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Evaluating Associations between Physical Activity and Growth, Academic Attainment, and Socioeconomic Factors in Primary School Children - A Prospective Cohort Study

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Abstract **Aim:** Previous research has shown that physical activity is positively associated with growth and academic attainment in primary school children. The aim of this study was to determine if this association is repeated and to identify differences in personal, social, and environmental factors that contribute to physical activity and academic attainment. **Methods:** Physical activity status was determined using the PAQ-C and measurements of mass and height were recorded and BMI calculated. Academic attainment was measured using nationally standardised end of year tests. Participants completed the Newcastle Food School Study questionnaire. Parents of participants provided information on their education, family income, profession and completed the ALPHA Environment Questionnaire. A Chi-square test of homogeneity and Independent Samples T Tests were used to determine if differences exist between children who were more or less active. Based upon these results, significant predictors were selected and included in a logistic regression model in to analyse their ability to predict educational attainment. **Results:** The mean of the mass children who were more active followed the growth expected trajectory, whereas those who were less active demonstrated a loss in mass at the January measurement. Children who were more active were 27.72 and 12.59 times more likely to achieve average or above performance in literacy and reading than less active children. In mathematics, children whose parents worked in professional occupations, were 28.38 times more likely to achieve average or above than those with manual occupations. There were no significant differences between children in personal, social and environmental factors. **Conclusion:** This study confirms previous findings which reported that there does appear to be an association between physical activity and body mass and academic performance in primary school children, with lower levels of reported physical activity being associated with negative effects.

Keywords: *physical activity, children, primary school, growth, academic attainment*

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1. Introduction

It is recommended that children and young people complete an average of least 60 minutes of physical activity a day which should consist of activity at moderate intensity (e.g. riding a bike and playground activities) and/or vigorous intensity (e.g. fast running or sports). Activities that strengthen muscles and bone (e.g. hopping, skipping and gymnastics) should also be incorporated three times a week [1,2]. Physically active children are likely to grow into physically active adults, it is therefore vital that children are being supported and given the opportunity to meet the recommended guidelines and form healthy attitudes and behaviours related to physical

activity [3,4]. Currently compliance with the physically activity guidelines is low, with only 46.8% of children in England [5], 38% in Scotland [6], 51% in Wales [7] and 11.9% in Northern Ireland [8] meeting these recommendations. This is likely to have an impact on the health of and wellbeing of children.

Previous research has shown that physical activity is positively associated with growth and academic attainment in primary school children based in Stoke-on-Trent, UK [9]. This study demonstrated that children who were less physically active, were lighter in weight, shorter in height and experienced more fluctuation in their weight during the year. Less active children were also more likely to achieve below average in nationally standardised testing in reading, writing and mathematics. However, the previous findings were potentially confounded as we had not accounted for the personal, economic, societal and environmental factors necessitating further investigation. Therefore, the primary aim of this study was to determine if the association between higher reported physical activity and growth and academic performance found in primary school children was repeated. The secondary aim was to identify differences between less active and more active children in personal, social and environmental factors that contribute to physical activity and academic performance

2. Methods

2.1. Participants

Children and their parents from Years 3, 4, 5 and 6 at one primary school in Stoke-on-Trent, Staffordshire, UK, were invited to participate in this prospective cohort analysis. Children and parents were asked to provide assent and written consent respectively for participation. All children participated in regular physical education at school in accordance with the National Curriculum in England for Physical Education [10]. Approval was granted to conduct this evaluation by an institutional review board.

2.2. Outcome Measures

2.2.1. Physical Activity

Physical activity status was determined using the Physical Activity Questionnaire – Children (PAQ-C) [11]. This is a self-administered, 7-day recall questionnaire that measures moderate to vigorous activity during the school year and has been shown to have acceptable validity, reliability, and internal consistency [11,12,13]. This study utilised a modified version which had been validated for use in the UK [14]. Each question scored between one and five with one indicating none/low physical activity and five indicating high physical activity. An overall score of 2.9 or less indicates a student who is less physically activity and a score of 3 or above indicates a student who is more active. Children completed this at the beginning of the academic year and an average score was calculated for each child.

