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ORIGINAL ARTICLE

Reductions in blood pressure during a community-based overweight and obesity treatment in children and adolescents with prehypertension and hypertension

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Due to the pandemic of childhood obesity and thus obesity-related hypertension, improvements in treatment availability are needed. Hence, we investigated whether reductions in blood pressure (BP) would occur in children with overweight and obesity exhibiting prehypertension/hypertension during a community-based overweight and obesity treatment program, and if changes in body mass index (BMI) are associated with changes in BP. The study included 663 children aged 3–18 years with a BMI $\geqslant$85th percentile for sex and age that entered treatment from June 2012 to January 2015. Height, weight and BP were measured upon entry and every 3–6 months. BMI and BP s.d. scores (SDSs) were calculated according to sex and age, or sex, age and height. Prehypertension was defined as a BP SDS $\geqslant$1.28 and $<$1.65. Hypertension was defined as a BP SDS $\geqslant$1.65. Upon entry, 52% exhibited prehypertension (11.9%) or exhibited hypertension (40.1%). After 12 months (range: 3–29) of treatment, 29.3% of the children with prehypertension/hypertension were normotensive. Children with systolic prehypertension/hypertension upon entry reduced their systolic BP SDSs by 0.31 (95% confidence interval (CI): 0.70–0.83, $P<0.0001$). Children with diastolic prehypertension/hypertension upon entry reduced their diastolic BP SDSs by 0.78 (95% CI: 0.78–0.86, $P<0.0001$). BMI SDS changes were positively associated with BP SDS changes ($P<0.0001$). Nonetheless, some children reduced BP SDSs while increasing their BMI SDSs, and prehypertension/hypertension developed in 23.3% of the normotensive children despite reductions in BMI SDSs ($P<0.0001$). These results suggest that community-based overweight and obesity treatment can reduce BP, and thus may help improve treatment availability.

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INTRODUCTION

Due to the pandemic of childhood obesity, the development of obesity-related hypertension during childhood and adolescence is a considerable health issue.[1] Hypertension increases the risk of cardiovascular disease and premature death in adulthood,[2] but importantly, this risk burden can be reversed if the degree of obesity is reduced.[3] Accordingly, reducing the degree of obesity is first line in prevention and treatment of obesity-related hypertension.[4,5] Specialized hospital-based child and adolescent overweight and obesity treatment programs can reduce blood pressure (BP),[6] but improvements in treatment availability and accessibility are needed to accommodate the large number of children and adolescents with overweight, obesity and obesity-related hypertension.[7] Community-based overweight and obesity treatment options may help improve treatment availability and accessibility, but mixed results have been demonstrated in studies investigating changes in BP attained during community-based child and adolescent overweight and obesity treatment.[8–11] A considerable weight reduction may be necessary to reduce BP[12,13] and several community-based child and adolescent overweight and obesity treatment programs resulted in only moderate weight reductions.[8–11] Thus, whether community-based child and adolescent overweight and obesity treatment can serve as a first-line treatment option for children and adolescents with obesity-related hypertension needs to be evaluated.

To address the need for improved community-based child and adolescent overweight and obesity treatment, an effective, hospital-based, chronic care child and adolescent overweight and obesity treatment protocol, The Children's Obesity Clinic's Treatment (TCOCT) protocol,[14] was transferred into a community healthcare setting in Denmark. This community-based overweight and obesity treatment program is delivered by nurses and dietitians at eight healthcare centres across Denmark.

In the present study, we investigated if reductions in BP would occur during community-based overweight and obesity treatment program in the children and adolescents exhibiting prehypertension or hypertension upon entry into treatment. Further, we investigated whether changes in body mass index (BMI) were associated with changes in BP, and if children with minor or no reductions in BMI would reduce their BP.

PATIENTS AND METHODS

Patients

Children and adolescents from eight municipalities in Denmark were invited to undergo community-based overweight and obesity treatment.

