 | 0.6 | 75.1 | 77.6 | 211 | 75.0 | 0.6 | 73.7 | 76.3 | 0.492 | - |
| HC (cm)† | - | - | - | - | - | 223 | 92.9 | 0.5 | 91.9 | 93.9 | 211 | 92.6 | 0.5 | 91.6 | 93.7 | 1.000 | - |
| Waist: hip ratio† | - | - | - | - | - | 223 | 0.8 | 0.0 | 0.8 | 0.8 | 211 | 0.8 | 0.0 | 0.8 | 0.8 | 0.160 | - |
| Waist: height ratio† | - | - | - | - | - | 223 | 0.4 | 0.0 | 0.4 | 0.5 | 211 | 0.4 | 0.0 | 0.4 | 0.4 | 0.192 | - |
| % Body Fat | - | - | - | - | - | - | - | - | - | - | 211 | 14.4 | 0.4 | 13.6 | 15.3 | - | - |
| *Females* | | | | | | | | | | | | | | | | | |
| Weight (kg)† | 224 | **54.5**[a] | 0.6 | 53.2 | 55.7 | 216 | **57.5**[b] | 0.7 | 56.2 | 58.8 | 214 | **59.6**[b] | 0.7 | 58.3 | 60.8 | **<0.001** | **0.046** |
| Height (cm)† | 224 | **160.4**[a] | 0.4 | 159.6 | 161.2 | 217 | **162.1**[b] | 0.4 | 161.3 | 163 | 215 | **162.5**[b] | 0.4 | 161.7 | 163.3 | **<0.001** | **0.024** |
| BMI (kg/m$^2$)† | 224 | **21.1**[a] | 0.2 | 20.7 | 21.6 | 216 | **21.9**[ab] | 0.2 | 21.4 | 22.3 | 214 | **22.5**[b] | 0.2 | 22 | 22.9 | **<0.001** | **0.027** |
| WC (cm)† | - | - | - | - | - | 214 | **73.5**[a] | 0.6 | 72.3 | 74.7 | 215 | **70.7**[b] | 0.6 | 69.5 | 71.8 | **<0.001** | **0.028** |
| HC (cm)† | - | - | - | - | - | 214 | 93.9 | 0.5 | 92.9 | 94.9 | 215 | 94.5 | 0.5 | 93.6 | 95.5 | 0.360 | - |
| Waist: hip ratio† | - | - | - | - | - | 213 | **0.8**[a] | 0.0 | 0.8 | 0.8 | 215 | **0.7**[b] | 0.0 | 0.7 | 0.8 | **<0.001** | **0.098** |
| Waist: height ratio† | - | - | - | - | - | 214 | **0.5**[a] | 0.0 | 0.4 | 0.5 | 215 | **0.4**[b] | 0.0 | 0.4 | 0.4 | **<0.001** | **0.032** |
| % Body Fat | - | - | - | - | - | - | - | - | - | - | 213 | 26.7 | 0.5 | 25.8 | 27.7 | - | - |

*Note*: Data presented as age-adjusted values. ANCOVA—covariates = age and, for total population, gender. $p < 0.05$ (Bonferroni post hoc correction for multiple comparisons). Values with significant differences are presented in bold. Statistically significant differences between groups are indicated by alternating superscript letters.

Abbreviations: 95% CI, 95% Confidence Interval; BMI, Body mass index; HC, Hip circumference (cm); INNS 1990, Irish National Nutrition Survey 1990; $n_p^2$, effect size; NTFS 2006, National Teens' Food Survey 200; NTSFII 2020, National Teens' Food Survey 2020; SE, standard error; WC, Waist circumference (cm).

†Log10 Transformation

*Adjusted values weighted by social class.