2.2.2. Growth

Measurements of mass and height were recorded at 3 time points during the academic year; in November, January and June. Mass was measured using a standard set of personal weighing scales with digital display and recorded in kilograms (kg) and height using a standard Leicester height measure and recorded in centimetres (cm) with clothes on and shoes off. After these measures were taken, BMI-scores were calculated in a Microsoft Excel add-in [15] using the LMSgrowth method [16]. BMI was classified using WHO Growth Reference for 5-19 years olds [17,18] and further categorised into nominal variable normal and overweight or obese for purposes of data analysis. Biceps and Triceps skinfold thickness was measured in millimetres (mm) using a skinfold calliper [18]. All staff were trained to ensure measurements were consistently taken and recorded.

2.2.3. Academic Attainment

Academic attainment was measured using results from end of year examinations using the National Foundation for Education Research (NFER) end of stage examinations in July 2019. Children study 3 core subjects (literacy, Mathematics and Science) with the assessment having been standardised for Key Stage 2 overall performance [19]. Results from the assessments were categorised for each child as below average or average and above based on their performance.

2.2.4. Nutrition

Participants were asked to complete the Newcastle Food School Study questionnaire [20] completed under the supervision of the school P.E. teacher. This diary is a self-recall questionnaire which tracks what children eat and drink over a 4-day period. Average portions of fruit and vegetables, proteins, carbohydrates, diary, fizzy drinks and sweets and chocolates were calculated. It was also further determined if participants were eating three school meals and day, having a fizzy drink daily and their lunch type, i.e. school or home lunches.

2.2.5. Parent/Guardian Background and Environment Perceptions

Parents/guardians of participants were asked to provide information relating to their highest levels of education, family income and their profession. This was further categorised as manual, professional or care based. They were also asked to complete the ALPHA Environment Questionnaire [21]. This is an outcome measure which assess environmental aspects of physical activity in the general adult populations in Europe and has been found to have moderate to good reliability, predictive validity and feasibility. Data was input, cleaned and analysed as per the guidance provided by the authors [22].

2.3. Data Analysis

IBM SPSS Statistics for Windows (Version 24.0. Armonk, NY: IBM Corp) was used to conduct a primary analyse of the results. Changes in mean mass, height and BMI during the academic year were presented. A

Chi-square test of homogeneity was used to determine if the probability distributions of academic attainment in reading, writing and mathematics for less active and active groups were different in categorical variables (appendix 1). Independent Samples T Tests were used to determine if there were differences in less active and more active children in continuous variables and childhood physical activity (appendix 2). Based upon these results, significant predictors were selected and included in a logistic regression model to analyse their ability to predict educational attainment in reading, writing and mathematics.

3. Results

In total, there were 62 (34 female and 28 male) children who participated. It included 8 in year-3 (Mean±SD, 7.76 ±0.33 years), 16 in year-4 (8.64 ±0.32 years), 18 in year-5 (10.08 ±0.31 years), 18 in year-6 (10.608 ±0.44 years) n=2 missing. 59 students were white British (95.2%), 1 was mixed race (1.6%) and 2 were white European (3.2%). 32% of students were in receipt of pupil premium[1] (n=20, 95% CI 21 to 44), 61% of students were not (n=38, 95% CI 49 to 73) and 7% were missing (n=4). In total 32% of students were found to be less active (n=20, 95% CI 21 to 44) and 68% as more active (n=42, 95% CI 56 to 79). In November (n=40, missing n=22, 35.5%), 35.5% had a normal BMI (n=22, 95% CI 0.24 to 0.47), 6% had overweight (n=4, 95% CI 0.004 to 0.13) and 23% had obesity (n=14, 95% CI 0.12 to 0.33). In January (n=40, missing n=22), 45% had a normal BMI (n=28, 95% CI 0.33 to 0.58), 3% had overweight (n=2, 95% CI -0.01 to 0.08) and 16% had obesity (n=10, 95% CI 0.07 to 0.25). In June (n=62, missing n=8), 55% had a normal weight (n=34, 95% CI 0.42 to 0.67), 9% had overweight (n=6, 95% CI 0.02 to 0.17) and 23% had obesity (n=14, 22.6%, 95% CI 0.12 to 0.33). Reasons for missing data include failure of parents to provide written consent for weight and height measurement or being unavailable to complete measures due to school absence (eg sickness).

