**One Year Surveillance of Body Mass Index and Cardiorespiratory Fitness in UK Primary School Children and the Impact of School Deprivation Level**

Short title: BMI, Fitness, and Deprivation in Children

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## WHAT ARE THE NEW FINDINGS?

- Both body mass index (BMI) and cardiorespiratory fitness (CRF) vary over the period of one year, including the school term and summer recess, in primary school children aged 9-10 years.
- CRF significantly increased throughout the school year, yet decreased back to baseline during the summer recess.
- This effect was influenced by school deprivation levels and pupils from the most deprived areas saw significantly greater reductions in CRF compared with pupils from affluent areas
- These results highlight a need for public health interventions aimed at increasing children's PA levels to be targeted towards the summer holiday period.

## ABSTRACT

**Objectives:** Cardiorespiratory fitness (CRF) is independently associated with health and academic attainment in childhood and adolescence. Yet overweight and obesity remain the focus in public health policy. Surveillance of body mass index and CRF considering school deprivation levels is limited. Therefore, we examined this in UK Primary Schools. **Methods:** Participants (n=409) were students (9-10 years), from 13 schools. BMI and CRF (20 m shuttle-run) were measured at four time-points across the academic year including summer recess. **Results:** BMI z-scores significantly decreased ($p$ = 0.015) from autumn (z = 0.336 [CI 0.212 to 0.460]) to spring (z = 0.252 [CI 0.132 to 0.371]), and then significantly increased ($p$ = 0.010) to summer (z = 0.327 [CI 0.207 to 0.447]). CRF significantly increased ($p$ < 0.001) from autumn (z = 0.091 [CI -0.014 to 0.196]) to spring (z = 0.492 [CI 0.367 to 0.616]), no change ($p$ = 0.308) into summer (z = 0.411 [CI 0.294 to 0.528]), and a significant decrease ($p$ < 0.001) into the following autumn term (z = 0.125 [CI 0.021 to 0.230]). BMI was unaffected by deprivation; however, pupils from the most deprived areas saw significantly greater reductions in CRF compared with pupils from affluent areas. **Conclusion**: Significant reductions in children's CRF occurred over the summer recess and was greater among children from schools in the most deprived areas. Systematic surveillance of children's CRF appears feasible and scalable. This should inform policy and funding into interventions targeting physical activity of school children, particularly over the summer recess.


**Key words:** Physical Fitness; Sport; Health Policy; Obesity

## INTRODUCTION

Cardiorespiratory fitness (CRF) is modifiable by physical activity (PA) and independently associated with health [1], and higher academic attainment [2,3]; in children and adolescents. Evidence supporting tracking of CRF from childhood to adulthood [4], and that childhood CRF predicts adult cardiovascular disease and metabolic syndrome risk [5], highlight the importance of maintaining and improving children's CRF [6]. Lang et al. [7] proposed these factors considered together indicate that population status of CRF in children may help predict future non-communicable disease burden.

Cross-sectional data and meta-analyses have demonstrated a rapid secular decline in CRF with global declines around 0.36% per annum over a 45-year period increasing in magnitude since 1970 [8]. Whilst public health agencies are encouraging novel interventions to increase childhood PA and subsequently improve health and wellbeing, widespread lack of routine health data hampers evaluation of their impact [9]. To this end, the UK Chief Medical Officer has stated, "*The introduction of a standardised school based fitness assessment in England may have multiple benefits that extend beyond the benefits for the individual*" [10].

However, the only currently mandated measure of children's health status in the UK is the National Child Measurement Programme (NCMP [11]). The NCMP is an annual programme that measures height and weight of children in Reception (aged 4–5 years) and Year 6 (aged 10–11 years). Although the NCMP only covers certain age groups, it includes the majority of children in those groups (the participation rate in 2015/16 was 94.0-95.6%). Tracking of children's height and weight is easily implemented in school settings to determine body mass index (BMI). Tracking of CRF levels should also follow a feasible and scalable approach.