**TABLE 2** BMI, % body fat and waist circumference derived weight status of Irish adolescents in 1990, 2006 and 2020

| | INNS 1990 | | | | | | NFTS 2006 | | | | | | NTFS II 2020* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | % | | | | | | % | | | | | | | |
| | n | UW | NW | OW | OB | MOB | n | UW | NW | OW | OB | MOB | n | UW | | NW | OW | OB | MOB | p |
| *Total population* | | | | | | | | | | | | | | | | | | | | |
| IOTF | 389 | **7.5**$^{a}$ | **79.4**$^{a}$ | 12.6 | **0.5**$^{a}$ | 0.0 | 440 | **2.7**$^{b}$ | **79.3**$^{a}$ | 15.2 | **1.8**$^{a}$ | 0.9 | 425 | **5.4**$^{ab}$ | | **71.1**$^{b}$ | 15.8 | **6.4**$^{b}$ | 1.4 | **<0.001** |
| UK1990 | 389 | 1.0 | **80.5**$^{a}$ | 12.6 | **5.7**$^{a}$ | | **0.3**$^{a}$ | 440 | 0.2 | **74.5**$^{a}$ | 13.0 | **10.2**$^{b}$ | **2.0**$^{ab}$ | 425 | 1.2 | **67.1**$^{b}$ | 13.5 | **14.0**$^{b}$ | **3.5**$^{b}$ | **<0.001** |
| WHO2007 | 389 | 1.0 | **84.3**$^{a}$ | 13.6 | **1.0**$^{a}$ | | - | 440 | 0.2 | **78.2**$^{ab}$ | 17.3 | **4.3**$^{b}$ | - | 425 | 1.4 | **71.3**$^{b}$ | 16.0 | **11.3**$^{c}$ | - | **<0.001** |
| % Body fat status | - | - | - | - | - | | - | - | - | - | - | - | - | 424 | 13.8 | 63.6 | 10.0 | 12.6 | - | - |
| WC Abd weight status | - | - | - | - | - | | - | 437 | - | 93.2 | - | 6.8 | - | 426 | - | 93.9 | - | 6.5 | - | 1.000 |
| WHtR Abd weight status | - | - | - | - | - | | - | 437 | - | 83.5 | - | 16.5 | - | 426 | - | 86.4 | - | 13.6 | - | 1.000 |
| *Males* | | | | | | | | | | | | | | | | | | | | |
| IOTF | | 165 | **7.3**$^{a}$ | **83.6**$^{a}$ | 8.5 | **0.6**$^{a}$ | 0.0 | 224 | **1.3**$^{b}$ | **80.8**$^{a}$ | 15.6 | **1.3**$^{a}$ | 0.9 | 211 | **6.2**$^{a}$ | **70.3**$^{b}$ | 15.3 | **6.7**$^{b}$ | 1.4 | **<0.001** |
| UK1990 | | 165 | 0.6 | **81.8**$^{a}$ | 12.7 | **4.8**$^{a}$ | 0.0 | 224 | 0.0 | **73.7**$^{ab}$ | 12.5 | **12.1**$^{b}$ | 1.8 | 211 | 2.4 | **67.5**$^{b}$ | 12.0 | **14.4**$^{b}$ | 3.3 | **0.036** |
| WHO2007 | | 165 | **0.6**$^{ab}$ | **87.3**$^{a}$ | 11.5 | **0.6**$^{a}$ | - | 224 | **0.0**$^{b}$ | **77.2**$^{b}$ | 17.4 | **5.4**$^{b}$ | - | 211 | **2.9**$^{a}$ | **71.6**$^{b}$ | 13.5 | **12.0**$^{c}$ | - | **<0.001** |
| % Body fat status | | - | - | - | - | - | - | - | - | - | - | - | - | 211 | 25.4 | 57.0 | 9.8 | 7.9 | - | - |
| WC Abd weight status | | - | - | - | - | - | - | 224 | - | 91.1 | - | 8.9 | - | 212 | - | 90.9 | - | 9.1 | - | 1.000 |
| WHtR Abd weight status | | - | - | - | - | - | - | 223 | - | 85.7 | - | 14.3 | - | 211 | - | 85.2 | - | 14.8 | - | 1.000 |
| *Females* | | | | | | | | | | | | | | | | | | | | |
| IOTF | | 224 | 7.6 | 76.3 | 16.0 | **0.4**$^{a}$ | 0.0 | 216 | 4.2 | 77.8 | 15.0 | **2.3**$^{ab}$ | 0.9 | 214 | 4.6 | 72.1 | 16.3 | **6.0**$^{b}$ | 1.4 | **0.026** |
| UK1990 | | 224 | 1.3 | **79.5**$^{a}$ | 12.5 | **6.3**$^{a}$ | **0.4**$^{a}$ | 216 | 0.5 | **75.5**$^{ab}$ | 13.4 | **8.3**$^{ab}$ | **2.3**$^{ab}$ | 214 | 0.0 | **67.0**$^{b}$ | 15.1 | **13.3**$^{b}$ | **3.7**$^{b}$ | **0.015** |
| WHO2007 | | 224 | 1.3 | **82.1**$^{a}$ | 15.2 | **1.3**$^{a}$ | - | 216 | 0.5 | **79.2**$^{ab}$ | 17.1 | **3.2**$^{a}$ | - | 214 | 0.0 | **71.0**$^{b}$ | 18.4 | **10.6**$^{b}$ | - | **<0.001** |
| % Body fat status | | - | - | - | - | - | - | - | - | - | - | - | - | 213 | 2.6 | 70.1 | 10.1 | 17.2 | - | - |
| WC Abd weight status | | - | - | - | - | - | - | 214 | - | 95.3 | - | 4.7 | - | 215 | - | 96.8 | - | 3.2 | - | 1.000 |
| WHtR Abd weight status | | - | - | - | - | - | - | 214 | - | 81.3 | - | 18.7 | - | 215 | - | 87.6 | - | 12.4 | - | 0.438 |