Table 1. Highest Level of Education and Household Income.

Highest Level of Education	Frequency (%)	Household Income (GBP)	Frequency (%)
Prefer not to say	7 (11.3)	Prefer not to say	27 (43.5)
GCSE or equivalent	28 (45.2)	0-19999	13 (21)
A Level or equivalent	22 (35.5)	20000 – 29999	9 (14.5)
Undergraduate	10 (16.1)	30000-49999	9 (14.5)
Postgraduate	3 (4.8)	50000+	4 (6.5)

Figure 1 illustrates the change in mass, height and BMI measured in November, January, and June during the academic year. The mean of the mass children who were more active followed the growth expected trajectory, whereas those who were less active demonstrated a loss in mass at the January measurement. The height changes were similar in both groups. The BMI changes reflected the changes in mass.

Table 1 Demonstrates Family Education and Income of participants parents / guardians. Median family income reported was £0-19999 and highest level of education was completion of GCSEs[2] achieved at 16 years old in the UK with 45.2% (n=28). Of those who reported occupation (n=50), 52% (n=26, 95% CI 0.38 to 0.66) where in occupations that did not require higher education or specialist training and 48% (n=24, 95% CI 3.4 to 0.62), where in occupations requiring higher education and/or specialist training and a high degree of knowledge and expertise in the specific field. Most participants held a more favourable perception of their local environment in supporting physically active lives (93.5%, n=58). There were no significant differences between children who were less or more active (Appendix 1 and Appendix 2).

Academic performance was high across all three subjects with the majority of students achieving results equating to average or above average performance: 84.8% in literacy, 82% in reading and 68.4% in mathematics (Figure 2). Chi square probability distributions between educational attainment and personal and social and economic variables are presented in appendix 2. Based on this physical activity, classroom behaviour, November BMI and parent occupation were selected as predictor variables in the logistic models in each subject.

In literacy, a logistic regression model was statistically significant $\chi^2(1) = 17.60$, p= 0.001. The model correctly classified 86.5% of cases and sensitivity was 93.3%, specificity was 57.1%. Positive predictive value was 90.3% and negative predictive value was 66.7%. Of the four predictor variables, only physical activity level was significant (p=0.04) with children who are active 27.72 times more likely to achieve average or above average performance than less active children.

In reading, a logistic regression was statistically significant $\chi^2(4) = 12.38$, p=0.02. Sensitivity was 94.4%, specificity was 37.5%. Positive predictive value was 87.19 and negative predictive value was 60%. Of the 4 predictor variables, only physical activity level was significant (p=0.02) with children who are active 12.59 times more likely to achieve average or above average performance than less active children.

In mathematics, a logistic regression was statistically significant $\chi^2(5) = 19.45$, p= 0.001. Sensitivity was 96%, specificity was 66.7. Positive predictive value was 88.89% and negative predictive value was 85.71%. Of the 4 predictor variables, only parental work type was significant (p=0.04) with children whose parents work in professional occupations 28.38 times more likely to achieve average or above average performance than less active children.

[1] Pupil premium is a grant given by the government to schools in England. For each pupil who is eligible for free school meals, their school receives funding to take action to decrease the attainment gap for disadvantaged children.

[2] The General Certificate of Secondary Education (GCSE) is an academic qualification, taken in a number of subjects by pupils in secondary education in the UK. These are accepted as a record of achievement at the age of 16, in place of a leaving certificate or baccalaureate qualification in other territories.