The 20 m shuttle run test (20mSRT) is the most commonly employed field based measurement of CRF in children because of its low cost, simplicity, and ability to test large groups simultaneously [7,12,13]. There is strong evidence the 20mSRT has criterion validity as a measure of CRF in children [12]. As a surveillance instrument the 20mSRT could help identify populations with either low or high CRF (based upon international normative values for children pooled from over 1 million children and youth representing 50 countries [13]) and provide socioeconomic indicators that inform policy or intervention practice [7].

Despite widespread application of the 20mSRT to estimate CRF in school settings there is limited evidence of the scalability of 20mSRT and/or the potential for it to become more routinely utilised, often alongside BMI measurement. Some work has shown that physical fitness including CRF increases, albeit marginally from school year to school year [14]. Both BMI and CRF also vary seasonally in children [15,16] with increases often seen over the school year [16,17]. However, improvements in CRF do not continue and are often lost over the summer recess [16,17]. Despite sedentary time and PA both potentially affecting BMI and CRF [18-21], the loss of CRF over the summer is particularly surprising as PA levels often increase during the summer periods [21].

Socioeconomic status also influences BMI with children from more deprived areas having greater obesogenic growth trajectories than their more affluent peers [22-24]. Yet, recent work suggests PA levels and CRF may explain the impact of deprivation levels upon BMI [23,24]. Children from more deprived areas often have greater barriers to PA in general thus potentially influencing their BMI and CRF [25]. However, it is unknown whether the seasonal variation seen in CRF, including the typical loss occurring over summer holiday periods, is also influenced by deprivation levels. It may be that children from more deprived areas have greater barriers to summer PA opportunities also [25] and thus, though in general children's PA levels increase through the summer [21], this may not be the case for those in more deprived areas.

Though as noted there are currently programmes of work examining anthropometric measures in children in the UK, there is a lack of consensus regarding CRF testing in primary schools. However, considering the importance of CRF, recent scoping work has highlighted that it can be measured in schools in a simple scalable way using the 20mSRT [9]. In light of this and the seasonal variation seen in CRF, in addition to the current lack of research examining the impact of deprivation upon CRF, the current study had the following aims:

1. To investigate the BMI and CRF in primary school pupils in the UK over a one year period.
2. Examine the impact of school deprivation levels upon CRF and BMI.
3. Provide further indication of the feasibility of the testing protocol as evidenced by parental opt-in rates and pupil enjoyment

In the present study, all testing was completed by *in-situ* service delivery staff, who were delivering PE lessons and other extra-curricular physical activities in schools. All staff were employees of Premier Sport, a provider who operate in over 3,000 schools throughout the United Kingdom and who deliver over 20,000 sessions each month. This organisation was identified by the authors as being well placed to deliver the type of fitness testing described above on the large scale necessary.

## METHODS

### Participants

Participants were (n=409) children aged 9-10 (Mean±SD; Height 132±6cm, Weight 30.75±7.15kg; 222 males and 187 females) from 13 schools in North West England. Uptake to the testing was 100% from children in the age groups tested across the schools involved. Participants were recruited through their schools' involvement with the investigation, and those schools were themselves recruited via National Teaching Schools in the local area and via existing links with Premier Sport.

### Ethics and informed consent

As the result of guidance from our institutional ethics panel, the protocol of the present investigation deviated from existing procedures for the governance of child measurement. The norm is for schools to opt in to an investigation and provide consent on behalf of the pupils with parents being provided the opportunity to opt their children out of the investigation. In the present investigation schools and parents/guardians were required to provide consent and opt in to the investigation. Institution ethics was granted for this study by the ethics committee at Aberystwyth University.

Consent was obtained from schools and then subsequently from parents/guardians of all potential participants. This is a model that has been developed through consultation with Public Health England and the Office for Standards in Education, Children's Services and Skills (Ofsted).

### Confidentiality

All data were anonymised immediately following collection and stored on secure systems approved by Ofsted information governance team. Opt-out forms and any paper files were stored in locked cabinets within the schools, and electronic files stored on password protected computers, in both cases in accordance with the Ofsted information governance team. All files were destroyed upon completion of the investigation. Data were anonymised when transferred to the research team, and stored on password protected computers.