*Note*: $X^2$ test of categorical variables $p < 0.05$ (Bonferroni correction for multiple comparisons). Values with significant differences are presented in bold. Statistically significant differences between groups are indicated by alternating superscript letters.

Abbreviations: UW, underweight; NW, normal weight; OW, Overweight; OB, Obesity; MOB, Morbid obesity (IOTF: International Obesity Task Force BMI cut offs, WHO 2007: World Health Organization 2007 growth reference BMI cut offs, UK90: UK1990 population level BMI reference curves cut offs: all BMI derived weight status determined based on age and gender adjusted BMI z score centiles) (INNS 1990: Irish National Nutrition Survey 1990, NTFS 2006: National Teens' Food Survey 2006, NTFS II 2020: National Teens' Food Survey 2020). % Body fat weight status determined based on McCarthy et al 2006 cut offs applied to age and gender adjusted % body fat z scores. Waist circumference (WC) Abdominal weight status determined based on CDC waist circumference cut offs applied to age and gender adjusted waist circumference centiles. WHtR Abd weight status: Waist to height ratio Abdominal weight status with abdominal obesity defined as a WHtR ≥0.50.

*Adjusted values weighted by social class weighting factor.

at 57% compared to 50% and 51% in NTFS 2006 and NTFS II 2020, respectively. The age profile of adolescents within each survey did not differ significantly, with the mean age of the NTFS II 2020 cohort at 15.4 yrs ± 1.4, compared to a mean age of 15.4 yrs ± 1.4 in NTFS 2006 and 15.4 yrs ± 1.6 in INNS 1990 ($p = 0.050$) (Table S1).

### 3.1 | Trends in adolescent weight status and anthropometry over time

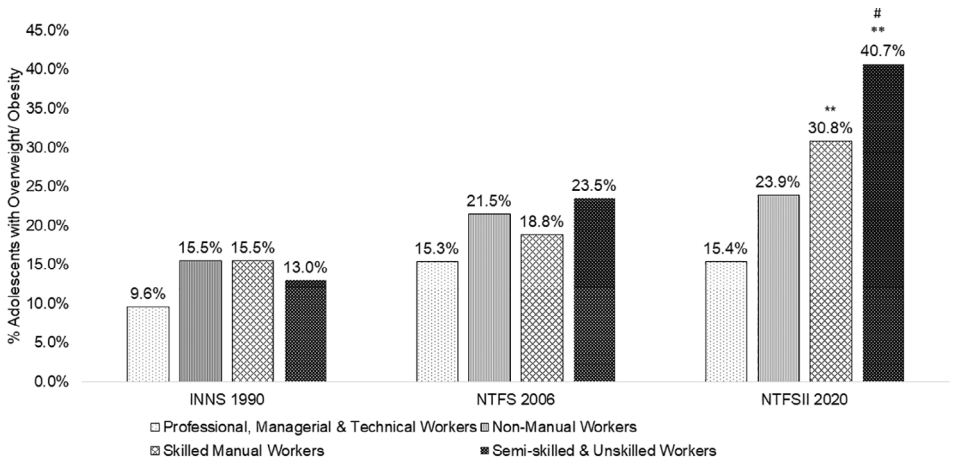
Table 1 details the body composition and anthropometric measurements of the adolescents across each of the surveys, with weight, height, and BMI measurements available for all three surveys, measures of WC and HC available for NTFS 2006 and NTFS II 2020 only and measures of % body fat available for NTFS II 2020 only. Analysis of anthropometric measures revealed that adolescents in 2020 were on average 4.7 cm taller and weighed an average of 7.4 kg more than adolescents in 1990 ($p < 0.001$). These differences became more pronounced upon stratification by gender, with male adolescents weighing on average 6.4 kg heavier in 2006 and 9.0 kg heavier in 2020 compared to male adolescents in 1990. A similar trend was also observed in female adolescents, with those in 2006 weighing an average of 2.9 kg heavier, and those in 2020 weighing 5.7 kg heavier compared to female adolescents in 1990. These changes are reflected in the significantly increased BMI of adolescents in more recent years, with a higher mean adolescent BMI observed in 2020 and 2006 compared to 1990 (22.1, 21.6 and 20.7 kg/m$^2$, respectively [$p < 0.001$]). There were no significant differences observed in mean measures of adolescent height, weight, BMI, and HC between 2006 and 2020. However, a lower average WC, waist: hip ratio and waist: height ratio was observed in adolescents in 2020 compared to 2006, with these lower measures observed mainly in adolescent females in 2020 (Table 1). Despite these slightly lower measures of WC, no difference in rates of abdominal obesity as determined via WC and WHtR z-scores was observed between 2006 and 2020 (Table 2).