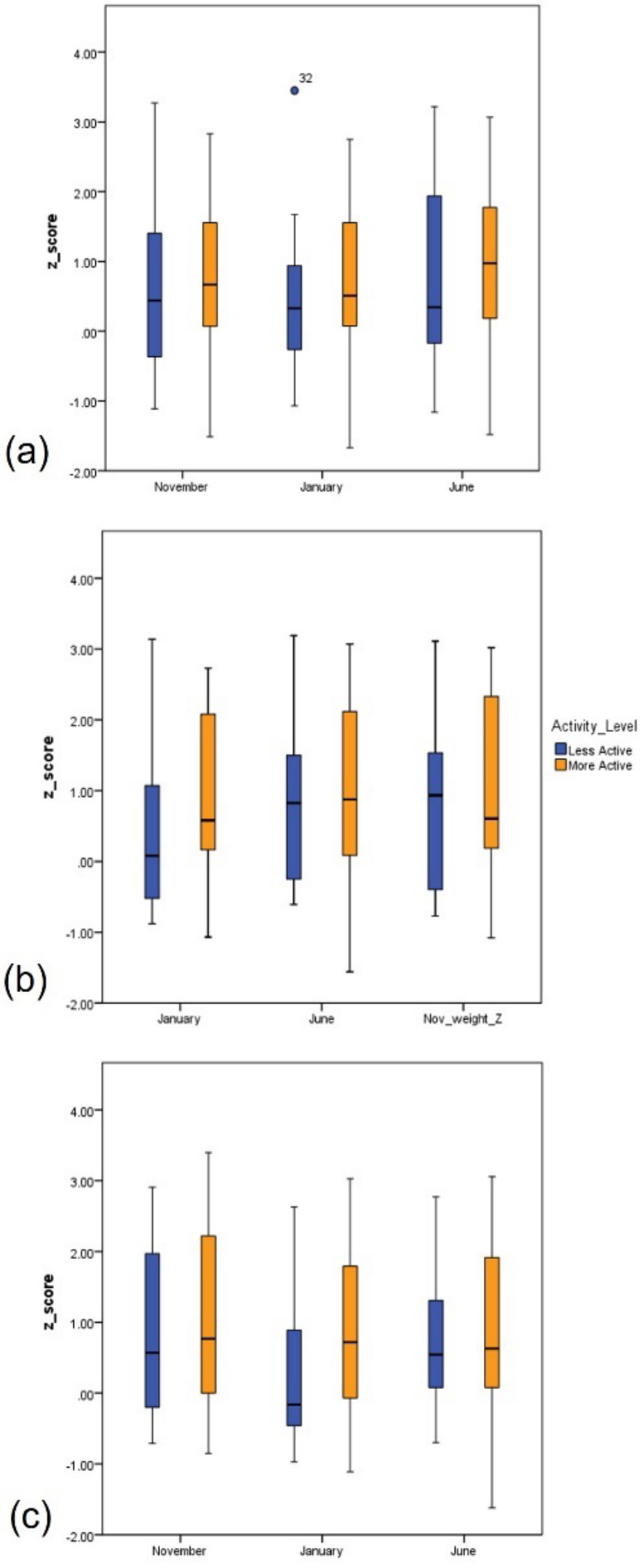

Figure 1. Changes in (a) Height, (b) Mass, and (c) BMI z-scores during the academic year