**Measures**

Measurements were taken at four time points throughout a single calendar year: autumn term (October 2014), spring term (March 2015), summer term (June 2015), and the following autumn term (October 2015)

**BMI:** Height was measured to the nearest centimetre and weight was measured to the nearest 0.1kg. Body Mass Index (BMI) was calculated from height and weight scores ($kg \cdot m^2$). BMI z-scores specific to age and sex were calculated using UK 1990 growth reference data [26] International Obesity Task Force (IOTF) classifications were then established [27].

**Fitness:** A recent systematic review [9] examined the scalability of children's fitness tests, and concluded that of all tests that met the criteria for validity and reliability, the 20mSRT was the most scalable. Participants completed 20m shuttles starting at an initial speed of 8.5 $km \cdot h^{-1}$ increasing by 0.5 $km \cdot h^{-1}$ each minute. An audible signal indicated when a participant should complete each shuttle. The final shuttle was recorded once a participant failed to maintain the audible controlled pace or stopped due to volitional exhaustion. End speed ($km \cdot h^{-1}$) was determined by the final stage of the 20-mSRT based on the number of completed shuttles. The speed for the final completed stage was used as the end speed [28]. Age and sex specific z-scores were calculated using the age global reference values for children [13]. Compared to the mean score for children of the same age and sex, a positive z-score indicates a higher than average test score, a negative z-score indicates a lower than average test score, and a z-score of zero indicates the test score is equal to the mean.

**Area-Level Deprivation:** The area-level deprivation of each school was classified using the English Index Deprivation 2015 (EID) [29] obtained from the school post-code (zip-code). The EID is a multidimensional measure of relative deprivation for small areas in England. The UK Government ranks areas based on decile of EID score (from decile 1 representing areas with the highest level of deprivation to decile 10 - the lowest). Areas falling in EID deciles 1 and 2 are considered deprived with area-level deciles 9 and 10 considered non-deprived (affluent). Participants were grouped from "Most Deprived" (deciles 1-2; $n$ = 153), "Mid Deprived" (deciles 3-8; $n$ = 124), to "Least Deprived" (deciles 9-10; $n$ = 132).

**Data treatment.**

The last observation carried forward (LOCF) method was used to provide a full data set. LOCF was used if a participant had two or more data entries producing a total sample of 409 for analysis. The total number of missing points, interpolated points, and comparison between the groups before and after data treatment are presented in the supplementary material. Independent samples t-test indicated no statistical difference between the original data and LOCF data, therefore only the 409 participants with full data were used in subsequent analysis.

**Statistical Analysis.**

Data were analysed using IBM SPSS Statistics 24 for Windows (IBM., Chicago, IL.). Significance was accepted at an α level of $p \leq 0.05$. Assumptions of sphericity were examined using Mauchly's Test of Sphericity. A two-way 'time' x 'group' ANOVA was used to compare main effects for 'time', 'group', and 'time' x 'group' interaction effects. Where sphericity was violated a Greenhouse-Geisser correction used. Post hoc pairwise using bonferroni adjustments were performed using estimated marginal means.

## RESULTS

IOTF classifications are reported in Table 1. These indicate that the majority of participants were classified as normal weight over the four time points. Autumn 2015 saw the lowest percentage of normal weight children and the highest percentage of overweight children, however the percentage of obese children at this point in time was lower than Autumn 2014.

***Table 1 see end of document ***

### Body Mass Index

For BMI, ANOVA revealed a significant effect by 'time' ($F_{(2.393,971.538}$ = 6.469, $p$ = 0.001), though no significant effect by 'group' ($F_{(2,406)}$ = 1.171, $p$ = 0.311). There was a significant 'time' x 'group' interaction effect ($F_{(4.786,971.538)}$ = 3.916, $p$ = 0.002), though no significant post hoc pairwise comparisons at any time point. BMI significantly decreased ($p$ = 0.015) from autumn (z = 0.336 [CI 0.212 to 0.460]) to spring (z = 0.252 [CI 0.132 to 0.371]), and then significantly increased ($p$ = 0.010) to summer (z = 0.327 [CI 0.207 to 0.447]). Thus there were no significant differences between the first and following autumn terms ($p$ > 0.999). Figure 1 shows mean z-scores over time for BMI and figure 2 shows BMI z-scores by deprivation group.