The prevalence of underweight, normal weight, overweight, obesity and morbid obesity in Irish adolescents in 1990, 2006 and 2020 as determined via a variety of methods is described in Table 2. The prevalence of adolescents classed as having a BMI above the healthy range has increased significantly in recent years, with nearly a quarter (23.6%) of the NTFS II 2020 cohort classed as having overweight/obesity compared to 18.0% in NTFS 2006 and 13.1% in INNS 1990 based on the IOTF BMI cut-offs ($p < 0.001$). A significantly greater proportion of adolescents were classed as having obesity/morbid obesity in 2020 at 7.9% compared to 2.7% in 2006 and 0.5% in 1990 ($p < 0.001$) based on the IOTF cut-offs. Application of the UK90 and the WHO 2007 cut-offs classified a higher number of adolescents as having obesity, with adolescents in 2020 consistently displaying the highest prevalence of obesity. Indeed, there was a significant rise in the prevalence of those living with a higher grade of obesity from 1990 to 2020, attributed mainly to a rise in the number of female adolescents classed as having morbid obesity based on UK90 cut-offs from 0.4% in 1990 to 3.7% in 2020 ($p < 0.001$).

Rates of %BF determined overfat and obesity in NTFS II 2020 were relatively similar to those determined by BMI using the UK 1990 and the WHO 2007 cut-offs for the total population, with 10% of overall adolescents classed as having overfat and 13% as having obesity in 2020. There were notable differences in the prevalence of those classed as having underfat based on %BF compared to those who were classed as underweight based on BMI, with a quarter of adolescent males in 2020 classed as being "underfat" in comparison to 6.2% deemed as "underweight" based on the IOTF BMI cut-offs.

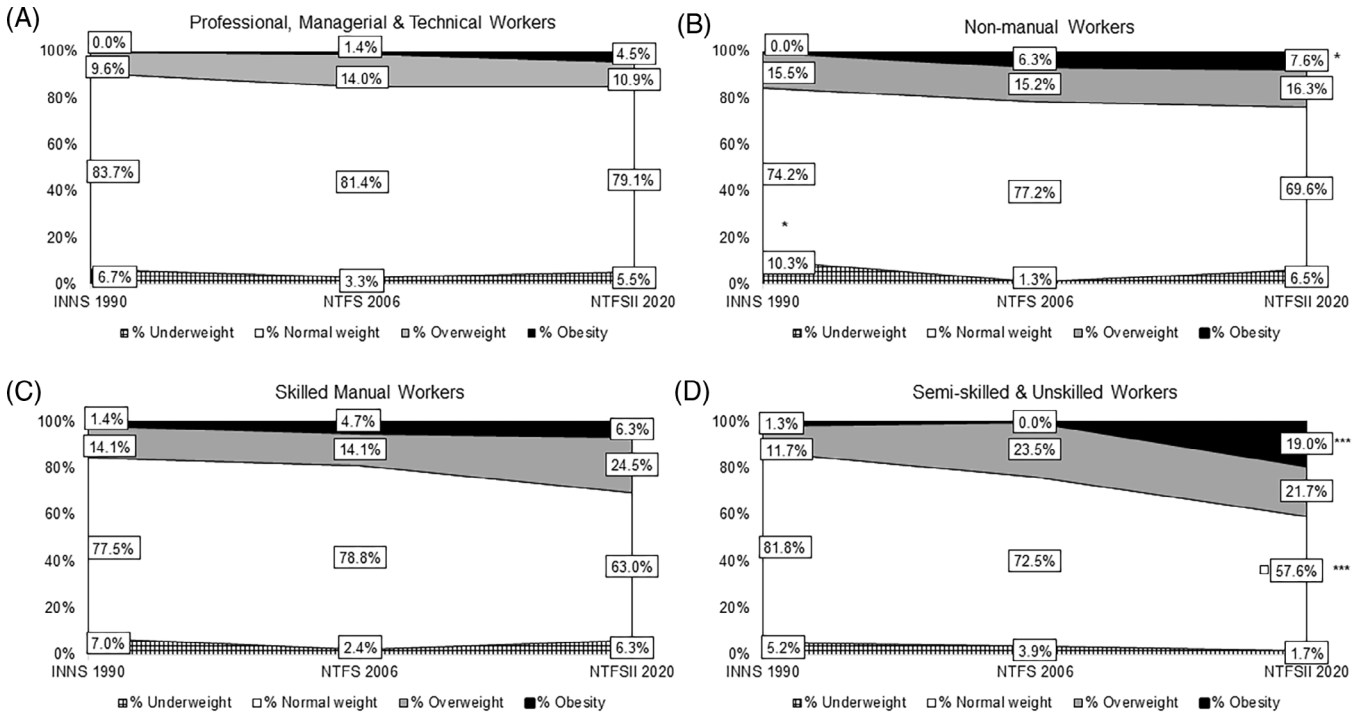
### 3.2 | Associations between socio-demographic factors and adolescent overweight/obesity

