Overweight and Cardiovascular Risk Factors in 4- to 18-Year-Olds

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Key Words

BMI · Blood pressure · Children · Cholesterol · Waist circumference

Summary

Background: The objective of this study was to investigate the relationships between overweight and high waist circumference and cardiovascular risk factors in children. **Material and Methods:** We carried out a secondary analysis of data from 1,944 participants of the 'National Diet and Nutrition Survey: young people aged 4–18 years'. Blood pressure and blood lipid levels were compared in overweight versus non-overweight and high versus low waist circumference groups. Overweight was defined using international cut-offs for body mass index. High waist circumference was defined as ≥ 91 st percentile of UK waist circumference charts. Analyses were done separately by sex and age group (4–10 and 11–18 years for overweight, and 11–17 years for waist circumference). **Results:** Overweight and high waist circumference were associated with increased systolic blood pressure, mean arterial pressure, low-density lipoprotein cholesterol (LDLC) and triacylglycerol, and decreased high-density lipoprotein cholesterol (HDL). Those who were both overweight and had a high waist circumference had the highest blood pressure, plasma LDLC and triacylglycerol, and the lowest plasma HDL. **Conclusion:** Overweight and high waist circumference were associated with increased blood pressure and a less favourable lipid profile. Children who were both overweight and had a high waist circumference had the most unfavourable cardiovascular risk profile. Both measurements may be useful in identifying children with increased health risks.

Introduction

Due to increasing prevalence of obesity in children, health concerns which were previously uncommon in childhood are occurring more frequently [1]. This is of particular concern due to tracking of obesity and associated health risks into adulthood [2–4]. There is some uncertainty over the best anthropometric measure to identify risk of adverse health outcomes in children due to age-related variation in body mass index (BMI) and the inability to relate specific BMI values to health outcomes [5]. In 2000, international cut-off points based on data from 6 countries were published [6], which may make comparisons across countries easier. These are age- and sex-specific cut-off points from 2 to 18 years passing through BMI 25 and 30 kg/m² (adult cut-offs for overweight and obesity respectively) at age 18, roughly equivalent to the 89th and 99th percentile of the distribution of the reference population. Studies of fat distribution in children have produced conflicting results: associations between abdominal obesity and concentrations of lipids and blood pressure have been reported in some but not all studies [7–11]. Results from recent studies suggest that waist circumference may be a good predictor of cardiovascular disease risk in children [7, 8, 10, 12–14]. The 'National Diet and Nutrition Survey (NDNS): young people aged 4 to 18 years' carried out in 1997 collected information on the nutritional status of approximately 2,000 young people across mainland Great Britain including anthropometric measurements, blood pressure, and fasting blood samples. The present study aimed to investigate the relationships between overweight and high waist circumference and blood pressure and blood lipids in children using the NDNS dataset.

Table 1. Descriptive characteristics of children in the National Diet and Nutrition Survey by age group and sex

	4- to 10-year-olds						11- to 18-year-olds					
	n	boys		girls		p	n	boys		girls		p
		mean	SD	mean	SD			mean	SD	mean	SD	
Height, m	952	1.25	0.12	1.24	0.13	0.450	994	1.64	0.14	1.59	0.09	< 0.001
SDS height	952	0.57	1.09	0.57	1.16	0.986	994	0.32	1.02	0.19	1.06	0.035
Weight, kg	956	26.5	7.7	26.9	8.4	0.971	990	56.9	17.1	54.2	12.8	0.038
SDS weight	956	0.63	1.04	0.60	1.03	0.693	990	0.56	1.09	0.46	1.14	0.148
BMI, kg/m ²	952	16.7	2.2	17.0	2.4	0.102	990	20.7	3.9	21.4	4.0	0.004
SDS BMI	952	0.43	1.03	0.42	0.40	0.837	990	0.53	1.11	0.48	1.10	0.445
Waist circumference, cm							987	75.6	10.8	71.1	8.8	< 0.001
SDS waist circumference ^a							884	1.05	0.98	1.20	1.11	0.032
Systolic blood pressure, mm Hg	919	103	9	103	9	0.870	979	115	11	111	10	< 0.001
Diastolic blood pressure, mm Hg	919	55	8	55	8	0.224	979	56	8	57	8	0.143
Mean arterial pressure, mm Hg	919	71	7	71	7	0.412	979	76	8	75	8	0.181
Total plasma cholesterol, mmol/l	355	4.20	0.75	4.34	0.97	0.135	603	3.93	0.80	4.12	0.72	< 0.001
Plasma HDLC, mmol/l	355	1.35	0.30	1.28	0.31	0.045	603	1.20	0.34	1.27	0.34	0.017
Plasma LDLC, mmol/l	355	2.86	0.73	3.06	0.96	0.027	603	2.73	0.73	2.85	0.71	0.031
Plasma triacylglycerol, mmol/l	353	0.77	0.34	0.91	0.35	< 0.001	603	1.02	0.64	1.01	0.41	0.150

SDS = Standard deviation score.