***Figure 1 see end of document***

***Figure 2 see end of document ***

**Cardiorespiratory Fitness**

For CRF, ANOVA revealed a significant effect by ‘time’ ($F_{(2.868,1164.256)} = 41.043$, $p < 0.001$), a significant effect by ‘group’ ($F_{(2,406)} = 4.351$, $p = 0.013$), and a significant ‘time’ x ‘group’ interaction effect ($F_{(5.735,1164.256)} = 5.987$, $p < 0.001$). CRF significantly increased ($p < 0.001$) from autumn (z = 0.091 [CI -0.014 to 0.196]) to spring (z = 0.492 [CI 0.367 to 0.616]), no change ($p = 0.308$) into summer (z = 0.411 [CI 0.294 to 0.528]), and a significant decrease ($p < 0.001$) into the following autumn term (z = 0.125 [CI 0.021 to 0.230]). Thus there were no significant differences between the first and following autumn terms ($p > 0.999$). Figure 3 shows z-scores over time for CRF.

Considering the significant ‘time’ x ‘group’ interaction effect, post hoc pairwise comparisons revealed pupils in the Most Deprived group had significantly lower CRF compared with the Least Deprived group in the autumn ($p < 0.001$). In the spring and summer there were no differences between groups based on deprivation. However, in the following autumn pupils in the Most Deprived group had significantly lower CRF compared with the Least Deprived group ($p < 0.001$) and the Mid Deprived group ($p = 0.003$). Figure 4 shows CRF scores by deprivation group.

***Figure 3 see end of document ***

***Figure 4 see end of document ***

## DISCUSSION

### Main Findings – BMI, CRF, and Deprivation Levels

The primary purpose of this investigation was to examine BMI and CRF of children in UK primary schools over a one year period including the academic year and summer recess, and the influence of school deprivation levels upon this. For the entire sample of children CRF increased (+3.8% end speed for 20-mSRT) from autumn to spring and was maintained throughout the school year. However, CRF levels decreased (-2.3% end speed for 20-mSRT) over the summer holidays to a level similar to the previous autumn. Over the course of the school year growth may impact on CRF. However, normative data indicate an annual increase in both boys and girls between 9-10 years of age [13] and so this was unlikely to have caused the variation seen. Further, climate is correlated with 20mSRT performance in developed countries with higher CRF in colder countries [7]. Climate was also unlikely to be a significant factor as meteorological data of the nearest UK station suggests mean temperature remained less than 20ºC over the summer [30]. The effect upon CRF was compounded by deprivation level within which the schools were located. Schools in the poorest areas saw significantly greater reductions in CRF over the summer period than those from more affluent areas. BMI followed a similar pattern with initial decreases followed by increases over the year such that BMI was similar at both the beginning and end of the academic year and summer recess. BMI however was relatively unaffected by deprivation level.

### Physical Activity, Cardiorespiratory Fitness, and Summer Recess

These findings have stark implications for policy makers and those responsible for the health and wellbeing of children. Firstly, from a positive perspective, data suggests school based PA delivery programmes and investments are likely positively impacting upon CRF of children during the academic year. Indeed, children from schools in all deprivation levels saw increases in CRF. The impact of such programs based on this data is not dissimilar from that of specific training to increase CRF in children (~ 4-5% [31]). Other work has reported CRF increases over the school year in Greek school children [16]. This finding is also similar to that reported by Carrel et al. [32] who found a school based PA intervention in US children improved CRF over the school academic year. Worryingly however, some studies show CRF stops increasing over the summer recess [31], and Carrel et al. [17] reported in a follow-up analysis that the improvements from their intervention were eradicated during this period. Recent work on seasonal variation in PA levels suggest children are least active during the autumn and winter seasons [33], and PA levels seem to increase consistently during the summer season [21]. It therefore seems counterintuitive that children in the present study should have lost CRF over this period.

As noted, CRF is independently associated with health1, and higher academic attainment [2,3]. Further, it appears at minimum moderate-vigorous PA rather than light PA is more strongly associated with sustained health, fitness, and wellbeing [1,3,34,35]. Yet, a recent study reported that reallocation of sedentary time to light or moderate PA was not associated with improved CRF whereas vigorous PA was [20]. Though PA tends to increase over the summer this is mainly due to increased moderate PA, whereas vigorous PA tends to vary far less [21]. As such, building CRF during youth through vigorous PA should be a focus of school based PA programs in addition to summer holiday based programs. Summer day camps have been shown to provide opportunities to increase vigorous PA by 15-18% [36].