Analysis of weight status across categories of social class revealed that a lower affluence social class was associated with a significantly increased prevalence of adolescent overweight and obesity in NTFS II 2020 only (Figure 1). The relationship between social class and adolescent overweight and obesity has increased significantly over time,




Proportion of adolescents with overweight or obesity within each social class group across survey time points. $X^2$ test of categorical variables assessing the proportion of adolescents with overweight/obesity based on International Obesity Task Force cut-offs. Social class weighting variable applied. INNS 1990: Irish National Nutrition Survey 1990. NTFS 2006: National Teens' Food Survey 2006. NTFS II 2020: National Teens' Food Survey 2020. * * p<0.001 with respect to NTFS II 2020 "professional, managerial, technical workers" vs NTFS II 2020 "skilled manual workers" and NTFS II 2020 "semi-skilled & unskilled workers". # p<0.05 with respect to INNS 1990 "semi-skilled & unskilled workers" vs NTFS II 2020 "semi-skilled & unskilled workers".

**FIGURE 1** Prevalence of IOFT BMI derived adolescent overweight/obesity across categories of parental/guardian social class between INNS 1990, NTFS 2006 and NTFS II 2020




Adolescent weight status as determined by IOTF BMI cut offs within each social class group from 1990 to 2020. *X2* test of categorical variables #* p<0.05 INNS 1990 vs NTFS II 2020, #*** p<0.001 INNS 1990 vs NTFS II 2020

**FIGURE 2** Trends in the weight status of Irish adolescents within each social class group in 1990, 2006 and 2020

**TABLE 3** Associations between socio-demographic factors and odds of overweight/obesity amongst Irish adolescents in 1990, 2006 and 2020

| | INNS 1990 | | | | NTFS 2006 | | | | NTFS II 2020 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adjusted model | | | | Adjusted model | | | | Adjusted model | | | |
| | OR | 95% CI | | p | OR | 95% CI | | p | OR | 95% CI | | p |
| Age | 0.92 | 0.76 | 1.12 | 0.41 | **0.80** | **0.67** | **0.96** | **0.01** | 1.02 | 0.88 | 1.18 | 0.80 |
| Gender | 1.95 | 1.03 | 3.70 | 0.04 | 1.01 | 0.62 | 1.65 | 0.98 | 1.05 | 0.67 | 1.65 | 0.82 |
| *Household location* | | | | | | | | | | | | |
| Urban | **0.52** | **0.27** | **0.98** | **0.04** | 1.12 | 0.67 | 1.85 | 0.67 | 1.59 | 0.98 | 2.58 | 0.06 |
| *Parental education* | | | | | | | | | | | | |
| Primary/intermediate | - | - | - | - | **2.23** | **1.24** | **4.00** | **0.01** | **2.74** | **1.39** | **5.41** | **0.01** |
| Secondary | - | - | - | - | 1.08 | 0.53 | 2.18 | 0.84 | 1.03 | 0.52 | 2.03 | 0.93 |
| *Parental social class* | | | | | | | | | | | | |
| Non-manual workers | 1.80 | 0.81 | 4.00 | 0.15 | 1.66 | 0.85 | 3.22 | 0.14 | 1.76 | 0.95 | 3.25 | 0.07 |
| Skilled workers | 1.80 | 0.76 | 4.28 | 0.18 | 1.26 | 0.65 | 2.44 | 0.50 | **2.53** | **1.31** | **4.89** | **0.01** |
| Semi-skilled & unskilled workers | 1.43 | 0.59 | 3.46 | 0.43 | 1.73 | 0.82 | 3.68 | 0.15 | **3.95** | **2.06** | **7.61** | **<0.001** |