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Information about the treatment offer was made public in local media and at the national webpage for community healthcare services. Children and adolescents were referred to treatment by school nurses, general practitioners, or directly by their families contacting their local healthcare center. The criteria for entering into treatment were an age from 3 to 18 years and a BMI ⩾85th percentile[15] according to age- and sex-specific Danish references.[16] No other eligibility criteria for entering treatment were applied.

This prospective and longitudinal study included children and adolescents who entered treatment during the period from 7 June 2012 to 23 January 2015. The follow-up period ended on 14 March 2015. Children and adolescents were eligible for inclusion in this study if height, weight and BP were measured at entry into treatment and at a follow-up consultation after more than 3 months of treatment.

The child and adolescent overweight and obesity treatment program

The TCOCT protocol has been described elsewhere.[14] The protocol is based upon the recognition of obesity as a chronic and complex disease[17] due to the tight neuroendocrine regulation of the fat mass counteracting attempts to reduce the excess fat mass,[18] and due to the multitude of medical and psychosocial comorbidities.[19,20] Hence, a comprehensive and chronic care treatment is required.[17,21] When transferring the TCOCT protocol from the hospital healthcare setting into the community healthcare setting, all community healthcare professionals completed a thorough initial training program consisting of theoretical lessons taught by experienced personnel at The Children's Obesity Clinic (pediatricians, dietitians, nurses, and psychologists) and a 7–9 days internship at The Children's Obesity Clinic. During this internship, practical training on anthropometric and BP measurements was conducted to insure a standardized method of measurement. Further, follow-up courses were held regularly during the study period, and the community healthcare personnel received a minimum of 2 days of supervision of consultations at the community healthcare centres to ensure correct use of the treatment protocol including the methods of anthropometric and BP measurements.

The treatment program was family-centred and all consultations were 'one-to-one' with each child or adolescent and adjacent family. Initially, a nurse conducted a comprehensive 1-h questionnaire-based interview, aimed at identifying all the lifestyle changes needed to reduce the degree of obesity. The questionnaire was developed at The Children's Obesity Clinic in 2008, based on the existing literature.[15,22,23] At this hospital-based clinic, considerable reductions in BMI SDSs have been documented in the children enroled in the TCOCT program.[14] The identified lifestyle changes were incorporated into a treatment plan, containing 15–20 individually tailored items of advice regarding the implementation of the lifestyle changes into the daily life of the family. As examples, regular sport activities were introduced and sedentary behaviours, such as screen time, were reduced to 2 h per day and limited to after 1700 hours. Other examples were: changes in daily diet, means of transportation to further reduce sedentary behaviours, and control of allowances to reduce the child's purchases of unhealthy snacks. Subsequently, ½–1-h consultations were scheduled with a nurse and dietitian in turn, and at each consultation, the treatment plan was adjusted to accommodate the current challenges in each family. The frequency of consultations was individualized, but an average of four to six consultations were conducted during the treatment of each family per year. The treatment program continued until the child/adolescent reached normal weight (BMI < 85th percentile[15] for age and sex[16]), until the adolescent turned 19 years, until the family wished to discontinue treatment for various reasons, or if the family repeatedly neglected appointments.

Anthropometrics

At each consultation, the child's height was measured to the nearest 0.1 cm on a Tanita HR100 stadiometer (Tanita Corp., Tokyo, Japan) and weight was measured to the nearest 0.1 kg on a Tanita BC418 scale (Tanita Corp.). The children wore light indoor clothes and no shoes during the measurements. BMI was calculated, and height and BMI were transformed into an SDS using the LMS method [22] based upon age- and sex-specific Danish references.[16]