Although PA levels were not specifically measured, a notable limitation, anecdotally parents of children in this study specifically suggested accessible opportunities to keep children active are hard to come by during long school holidays, and are often unaffordable or difficult to manage around working hours. As noted, this may be a barrier that is amplified for those from deprived areas [25] and may explain the greater loss of CRF in the most deprived children. This highlights the need for investment in opportunities for children that promote an active summer period, and are also built around the needs of working parents and affordable (ideally of course, free of charge).

**Limitations**

As mentioned, PA levels were not measured in this study and so it is not clear whether changes in CRF were a result of PA levels. Further, deprivation was considered on the basis of the area that the school that children attended was situated in. Individual participant level data was not available for determination of individual deprivation levels based on the EID. Some participants may have been based in areas outside of the schools that represented differing EID levels. Future work should consider this and also other factors indicative of deprivation level such as whether students are eligible for free school meals.



**Implications for Public Health Policy**

Our data also indicate that the delivery of CRF testing in primary schools is feasible and scalable providing support for previous scoping work in this area [9]. No parents or guardians in the present study refused to provide consent for their child to take part in the investigation and complete the CRF measurement protocol. Further, only one child reported not enjoying being part of this process. As such, systematic testing of CRF might be encouraged as an adjunct to the current NCMP in the UK and this evidence supports the UK Chief Medical Officers recommendations for this [10].

These data are also given particular pertinence by the context of the increased investment being allocated to childhood PA and sport, as seen in recent (2016) UK policy documents [37]. This includes the allocation of funds raised via a soft drinks levy (estimated to be £420 million) to be invested into school sport when perhaps there may be a case for this to be directed to activity outside of the school term times. In light of the findings of this study, further research is warranted in this area.

## CONCLUSION

Our data highlight that, although increases in CRF occur throughout the academic year, dramatic and significant reductions in children's CRF levels occur over the summer holiday period – an effect which is significantly more apparent among children from the most deprived areas. As such, these results highlight a need for public health interventions aimed at increasing children's PA levels to be targeted towards the summer holiday period in order to maintain the improvements produced by engagement in PA during the school year. Further, the present study, building on previous scoping work, suggests that the systematic measurement of children's CRF is both feasible and scalable in schools. Such data has strong implications for informing policy positions and the allocation of funding towards interventions that target the PA of primary age children.

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Table 1. Number of participants in each IOTF grade at each of the four measurement points.

| Grade | Autumn 2014 | | Spring 2015 | | Summer 2015 | | Autumn 2015 | |
|---|---|---|---|---|---|---|---|---|
| | % | n | n | % | n | % | n | % |
| Underweight | 8.1 | 33 | 41 | 9% | 35 | 8.6 | 35 | 8.6% |
| Normal weight | 68.9% | 282 | 285 | 69.7% | 286 | 69.9% | 276 | 67.5% |
| Overweight | 14.9% | 61 | 60 | 14.7% | 64 | 15.6% | 70 | 17.1% |
| Obesity | 8.1% | 33 | 23 | 5.6% | 24 | 5.9% | 28 | 6.8% |