*Note*: Binary logistic regression analysis adjusted for age and gender examining the associations between socio-demographic factors and adolescent overweight/ obesity. Gender: reference = males. Location reference = rural. Parental education: reference = tertiary. Parental social class: reference = professional/managerial/technical. OR, Odds ratio; CI, Confidence Interval. $p < 0.05$. Values with significant differences are presented in bold.

with 41% of adolescents from the lower affluence social class of unskilled and semi-skilled workers in 2020 classed as having a BMI outside of the healthy range compared to 13% in 1990 ($p = 0.007$) (Figure 1). Figure 2 depicts trajectories of the weight status of Irish adolescents from 1990 to 2020 and highlights the substantial increase in the number of adolescents with obesity within the lower affluence social class of semi-skilled/unskilled workers, increasing from 1.3% in 1990 and 0.0% in 2006 to 19.0% in 2020 ($p < 0.001$).

Logistic regression analyses examining the associations between socio-demographic factors and adolescent overweight/obesity are presented in Table 3. Parental educational level was significantly inversely associated with adolescent overweight/obesity in 2006 and 2020, with adolescents whose parents completed only primary education 2.23 times more likely to have overweight/obesity in 2006 and 2.74 times more likely to have overweight/obesity in 2020 compared to adolescents whose parents have completed tertiary education.

A strong inverse association between social class and risk of adolescent overweight and obesity was only apparent in the most recent survey of NTFSII 2020, with adolescents from the lowest affluent social classes of unskilled/semi-skilled workers and skilled manual workers displaying a 3.95-fold increased odds and a 2.53-fold increased odds of having overweight/obesity, respectively, compared to the highest affluent social class of professional, managerial, and technical workers (Table 3).

## 4 | DISCUSSION

The present study depicts trends in adolescent weight status in the Republic of Ireland across three separate time points from 1990 to 2020 and highlights the issue of the rising prevalence of adolescent overweight and obesity in recent years. Nearly one in four Irish adolescents were living with overweight/obesity in 2020, a prevalence which has increased significantly from 1990. Furthermore, an increasing prevalence of those affected by obesity and morbid obesity was apparent over time, indicating not only a rising incidence of adolescent overweight and obesity but also an increase in obesity severity. Lastly, of note, there was an indication of a strengthening socioeconomic gradient of adolescent overweight/obesity in Ireland, with a substantially higher proportion of adolescents from more socioeconomically disadvantaged backgrounds displaying a BMI above the healthy range in 2020 compared to previous years. The rising prevalence of Irish adolescents living with overweight/obesity in 2020 is similar to data from the UK, which indicated that one in three 17-year-olds were classed as having overweight/obesity in 2018 to 2019.[27] A similar upward trend in the prevalence of adolescent obesity has also been observed in the US, with the latest NHANES data indicating that 21.2% of American adolescents were living with obesity in 2017/2018,[28] with the prevalence having tripled in the past three decades.[29] Indeed, recent results from the WHO indicate that one in four adolescents in the WHO European region are now living with overweight or obesity, mirroring the results of the present study.[6] The results of this analysis continue the rising trajectory of overweight/obesity prevalence that has been observed amongst Irish adolescents in more recent years, with data from the Health Behaviour in School-aged Children survey indicating that 16% of 15-year-old boys and 12% of 15-year-old girls were classed as having overweight/obesity in 2010, increasing to 18% of 15-year-old boys and 13% of 15-year-old girls in 2013/2014.[30] The rising prevalence of adolescents living with overweight/obesity contrasts with the plateauing, or in some cases, decreasing, rates of childhood obesity observed across several affluent countries, including Ireland, in recent years.[4,5] This stabilization has been attributed to the cumulative effect of numerous public health programmes targeting childhood obesity.[5] However, there is a conspicuous lack of similar efforts to protect adolescents, with this age group largely overlooked in global health and nutrition policies.[31] This includes Ireland, where not only is there a relative scarcity of health policies and interventions targeting adolescents but also a paucity of research and monitoring of adolescent health. This is apparent in the notable lack of surveillance of adolescent obesity in Ireland in recent years, meaning that the results of the present study are highly relevant in providing an updated depiction of the more recent prevalence of Irish adolescents affected by overweight and obesity.