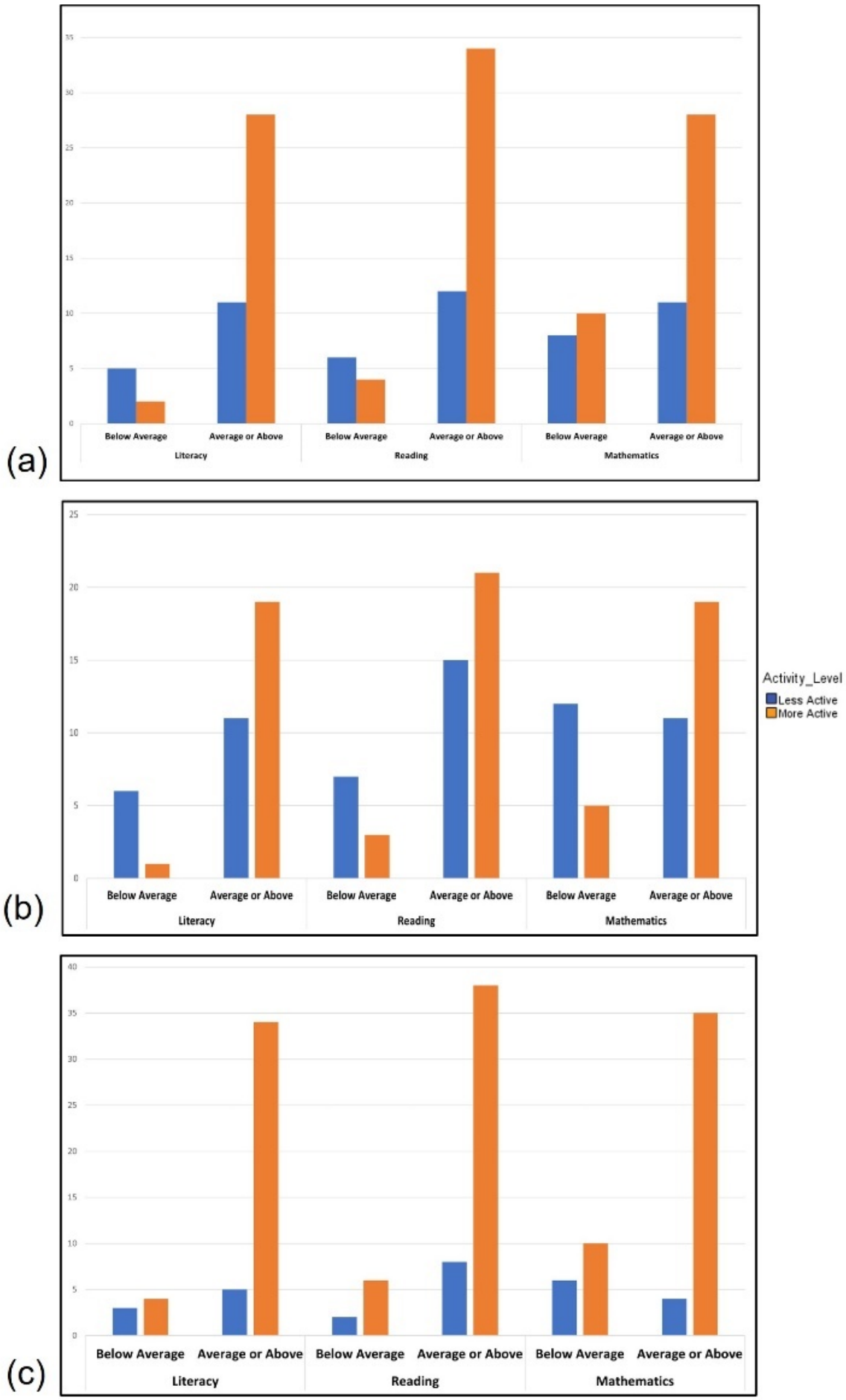

Figure 2. Differences in academic attainment based on (a) Physical Activity Level, (b) Parent Occupation, and (c) Classroom Behaviour

4. Discussion

The primary aim of this study was to determine if the association between higher reported physical activity and growth and academic performance found in primary school children was repeated. Findings from this study show that the association between physical activity and body mass and academic performance in primary school children was repeated in a distinct population of primary school children. Children who reported being more physically active were 27.72 and 12.59 times more likely to achieve average or above average performance than less active children in literacy and reading respectively.

4.1. Growth

The majority of children in this study had a normal BMI, however, it was shown that less active primary school children experience a decrease in mass over the winter holiday followed by a rapid recovery over the following months to June, compared to more active peers who maintain relatively stable mass. Although it is not a statistically significant decrease, it is likely to be of clinical significance as those who display greater variation in their mass over time are more likely to experience future growth disturbance such as being over or underweight [23].