Blood pressure

BP was measured upon entry into treatment and at consultations every 3–6 months. The measurements were conducted in accordance with the recommendations in the fourth report from the National High Blood Pressure Education Program Working Group on Children and Adolescents.[4] Hence, BP was measured after 5 min of rest using an oscillometric device, Omron 705 IT (Omron Corp., Kyoto, Japan), which is validated in children and adolescents.[23] The appropriate cuff size (small < 22 cm, medium 22–32 cm or large > 32 cm) was used after measuring the circumference at the middle of the right upper arm.[4,23] During the measurements, the child sat relaxed in an upright position with his/her arm resting on a table or an armrest.[4] Three measurements were conducted and the mean of the last two was calculated and converted to an SDS based on age-, sex- and height-specific reference charts.[4,5,24] Prehypertension was defined as a BP ⩾90th and < 95th percentile (equivalent to a BP SDS ⩾1.28 and < 1.65), and hypertension was defined as a BP ⩾95th percentile (equivalent to a BP SDS ⩾1.65).[4]

The pubertal development stage

The pubertal developmental stage was classified according to Tanner.[25,26] Upon entry, all families received a questionnaire containing a depiction of the pubertal development stages and written instructions as to enable self-assessment by the child or adolescent. If the questionnaire was not completed, girls below 8 years of age and boys below 9 years of age were considered pre-pubertal.[27] Questions regarding menarche were asked and if menarche had occurred, the girl was considered pubertal.[27]

Socioeconomic status

Upon entry, information regarding parental occupation was obtained, and the socioeconomic status was classified in accordance with the Statistics Denmark's national classification scheme.[28] This classification scheme is based upon the Danish version of the International Standard Classification of Occupation (ISCO-88) and defines five classes with class one being the highest and class five the lowest.[28]

Ethical considerations

All participants gave informed assent. Parents signed an informed written consent before enrolment into treatment. The study was approved by the regional Danish Ethics Committee (Protocol ID SJ-104, including 24 approved supplementary protocols) and by the Danish Data Protection Agency, and is registered at Clinicaltrials.gov, ID-no.: NCT02013843.

Statistics

The statistical analyses were conducted using R version 3.2.2 (A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria). Baseline characteristics were compared in those who were eligible and those who were ineligible for this study: age and BMI SDSs were compared using the Wilcoxon signed-rank test, whereas the percentages with obesity, socioeconomic status and Tanner stages were compared using the Chi-squared test. Associations of baseline BMI SDSs with baseline BP SDSs were analysed in linear regression models, with BP SDSs as the dependent variable, and in covariance models adjusted for sex, age, height SDS, socioeconomic status and Tanner stage.

As BP was measured at follow-up consultations approximately every 3–6 months, the mean changes in BMI SDS and BP SDS after 3–6 months, 6–12 months, 12–18 months, 18–24 months and 24–30 months of treatment, respectively, were analysed using the paired Student's *t*-test. If more than one measurement of the BP was performed in the same child within each time period, only the latest measurement was included in the analyses. Further, the mean changes in BMI SDS and BP SDS upon the latest consultation within the study period were analysed using the paired Student's *t*-test

Associations of changes in BMI SDS with changes in BP SDS upon the latest consultation within the study period were analysed in covariance models, with changes in BP SDS as the dependent variables, adjusted for the baseline values of BMI SDS and BP SDS, and in covariance models further adjusted for sex and baseline values of age, BMI SDS, BP SDS, height SDS, socioeconomic status and Tanner stage. Changes in BP SDS upon the latest consultation within the study period were analysed in the groups reducing BMI SDS by > 0.25, by > 0.25, or increasing BMI SDS. In all models, Tanner stages were divided into groups representing pre-pubertal (Tanner 1), pubertal (2–4) or post-pubertal (5), and socioeconomic status was dichotomized into groups representing high (1–3) or low (4–5) socioeconomic status.

RESULTS

During the study period, 1001 children and adolescents (455 boys) entered treatment. A number of 338 children and adolescents were ineligible for inclusion in this study due to not having their BP measured at entry ($n = 32$) or at follow-up ($n = 138$), or due to not having attended a follow-up consultation later than 3 months after enrolment when the follow-up period ended ($n = 168$). The reasons for not measuring the BP were not recorded. The children and adolescents who were ineligible for inclusion were older ($P = 0.02$), exhibited a higher BMI SDS ($P = 0.03$), and had a lower socio-economic status ($P = 0.02$) than those who were eligible ($n = 663$). Of the 663 children and adolescents, who were included in this study, 91 (14%) children were dropped out after a median of 14 months of treatment (range: 4–26 months). The children were dropped out due to neglected appointments ($n = 66$), requesting to end treatment ($n = 20$) or due to moving away ($n = 5$).