The degree of obesity is an important factor when considering the potential health implications of adolescent obesity, with morbid obesity thus coined due to the substantially increased risk of comorbidities associated with the condition. The current study highlights an increased prevalence of adolescents living with a higher grade of obesity in 2020, with rates of those who are overweight remaining at similar levels since 1990 but rates of those affected by obesity and morbid obesity increasing substantially. The increased presentation of Irish adolescents affected by a higher grade of obesity is similar to trends observed in the US, where 4.5% of 16–19-years old were classed as having morbid obesity in 2015 to 2016, a substantial increase from 1.9% in 1999 to 2000.[32] It should be noted that the prevalence of overweight, obesity and morbid obesity can differ depending on the classification criteria used, with the UK90 cut-offs identifying the highest prevalence of adolescents with an unhealthy BMI in the present study. Considerable differences in weight status prevalence estimates have been highlighted in the present study and other Irish studies.[4,33] Even so, the need for obesity research to report weight status prevalence using more than one reference has been highlighted as essential to enable global comparisons and data harmonization.[34] Nevertheless, there has evidently been an increase in the presentation of obesity and morbid obesity in Irish adolescents in recent years, with these findings particularly concerning due to the major burden of comorbidities that are associated with a higher grade of obesity in adolescence.[35]

The data from the current study clearly displays widening differences in the prevalence of adolescent overweight and obesity between those who come from more economically privileged backgrounds versus those from a lower affluence background. In 2020, the majority of Irish adolescents living with overweight and obesity were contained within more socioeconomically disadvantaged social class groups, a difference that was absent in 1990 and only beginning to emerge in 2006. This socioeconomic gradient of adolescent obesity has also been observed across the majority of high-income western and central European countries, with the disparity continuing to widen in more recent years despite general increases in economic wealth across these countries.[36] Economic growth generally disproportionately benefits the top distribution of income shareholders, meaning that despite perhaps a decreasing prevalence of those within lower social classes, there may be a growing disparity between the

most and least economically privileged in society. Indeed, the majority of income inequality in Europe in 2019 has been attributed to within-country inequalities as opposed to those between countries.[37] Recent record-breaking increases in food prices[38] and cost of living expenses, fuelled by current global conflicts, coupled with the aftereffects of the pandemic are undoubtedly exacerbating issues of food insecurity and financial strain within the most vulnerable in society.[39] Deepening poverty and growing inequality will likely have significant implications for strengthening the socioeconomic gradient of obesity, with those of low socioeconomic status suggested to be more influenced by obesogenic environments due to a lack of choice and less financial freedom.[40] Adolescents affected by social deprivation have been shown to display an increased risk of obesity-related behaviours including increased screen time, lower participation in exercise and increased consumption of sugar-sweetened beverages and food of minimal nutritional value.[41]

The inverse relationship between socioeconomic status and child/adolescent weight status has been shown consistently across several wealthy countries, with parental education identified as the most influential socioeconomic position indicator with regard to child-adolescent overweight/obesity.[42] A lower level of parental education was associated with a significantly increased likelihood of overweight/obesity amongst.

Irish adolescents in both 2006 and 2020, with a slightly stronger association in 2020. These findings are consistent with recent results from Germany, which found that a lower level of parental educational attainment was associated with a significantly higher BMI in children and adolescents and displayed a significant effect on various mediators of obesity, including a less healthful dietary pattern and increased screen time.[43] This study indicated that a lower level of parental educational attainment was the strongest predictor of increased risk of adolescent overweight/obesity in 2006, with the effect of social class only becoming apparent in 2020. Ireland experienced rapid economic growth during the early 2000s and had the second highest rate of employment and gross domestic product per capita in 2005/2006.[44] The deprivation gap and consistent poverty rate were considerably lower in Ireland in 2006 up until the economic crisis of 2008, with modern-day Ireland continuing to display a considerable disparity between the most and least affluent in society.[44] Social inequalities in health in Ireland have become stronger due to the recessions and cost of living crises of recent years, meaning that the influence of parents' knowledge and education on their child's health can be exacerbated and overridden by the lack of choice and increased vulnerability that social disadvantage brings. While being a member of a particular social class and having a parent who has achieved a certain level of education do not directly affect the development of overweight/obesity in adolescence, these social factors exert very strong influences on behavioural and lifestyle determinants that are directly involved in excessive weight gain in adolescence. Various obesity-related risk factors are present differently in each class of society, with household food insecurity, less healthful local food environments and a lack of access to safe and appropriate places to exercise highlighted as particular risk factors for those experiencing a greater level of socioeconomic deprivation.[45]