School attendance may have a protective effect on weight maintenance due to the routine it provides via protected and regular mealtimes, free school meals, paid school meals and breakfast and after school clubs which provide snacks. Outside of the school term children may not have similar routine and nutritional support. Winter pressures can lead to increased strain on family budgets due to surges in fuel use, holiday related expenses and additional costs of providing breakfast, lunch and snacks to growing children outside of school term which may lead to food poverty. Further research which evaluates the role of school support in maintaining healthy growth in areas at risk of food poverty is required.

Children who are more active, did not experience the same decrease in mass; It is possible that physical activity may be protective. Regular exercise in adults can help maintain energy balances and homeostatic regulation of the bodies physiological systems though increased fat oxidation, sympathetic nervous system activity, and regulation of blood sugar and leptin levels [24]. Much of this research has been done in adults who are overweight or obese, or have lost weight so it is not directly generalisable to primary school children. It is also possible that being lower physical activity exacerbates the toxic stress effect of calorie restriction and food poverty, leading to an amplified impact on growth and wellbeing as a result [25]. Further research is required to evaluate the effect of exercise on weight regulation in children.

The differences in height between children who are less active and more physically active identified in our work is challenging to explain however, it is well accepted that childhood growth is influenced by genetics, hormonal factors and environmental factors such as nutrition, climate, psychological factors and physical activity [26]. Experience of food poverty, chronic stress and living in lower socio-economic settings have been shown to be at increased risk of shorter stature [27] possibly due to a suppressive effect on the production and action of Growth Hormone (GH) [28]. It has been suggested that physical activity may reduce this risk and can lead to stimulation of GH, negating some of these negative effects on growth, however research findings on this hypothesis have been inconclusive to date. It is also possible that the differences noted are due to self-selection, with those children who are taller, more likely to enjoy and be encouraged to be more physically active. Further research is warranted.

4.2. Academic Attainment

We identified that academic attainment appears to be associated with several factors including physical activity level, classroom behavior and parent/guardian occupation. Application of a regression model showed that activity level, classroom behavior and occupation type is a good fit for predicting likelihood of achieving average or above average scores in literacy and reading. Physical activity is shown to be the strongest influence in literacy and reading. This is consistent with the findings from our previous evaluation which supports associations between physical activity and positive academic performance [9]. Although physical activity is still important in mathematics attainment, parent or guardian occupation appears to be the most influential factor.

These findings add further support to the role physical activity and cardiorespiratory fitness play in the academic development of children. It has been associated with improvements in memory [29], decision making and critical thinking, cognition [29,30,31,32], behaviour [31,33], concentration [29], and overall academic attainment [29,34]. Participation in physical activity and sport can also lead to the development of personal and social skills that would be of benefit in academic settings. Physically active children are more likely to be happier, have higher self-esteem and less prone to anxiety [35,36,37]. They are also likely to enhance their communication and team working skills, and develop characteristics such as leadership, respect for authority and rules, commitment, resilience, perseverance [38,39].

Parental occupation appears to be significantly associated with the stronger academic performance in this population especially in mathematics, with those children with at least one parent from a professional background 28.38 times more likely to perform average or better in comparison to those with parents working in manual occupations. Research findings suggest that parent engagement in their child's education is associated with better academic performance [40,41,42]. Parents from professional backgrounds, are likely to have studied for longer, experiencing academic success by gaining one or more academic qualification. This may mean they are likely to have a positive view of the importance of education, have higher expectations, be more competent and/or comfortable in supporting and contributing to their child's academic work and communicating with teachers proactively during school years [40,41,42]. However, those working manual jobs may have also undertaken specialist training to support their career development.