^aChildren aged 11–17 years.

Material and Methods

The NDNS dataset was obtained from The Data Archive, University of Essex. A short description of methods for the collection of data of interest to the present study follows, further details can be found in the survey report [15]. An interview was completed for 2,127 young people (80% of the identified sample). Height and weight were measured in all children who consented, and used to calculate BMI, and for those aged 11 years and over, waist circumference was also measured. The first of 3 blood pressure measurements was discarded, and the mean of the following 2 calculated. Overnight fasted blood samples were taken and analysed for lipids, although a sample was still taken if the child had not fasted. Physical measurements were obtained for over 90% of the interview sample, and a blood sample from 56%. Overall, a greater proportion of 15–18-year-olds were non-responders. For anthropometric and blood pressure measurements, boys aged 15–18 years were less likely to give consent, however, response rate did not vary with age in girls. For blood samples, parents of children aged 4–6 years were least likely to give consent. There were no significant differences in co-operation rates by social class of head of household.

Statistical Analysis

Analysis of the data was carried out using SPSS for Windows version 15.0 (SPSS Inc., Chicago, IL, USA). Children were divided into subgroups based on sex and age (4–10 and 11–18 years). Variables were checked for normal distribution using a Kolmogorov-Smirnov test. Children were divided into overweight (including obese) and non-overweight according to BMI using the international cut-offs [6]. For waist circumference, the data were divided into high and low circumference with a high circumference defined as ≥ 91 st percentile of UK waist circumference charts [16]. Kappa was used to assess the degree of agreement for individuals between the groups for anthropometric measures. For normally distributed data, t-tests were carried out to compare blood pressure and blood lipids in overweight and non-overweight, and high and low waist circumference groups, and for data that was not normally distributed, Mann-Whitney tests were used. BMI and blood pressure measurements were available for 1,888

Table 2. Agreement between classifications of BMI and waist circumference in children aged 11–17 years by sex and overall

Waist circumference	BMI		% Agree- ment	Kappa
	high (overweight)	low (non-overweight)		
Boys				
High	94	60	85	0.65
Low	4	283		
Girls				
High	95	104	76	0.50
Low	1	241		
All children				
High	189	164	81	0.57
Low	5	524		

young people aged 4–18 years, and 955 had BMI and blood lipid measurements. Waist circumference and blood pressure measurements were available for 869 young people aged 11–17 years, and 533 had waist circumference and blood lipid measurements. The data were further categorised into 3 groups based on a combination of BMI and waist circumference: overweight and high waist circumference (high/high), overweight and low waist circumference or non-overweight and high waist circumference (high/low or low/high) (combined due to small numbers in the overweight and low waist circumference group), and non-overweight and low waist circumference (low/low). For normally distributed data, ANOVA tests were carried out to assess the trend across the groups, and for data that was not normally distributed, Jonckheere-Terpstra tests were used. BMI, waist circumference, and blood pressure measurements were available for 867 young people aged 11–17 years, and 532 had BMI, waist circumference, and blood lipid measurements.

Table 3. Mean and SD for blood pressure for overweight and non-overweight and high and low waist circumference by sex and age category