Figure 1. Mean BMI z-scores and 95%CIs by time point for entire sample

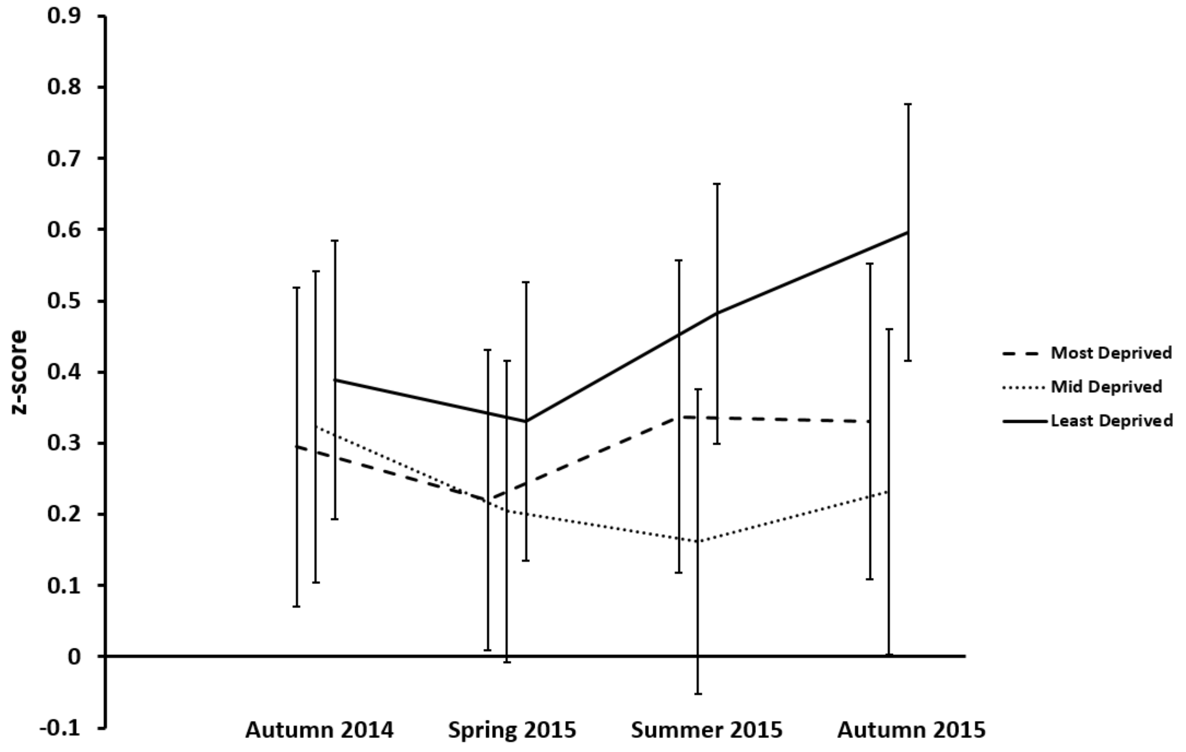


Figure 2. Mean BMI z-scores and 95%CIs by time point grouped by deprivation level