Baseline

The median age was 10.7 years (range: 3.2 – 17.5) and the median BMI SDS was 2.60 (range: 1.10 – 5.40; Table 1). Upon entry, 11.9% exhibited prehypertension and 40.1% exhibited hypertension, which was mainly systolic. Among young children (age below 10.7 years), 10.0% exhibited prehypertension and 18.5% exhibited hypertension, while higher percentages of older children and adolescents exhibited prehypertension (13.8%) and hypertension (61.6%; $P < 0.0001$). BMI SDS was positively associated with systolic and diastolic BP SDSs, and these associations persisted when adjusting for sex, age, height SDS, socioeconomic status and Tanner stage (Table 2).

Follow-up

After a median of 12 months (range: 3–29 months) of treatment, 10.1% exhibited prehypertension and 38.2% exhibited hypertension (Table 1). Among young children 7.9% exhibited prehypertension and 14.2% exhibited hypertension at follow-up, while higher percentages of older children exhibited prehypertension (11.8%) and hypertension (62.4%, $P < 0.0001$).

Among the 345 children and adolescents with prehypertension or hypertension at entry, 29.3% were normotensive upon follow-up.

In the 328 children and adolescents with systolic prehypertension or hypertension at entry, the systolic BP SDS was reduced by a mean of 0.42, 0.38 and 0.32 BP SDS after a median of 5, 7 and 13 months of treatment, respectively (Table 3). Of the children with systolic prehypertension or hypertension at entry, only 34 and 7 children had their BP SDSs measured beyond 18 and 24 months of treatment, respectively, and the reductions in systolic BP SDS at these measurements were not statistically significant (Table 3). At the latest measurement within the study period, the systolic BP SDS was reduced by a mean of 0.31 (CI 95%: 0.21–0.41, $P < 0.0001$; Figure 1), and 28.7% exhibited a normal systolic BP SDS at this measurement. In the 222 (67.7%) children and adolescents with systolic prehypertension or hypertension at entry who reduced their systolic BP SDS, the mean reduction was 0.78 BP SDS (95% CI: 0.70–0.83, $P < 0.0001$).

In the 139 children and adolescents with diastolic prehypertension or hypertension at entry, the diastolic BP SDS was reduced by a mean of 0.68, 0.75, 1.05, 0.88 and 1.11 BP SDS after a median of 4, 8, 13, 21 and 24 months of treatment, respectively (Table 2). At the latest measurement within the study period, the diastolic BP SDS was reduced by a mean of 0.78 (CI 95%: 0.66–0.90, $P < 0.0001$; Figure 1), and 68.0% exhibited a normal diastolic BP SDS at this measurement. In the 126 (91.0%) children and adolescents with diastolic prehypertension or hypertension at entry who reduced their diastolic BP SDS during treatment, the mean reduction was 0.89 BP SDS (95% CI: 0.78–0.86, $P < 0.0001$).