Further research is required to evaluate this finding and to identify and implement appropriate strategies to reduce the attainment gap

4.3. Differences between Less and More Active Children

The secondary aim of this study was to identify differences between less active and more active children in personal, social and environmental factors that may contribute to physical activity and academic attainment. There were no statistically significant associations identified based on child gender, diet, family income, parent education or parent perceptions of their local environment based on our analysis. The population in this study live in an area of high deprivation in the UK, with the modal family income £0-19999 and most parents or guardians exiting education at 16 years old. It is encouraging that many children in this population thrive, showing healthy growth, meet physical activity guidelines and show strong academic attainment. It is possible that the benefits of physical activity could mediate the potential negative outcomes of lived experiences of poverty [9,30,31,32,33,43,44]. Whilst it may not be possible to immediately remove existing socio-economic barriers during physical activity interventions, these barriers are likely to confound the findings of studies that have poor control. Future research will need to consider designs that are able to mitigate for these confounding effects.

Although there were no differences in diet among children who reported they were more or less active, analysis showed there were limitations in nutritional intake for both groups (appendix 1 and 2). Daily diets tended to be higher in daily portions of carbohydrate and low in protein, diary and fruit and vegetables. This increases the likelihood of having deficiencies in fibre, iron and essential vitamin and mineral intake which can have negative effects on current health and wellbeing and risk of longer term metabolic and cardiac health and increases becoming overweight or obese in future [45,46,47,48]. Hunger can cause toxic stress due to the excessive or prolonged activation of the bodies physiological responses which can disrupt normal regulatory processes and brain circuitry negatively impacting physiological development, behaviour and health [46,49] Poor quality diet is not an uncommon finding in children and adolescents, the reasons why can be complex in nature [50,51], however, given the modal family income in this population and food bank use in the UK has risen by 74% from 2015-2020, food poverty could be a contributing factor and may therefore be a lived experienced for the children included in this study [52]. It is possible dietary supplementation, in addition to physical activity interventions, may enhance positive effects of physical activity in primary school children, further investigation is warranted.

4.4. Limitations

Due to the nature of data collection in primary school children during normal term time, it is limited in places by missing data due to factors that could not be controlled by researchers but reflect the true nature of research in this environment. Reasons for missing data include absenteeism, school events, attendance at unspecified meetings and classroom behaviour management issues. Where feasible repeated opportunities for data collection were utilised but could not always account for missing data. Due to the sensitive nature of some of the data collected, it may have led to a reduction in sample size due to reluctance of parents or guardians to provide consent for their child to take part in this study. This was accounted for by offering options for parents to not disclose information they were not comfortable sharing

Although there does not appear to be a difference in diet between children who are active and those who are less active in this population, this finding may be limited as food diary data was collected during term in September, while the children were attending school, with support of teaching staff to facilitate the collation of the data. It is not possible to identify if there were differences in diet over the holiday period where the reduction in mass was identified between children who were active and those who were less active.

5. Conclusion

This study confirms previous findings which reported that there does appear to be an association between physical activity and body mass and academic performance in primary school children, with lower levels of reported physical activity being associated with negative effects. Children who reported being less active showed greater variability in mass during the academic year as they experienced a decrease over the winter holiday followed by a rapid recovery over the following months to June, compared to more active peers who maintain relatively stable mass. Physically active children were 27.72 and 12.59 times more likely to achieve average or above average attainment than less active children in literacy and reading respectively. Although physical activity is also important in mathematics, this study adds that parent occupation is a key factor as children with one or more parents work in a professional occupation are more likely to achieve average or above average performance in mathematics. There were no statistically significant associations between academic attainment or physical activity levels in child gender, diet, family income, parent education or parent perceptions of their local environment. Primary school children may benefit from extension of school support systems beyond traditional term times and interventions to support physically active lifestyles. Those involved in the development and implementation of policy should consider effective and coherent strategies to deliver this at national, regional and local levels.

6. Implications

- Physical activity is positively associated with healthy growth and academic attainment.
- Socioeconomic factors were not found to be a significant factor in determining physical activity levels or academic attainment in primary school aged children.

- Primary school children may benefit from extension of school support systems beyond traditional term times and interventions to support physically active lifestyles.
- Schools may benefit from monitoring student physical activity, classroom behaviour and parent occupation to identify students who may benefit from additional academic support.