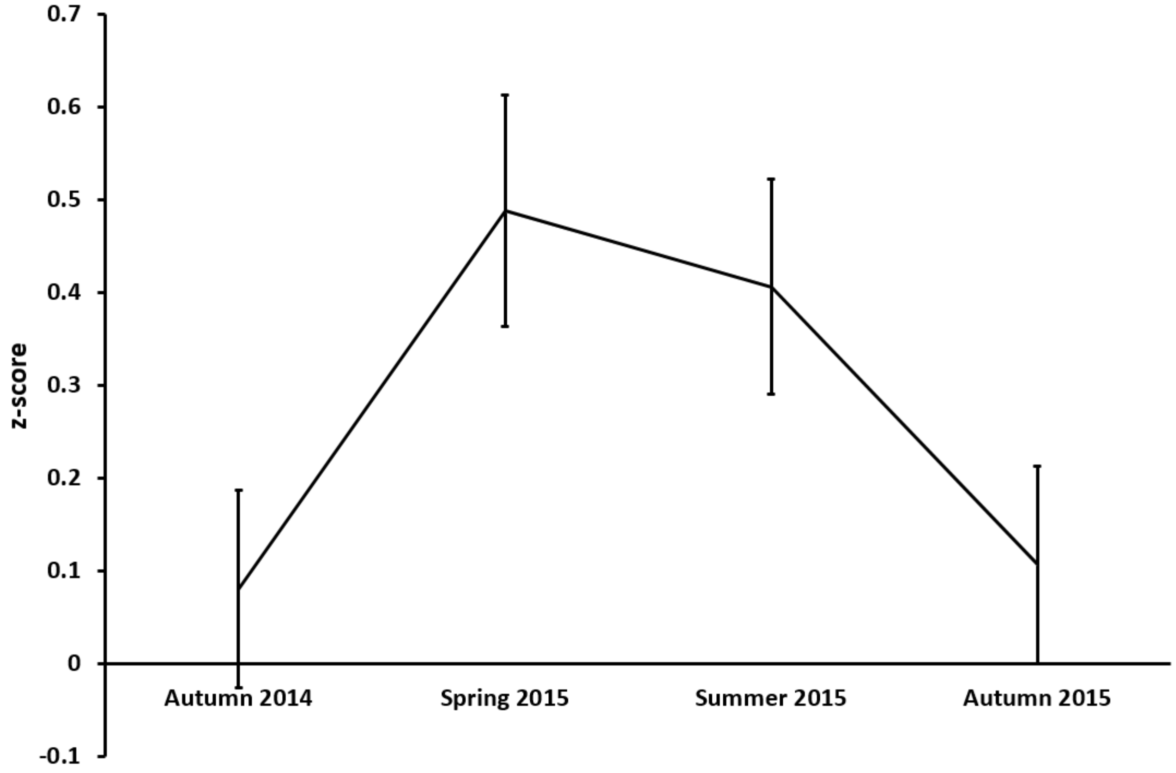


Figure 3. Mean CRF z-scores and 95%CIs by time point for entire sample

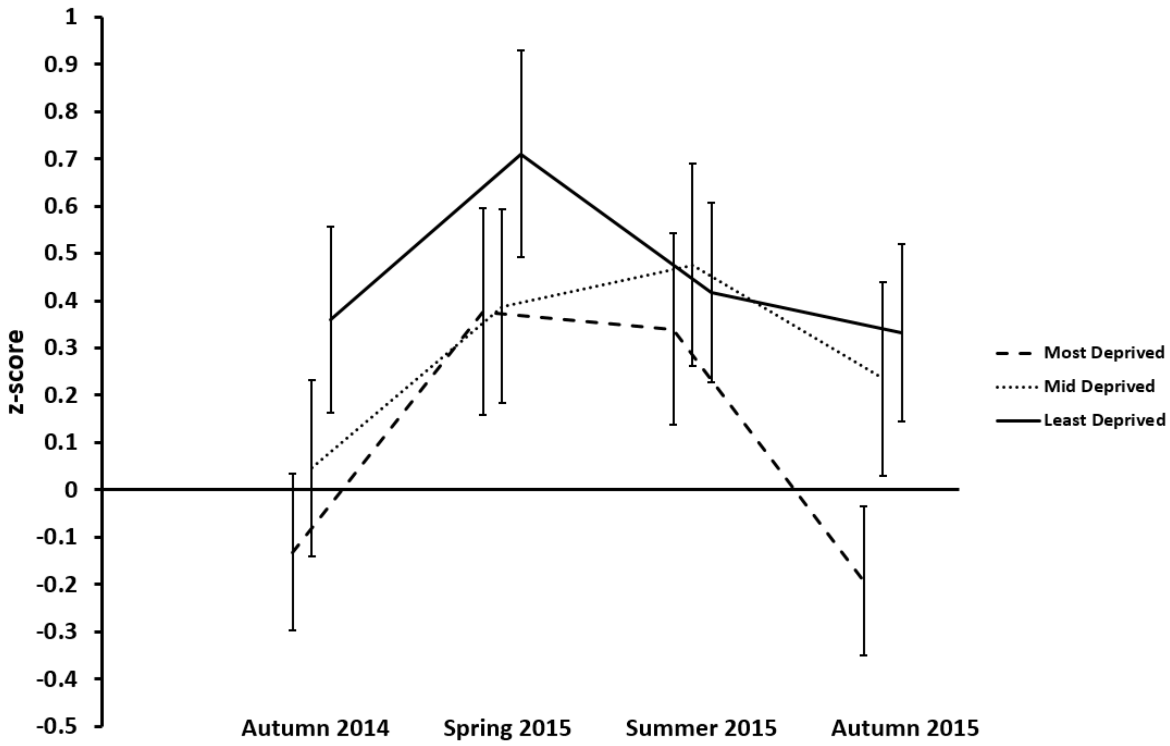


Figure 4. Mean CRF z-scores and 95%CIs by time point grouped by deprivation level