	n	Systolic blood pressure, mm Hg			Diastolic blood pressure, mm Hg			Mean arterial pressure, mm Hg		
		mean	SD	p	mean	SD	p	mean	SD	p
<i>BMI</i>										
Boys										
4- to 10-year-old										
Overweight	77	106	9	0.006	56	9	0.202	72	8	0.035
Non-overweight	405	103	9		54	8		70	7	
11- to 18-year-old										
Overweight	107	121	12	< 0.001	58	8	0.045	79	8	< 0.001
Non-overweight	376	113	11		56	8		75	8	
Girls										
4- to 10-year-old										
Overweight	113	106	9	< 0.001	56	8	0.371	73	7	0.020
Non-overweight	320	102	9		55	8		71	7	
11- to 18-year-old										
Overweight	112	116	11	< 0.001	58	8	0.114	77	8	0.001
Non-overweight	378	110	10		57	8		74	8	
<i>Waist circumference</i>										
Boys 11- to 17-year-old										
High	151	117	11	< 0.001	56	8	0.319	77	7	0.002
Low	284	112	11		55	8		74	8	
Girls 11- to 17-year-old										
High	196	114	11	< 0.001	57	8	0.232	76	8	0.002
Low	238	109	10		56	8		74	8	
<i>BMI and waist circumference</i>										
Boys 11- to 17-year-old										
High/high	91	120	11	< 0.001	57	8	0.139	78	7	< 0.001
High/low or low/high	64	114	10		55	7		75	7	
Low/low	279	112	11		55	8		74	8	
Girls 11- to 17-year-old										
High/high	93	115	10	< 0.001	58	8	0.136	77	7	< 0.001
High/low or low/high	103	112	10		57	8		75	8	
Low/low	237	109	10		56	8		74	8	
All 11- to 17-year-old										
High/high	184	117	11	< 0.001	57	8	0.028	77	7	< 0.001
High/low or low/high	167	113	10		56	8		75	7	
Low/low	516	110	10		56	8		74	8	

Results

Means and standard deviations (SD) for the NDNS variables used are shown in table 1. In the younger age group, there was little difference between the sexes for anthropometric measures. Boys had a better lipid profile, with significantly higher high-density lipoprotein cholesterol (HDL) and lower low-density lipoprotein cholesterol (LDL) and triacylglycerol levels. In older children, there was greater difference between the sexes with regards to anthropometric measures. Boys were significantly taller, heavier, had lower BMI, and greater waist circumferences than girls. Boys had significantly higher systolic blood pressure but lower total plasma cholesterol, HDL, and LDL than girls. Significantly more girls than boys aged 4–10 years were classified as overweight (26.2 vs 16.4%; $p < 0.001$), but in older children, there was little differ-

ence between the sexes (22.5% in boys and 22.8% in girls). In boys, the percent overweight rose significantly with age ($p = 0.01$), but in girls the percent overweight decreased slightly but not significantly with age. As shown in table 2, the agreement between overweight (including obese) and non-overweight and waist circumference classifications in children aged 11–17 years was moderate to good, and was higher in boys than girls. The comparison of blood pressure between overweight and non-overweight and high and low waist circumference groups and groupings based on a combination of the 2 measures is shown in table 3. Systolic blood pressure was significantly higher in overweight children compared to non-overweight children of both sexes and age groups but differences were greater in older children. Systolic blood pressure was also significantly higher in children with high waist circumferences compared to children with low waist circumferences of both

Table 4. Mean and SD for blood lipids for overweight and non-overweight and high and low waist circumference by sex and age category

	n	Total plasma cholesterol, mmol/l			Plasma HDLC, mmol/l			Plasma LDLC, mmol/l			Plasma triacylglycerol, mmol/l		
		mean	SD	p	mean	SD	p	mean	SD	p	mean	SD	p
<i>BMI</i>													
Boys													
4- to 10-year-old													
Overweight	34	4.29	0.69	0.477	1.21	0.31	0.005	3.07	0.71	0.059	0.98	0.42	< 0.001
Non-overweight	159	4.18	0.77		1.37	0.29		2.81	0.73		0.72	0.30	
11- to 18-year-old													
Overweight	62	3.89	0.61	0.945	1.08	0.31	0.001	2.81	0.68	0.308	1.28	1.03	0.035
Non-overweight	243	3.94	0.84		1.23	0.35		2.70	0.75		0.96	0.48	
Girls													
4- to 10-year-old													
Overweight	46	4.36	1.18	0.826	1.21	0.30	0.085	3.15	1.19	0.440	1.03	0.48	0.072
Non-overweight	115	4.33	0.88		1.30	0.31		3.02	0.86		0.86	0.28	
11- to 18-year-old													
Overweight	66	4.06	0.84	0.380	1.09	0.30	< 0.001	2.97	0.85	0.148	1.21	0.57	0.033
Non-overweight	230	4.15	0.68		1.32	0.34		2.83	0.66		0.96	0.34	
<i>Waist circumference</i>													
Boys 11- to 17-year-old													
High	89	3.91	0.64	0.610	1.12	0.30	0.001	2.79	0.67	0.291	1.22	0.90	0.001
Low	184	3.96	0.87		1.27	0.36		2.69	0.75		0.90	0.40	
Girls 11- to 17-year-old													
High	119	4.18	0.85	0.458	1.18	0.35	< 0.001	2.99	0.81	0.008	1.10	0.48	0.019
Low	141	4.11	0.59		1.36	0.32		2.75	0.60		0.93	0.30	
<i>BMI and waist circumference</i>													
Boys 11- to 17-year-old													
High/high	49	3.96	0.60	0.653	1.09	0.33	< 0.001	2.87	0.66	0.218	1.29	1.01	0.003
High/low or low/high	43	3.80	0.69		1.15	0.26		2.65	0.66		1.09	0.74	
Low/low	181	3.98	0.87		1.28	0.36		2.70	0.76		0.91	0.40	
Girls 11- to 17-year-old													
High/high	55	4.10	0.86	0.764	1.09	0.31	< 0.001	3.01	0.88	0.009	1.21	0.55	0.004
High/low or low/high	63	4.26	0.83		1.25	0.36		3.01	0.74		1.01	0.40	
Low/low	141	4.11	0.59		1.36	0.32		2.75	0.60		0.93	0.30	
All 11- to 17-year-old													
High/high	104	4.04	0.75	0.589	1.09	0.32	< 0.001	2.94	0.78	0.004	1.25	0.80	< 0.001
High/low or low/high	106	4.07	0.81		1.21	0.33		2.86	0.73		1.04	0.56	
Low/low	322	4.03	0.76		1.31	0.34		2.72	0.69		0.92	0.36	