Conflict of Interest Statement

The authors declare there are no conflicts of interest.

Author Contributions

Study design and Ethics approval process - Michael McCluskey, Neil Gilson, Janine Bridges & Anand D Pandyan

Data Collection – Damian Penk & Michael McCluskey

Data Analysis – Michael McCluskey, Ahmad Al-shallawi, Anand D Pandyan & Jaap J Buurke

Manuscript Development – Michael McCluskey, Janine Bridges, Jaap J Buurke & Hermanus J Hermens & Anand D Pandyan

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Appendix 1. Probability distributions of academic attainment in reading, writing and mathematics for less active and active children in categorical variables

		Literacy	Reading	Mathematics	Activity Level
	Gender	0.83	0.53	0.80	0.57
	Activity Level	0.03*	0.04*	0.23	
	Classroom Behaviour	0.05	0.61	0.02*	0.73
BMI Classification	November BMI Status	0.89	0.87	0.03*	0.78
	January BMI Status	0.96	0.58	0.85	0.51
	June BMI Status	0.43	0.40	0.19	0.69
Diet	5 Fruit and Vegetables a day	0.93	0.31	0.07	0.39
	Fizzy Drinks Daily	0.46	0.75	0.36	0.96
	3 Meals a day	0.79	0.69	0.67	0.48
	School or Packed Lunch	0.16	0.15	0.44	0.54
Parent / Guardian Information	Parent Education	0.76	0.26	0.75	0.25
	Family Income	0.92	0.65	0.79	0.87
	Occupation Type	0.19	0.11	0.03*	0.92
	Pupil Premium	0.6	0.41	0.81	0.79
Parent / Guardian Perception of Local Environment	Availability Sidewalks	0.80	0.18	0.83	0.88
	Availability Bike Lanes	0.68	0.34	0.90	0.35
	Availability Infrastructure	0.72	0.18	0.81	0.99
	Maintenance Infrastructure	0.79	0.84	0.72	0.46
	Total Safety	0.80	0.30	0.42	0.21
	Crime	0.81	0.24	0.55	0.96
	Traffic	0.97	0.41	0.51	0.47
	Pleasant	0.94	0.36	0.73	0.93
	Aesthetics	0.63	0.23	0.78	0.75
	Network	0.68	0.18	0.02*	0.24
	Connectivity	0.58	0.10	0.02*	0.52
	Home	0.92	0.18	0.64	0.93
	Work/Study	0.61	0.86	0.75	0.26

Appendix 2. Probability distributions of academic attainment in reading, writing and mathematics for less active and active children in continuous numerous variables

	Physical Activity					
	Mean (SD)		**Mean Diff**	**95% CI**		**α**
	Less active	More Active		Lower	Higher	
Average Biceps Skinfold thickness	8.7 ±3.34	9.83 ± 3.57	1.13	-3.71	1.45	0.38
Average Triceps Skinfold Thickness	15.09 ± 5.71	15.43 ± 5.25	1.95	-4.30	3.63	0.86
Density	137.39 ± 43.09	160.02 ± 46.02	22.63	-48.52	3.25	0.09
Distance	19.75 ± 5.14	20.0 ± 5.33	0.25	-3.13	2.63	0.86
Fruit and veg	1.46 ± 0.85	2.1 ± 2.4	0.63	-1.76	0.49	0.26
Protein	1.34 ± 0.5	1.30 ± 0.55	0.04	-0.36	0.43	0.85
Carbohydrate	2.97 ± 0.79	2.75 ± 0.80	0.22	-0.36	0.81	0.44
Diary	0.93 ± 0.54	1.52 ± 0.87	0.59	0.11	1.08.	0.02*
Fizzy drinks	0.43 ± 0.36	0.52 ± 0.61	0.09	-0.49	0.31	0.66
Sweets and chocolate	1.57 ± 0.9	2.26 ± 1.45	0.69	-1.66	0.27	0.15