A plethora of health promotion policies and strategies exist with the aim of combating obesity, however, very few mention adolescents and even fewer specifically target this age group. One of the key goals of the Healthy Ireland Framework is to increase the proportion of people who are healthy at all stages of life, including adolescence, with the issue of increased rates of people with overweight and obesity and the rising incidence of metabolic disease in youth highlighted within the report.[46] The Irish Obesity Policy and Action Plan raises the need for nutritional clinics for adolescents to help them make more informed and healthier choices,[46] however, outside of this, no targeted action plan for adolescents is specified. The substantial increase in the prevalence of adolescents classified as having a BMI above the healthy range in recent years highlights the acute need for these and other targeted actions to combat adolescent obesity at both national and global levels. The Lancet Commission on Adolescent Health and Wellbeing has criticized the omission of adolescents from global health and social policies and highlighted a critical need for investment in adolescent health to benefit and protect this age group now, into future adult life, and for the next generation of children.[31] The results of this study highlight not only the need for adolescent-specific health promotion strategies but also emphasize that these strategies must be tailored for and targeted toward the offspring of parents with lower education levels and those who experience more socioeconomic disadvantage to effectively aid and protect those most at risk.

It must be noted that the prevalence of adolescent overweight and obesity from the NTFS II 2020 cohort is representative of the weight status of Irish adolescents pre- the COVID-19 pandemic. It is likely that the sharp increase in childhood obesity that has occurred in the UK during the pandemic[47] may also be reflected in detrimental effects on the weight status of Irish adolescents. The COVID-19 pandemic is also likely to have widened the deprivation gap for obesity, with the UK data demonstrating an increase in the deprivation gap for obesity in both older and younger children in 2020/2021 compared to 2019/2020.[47] Early studies have suggested that the pandemic has had a detrimental impact on the health and wellbeing of adolescents globally, including an increased prevalence of more unhealthy eating behaviours[48] and increased inactivity.[49] The rapid deterioration in social determinants of health triggered by crises, such as global pandemics, recessions, and wars often has long-term consequences for health that may take time to become fully apparent. The threats posed by these crises disproportionately affect the most vulnerable in society, including youth and those who are more economically disadvantaged,[50] amplifying the need for immediate and effective action to protect the health of adolescents amid current global upheavals. The current analysis has many strengths, including the availability of comprehensive, comparable anthropometric measures of height, weight and WC and HC, which were assessed by trained researchers in all three surveys, thereby allowing more precise measures of BMI and avoiding the inaccuracies that can be associated with self-reported measurements. The assessment of weight status via several methods including the application of various BMI thresholds and WC, WHtR and %BF weight status classifications facilitated

a robust investigation into changes in adolescent weight status and body composition that have occurred over time. Furthermore, the availability of three nationally representative data sets specifically investigating adolescents is a major strength of this study and relatively rare within the current evidence, with adolescents more commonly being assessed in conjunction with either children or adults. However, the limitations of this analysis should be addressed. There was a lack of some relevant data across all three surveys, particularly from the INNS 1990 survey, meaning certain measures, such as WC and HC, %body fat and the influence of parental education, could not be examined across all time points. The cross-sectional nature of each of the national food consumption surveys is a relative limitation of the study, as the tracking of adolescents' health and weight status throughout the lifespan to determine the potential long-term consequences of an unhealthy BMI in adolescence was not possible.

Adolescence is a distinct life stage in which risk factors related to overweight and obesity can develop and be present in very particular ways. Therefore, garnering an understanding of the individual influential factors on overweight and obesity in adolescence is critical to effectively combating the growing issue of unhealthy weight status amongst modern-day adolescents. This study adds to the literature by providing insight into the trends and recent status of adolescent overweight and obesity in Ireland and highlights the growing socioeconomic gradient of adolescent obesity. Consideration of the effects of socioeconomic disadvantage on the presentation of obesity risk factors in adolescence is imperative in ensuring those most at risk are identified and appropriately assisted. Further research investigating changes in food consumption patterns, physical activity and other obesity-related behaviours amongst Irish adolescents is very much warranted to appropriately identify significant risk factors, allowing for targeted intervention strategies to combat and prevent adolescent overweight and obesity.

## AUTHOR CONTRIBUTIONS

Breige McNulty, Albert Flynn, John Kearney, Janette Walton, Aisling O'Donnell, and Laura Kehoe contributed to the design and implementation of the study. Breige McNulty, Albert Flynn, John Kearney and Janette Walton are principal investigators on the project. Aoibhín Moore Heslin and Breige McNulty were involved in data analysis and wrote the manuscript. All authors reviewed and approved the final manuscript.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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