sexes. Diastolic blood pressure was not significantly different in overweight children compared to non-overweight children except for boys aged 11–18 years, or in children with high waist circumferences compared to children with low waist circumferences. Mean arterial pressure was significantly higher in overweight children compared to non-overweight children of both sexes and age groups, with differences being greater in older children. Mean arterial pressure was also significantly higher in children with high waist circumferences compared to children with low waist circumference in both sexes. When the data were divided into 3 groups based on a combination of BMI and waist circumference, those who were both overweight and had a high waist circumference had the highest systolic and mean arterial pressure. There was a significant trend of increasing systolic and mean arterial pressure moving

from low/low to high/high in all children and when split by sex. There was also a significant trend for increasing diastolic pressure in both sexes combined.

Table 4 shows the comparison of blood lipids between overweight and non-overweight and high and low waist circumference groups, and groupings based on a combination of the 2 measures. Total plasma cholesterol was not significantly different between overweight and non-overweight children or between children with high and low waist circumferences. Plasma HDLC was significantly lower in overweight children compared to non-overweight children except for girls aged 4–10 years. Plasma HDLC was also significantly lower in children with high waist circumferences compared to children with low waist circumferences of both sexes. Plasma LDLC was not significantly different in overweight children com-

pared to non-overweight children, however, plasma LDLC was significantly higher in girls with high waist circumference compared to those with low waist circumference, but not in boys. Plasma triacylglycerol was significantly higher in overweight children compared to non-overweight children except for girls aged 4–10 years, and was also significantly higher in children with high waist circumference compared to children with low waist circumference of both sexes. When the data were divided into 3 groups based on a combination of BMI and waist circumference, those who were both overweight and had a high waist circumference had the lowest plasma HDLC and highest plasma LDLC and triacylglycerol. There was a significant trend of decreasing HDLC and increasing triacylglycerol moving from low/low to high/high in all children and when split by sex. There was also a significant trend for increasing LDLC in girls and both sexes combined.

8% of boys and 9% of girls had a mean plasma total cholesterol level greater or equal to the adult cut-off of 5.2 mmol/l, as no cut-offs have been agreed for children. However, only 10% of boys and 21% of girls with elevated total cholesterol levels were in the overweight category, but 11% of boys and 72% of girls aged 11–17 years with elevated total cholesterol were in the high waist circumference category, and 5% of boys and 22% of girls aged 11–17 years with elevated total cholesterol were both overweight and had a high waist circumference.

Discussion

The percentage of overweight and obesity in the NDNS children was almost double the rates in 1994 [17] but reasonably comparable with those in 1998 [18–19] suggesting a sharp increase in the percentage of overweight and obese children between 1994 and 1997/1998. In this population, overweight and high waist circumference were clearly associated with unfavourable cardiovascular risk profiles. The strength of using the NDNS data is that it provides good quality measurements in a large representative sample of children across Great Britain [15].

The findings are consistent with studies from other countries which found increased blood pressure to be associated with increasing adiposity with the relationship being most consistent for systolic blood pressure [20–23]. The findings of this study are also broadly consistent with studies from other countries, which found that childhood obesity was associated with higher levels of LDLC and triacylglycerol, and lower HDLC. However, unlike the present study, the majority of previous studies have also found a relationship with total cholesterol [21, 23]. Like the present study, Chu et al. [24] failed to find a relationship between anthropometric variables and total cholesterol in 12–16-year-old Taiwanese children, however, most anthropometric variables were positively associated with triacylglycerol and total cholesterol/HDL ratio, and negatively correlated with HDLC.

Studies of fat distribution in children have produced inconsistent associations with lipids and blood pressure. Differences in sex may account for the differences found between studies. Previous studies have suggested that the relationship may be stronger in girls [11]. Contrasting findings may also be due to differences in anthropometric measures, cut-offs used, and age. There is some evidence that the relationship of lipids to obesity may change with age and sexual development [7, 8, 25]. Unfortunately, in the NDNS, waist circumference was only measured in those aged 11 and over. It could be that sex differences in fat patterning that happen with the onset of puberty are responsible for the differences seen. It has been suggested that body fat distribution is only important after puberty, however, associations between waist circumference or waist to hip ratio and lipids have been found even at age 4 years [11, 26].

The present study provides evidence that overweight and obesity defined by the international cut-offs are associated with increased cardiovascular health risks in British children. The benefit of using this as a common standard is that it will allow worldwide comparisons of childhood obesity. However, there is still some debate over the use of international vs. national reference data [27, 28]. Until now, childhood cut-offs for BMI have been arbitrary, as the long-term health risks associated with specific BMI values are unknown. However, as obese children are suffering from more immediate morbidity it may now become possible to link cut-offs with health risks as in adults. This will help to eliminate the problem of the lack of consensus over the definition of obesity in children and allow for international comparisons.

The present study also provides evidence that a high waist circumference as defined by the 91st percentile of the UK waist circumference charts [16] is associated with increased cardiovascular health risks in British children. These are sex- and age-specific centiles based on data from British schoolchildren collected in 1977 for boys and 1987 in girls. McCarthy et al. [29] compared data from the NDNS with the surveys from 1977 and 1987, and concluded that waist circumference trends over the time period had greatly exceeded trends in BMI, particularly in girls. Using the 91st percentile as a cut-off in the present study, 35% of boys and 45% of girls in the NDNS sample were above this, confirming that waist circumference was particularly high in girls.

The fact that obesity even in young children is associated with increased cardiovascular risk factors such as higher blood pressure and unfavourable blood lipids is of concern particularly with the increasing prevalence of childhood obesity. It is important to treat obesity in childhood, as blood pressure and blood lipids have been shown to follow from childhood into adulthood, with obesity at baseline being a significant predictor of adult values [7, 11]. It is encouraging to note that adverse cardiovascular risk factor profiles in obese children, including hypertension and dyslipidaemia, have been found to improve with weight loss [23, 30–32].

Recent studies indicate that waist circumference may be increasing as fast as, if not faster than BMI rates [29, 33]. This is of particular concern due to the association of health risks with abdominal obesity. Evidence from the present study suggests that there is good agreement amongst the anthropometric measures, and that the relationship of them to cardiovascular risk factors in children is similar. Children who were both overweight and had a high waist circumference had the most unfavourable cardiovascular risk profile, suggesting that both measurements may be of use to detect children at risk from excess body fat. Unfortunately, as the NDNS only measured waist circumference in those aged 11 and over, the results are only applicable to this age group, however, other studies also suggest that waist circumference may be as good as if not better than BMI for assessing health risks in children. As with BMI, the cut-offs suggested for waist circumference in children are arbitrary, and not related to health risks, however, it may now be possible to link cut-offs to health outcomes. Fu-

ture studies should look into cut-offs for anthropometric variables in children and adolescents, associated with increased health risks. Also, longitudinal studies are required to assess the degree of overweight or abdominal obesity associated with future morbidity and mortality in adulthood.

Contribution of Authors

Leone C.A. Craig conducted the statistical analysis and drafted the manuscript. Joan Love, Brian Ratcliffe, and Geraldine McNeill supervised the design and conduct of the analysis, and commented on the drafts of the manuscript. All authors read and approved the final draft of the manuscript.

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