Table 1. The characteristics of the study population

	Baseline	*Follow-up*[a]	P-*value*
N (boys)	663 (311)	663 (311)	
Age, median (range)	10.7 (3.2–17.5)	12.1 (4.3–19.4)	< 0.0001
BMI SDS, median (range)	2.60 (1.10–5.40)	2.33 (0.28–6.05)	< 0.0001
Obese, *n* (%)	628 (94.7%)	456 (82.4%)	< 0.0001
Follow-up, months, median (range)	12 (3–29)		
Tanner			
Boys, median (range)	2 (1–5)		
Pre-pubertal, *n* (%)	107 (43.9%)		
Pubertal, *n* (%)	125 (51.1%)		
Post pubertal, *n* (%)	12 (0.5%)		
Girls, median (range)	2 (1–5)		
Pre-pubertal, *n* (%)	83 (25.5%)		
Pubertal, *n* (%)	208 (64.0%)		
Post pubertal, *n* (%)	34 (10.5%)		
Socioeconomic status			
Median (range)	3 (1–5)		
High, *n* (%)	411 (68.2%)		
Low, *n* (%)	192 (31.8%)		
Systolic BP, mm Hg, median (range)	111 (75–149)	109 (76–144)	< 0.0001
Systolic BP SDS, median (range)	1.28 (−2.62 to 5.65)	1.19 (−2.70 to 5.35)	0.90
Normal, *n* (%)	335 (50.5%)	350 (52.7%)	
Prehypertension, *n* (%)	79 (11.9%)	63 (9.5%)	
Hypertension, *n* (%)	249 (37.5%)	250 (37.8%)	0.34
Diastolic BP, mm Hg, median (range)	66 (49–96)	64 (41–97)	< 0.0001
Diastolic BP SDS, median (range)	0.66 (−1.38 to 2.98)	0.50 (−1.90 to 3.25)	< 0.0001
Normal, *n* (%)	524 (79.0%)	580 (87.5%)	
Prehypertension, *n* (%)	67 (10.1%)	46 (6.9%)	
Hypertension, *n* (%)	72 (10.9%)	37 (5.6%)	< 0.0001
Systolic and/or diastolic			
Prehypertension, *n* (%)	79 (11.9%)	67 (10.1%)	
Hypertension, *n* (%)	266 (40.1%)	253 (38.2%)	

Abbreviations: BMI, body mass index; BP, blood pressure; SDS, s.d. score. [a]Follow-up refers to the latest follow-up measurement within the study period. BMI SDS and BP SDS at baseline and follow-up were compared using the paired Student's *t*-test. Percentages with obesity and percentages with normal BP, prehypertension or hypertension at baseline and at follow-up were compared using the Chi-squared test. Obese: ⩾95th percentile for sex and age; pre-hypertension: BP ⩾90th and < 95th percentile; hypertension: BP ⩾95th percentile for sex, age and height; pre-pubertal: Tanner 1; pubertal: Tanner 2–4; post pubertal: Tanner 5; socioeconomic status: high: 1–3, low: 4–5.

Among the 318 children and adolescents who were normotensive upon entry, 8.2% developed prehypertension and 15.1% developed hypertension, which was mainly systolic (97.0%), though a smaller fraction (16.0%) developed both systolic and diastolic prehypertension or hypertension. In the 335 children and adolescents with a normal systolic BP SDS at entry, the systolic BP SDS increased by a mean of 0.29 (95% CI: 0.20–0.38, $P > 0.0001$). In the 524 children and adolescents with a normal diastolic BP SDS at entry, the diastolic BP SDS did not change significantly (0.02, CI 95%: −0.04 to 0.07, $P = 0.53$).

Changes in BMI SDS and BP SDS

Changes in BMI SDS were positively associated with changes in BP SDS, when adjusting for the baseline values of BMI SDS and BP SDS, and the associations persisted when further adjusting for sex, age, height SDS, socioeconomic status and Tanner stage (Table 2).

Table 2. Associations of baseline BMI SDS with baseline BP SDS, and of changes in BMI SDS with changes in BP SDS at the latest follow-up measurement

	β	*Basic models*[a]			β	*Adjusted models*[b]		
		95% CI	*P-value*	R^{2c}		*95% CI*	*P-value*	R^{2c}
BMI SDS								
Systolic BP SDS	0.31	0.18–0.45	< 0.0001	0.03	0.31	0.19–0.43	< 0.0001	0.57
Diastolic BP SDS	0.14	0.06–0.22	< 0.0001	0.01	0.19	0.10–0.28	< 0.0001	0.23
ΔBMI SDS								
ΔSystolic BP SDS	0.41	0.27–0.56	< 0.0001	0.19	0.49	0.35–0.63	< 0.0001	0.38
ΔDiastolic BP SDS	0.26	0.16–0.36	< 0.0001	0.32	0.25	0.14–0.35	0.0001	0.43

Abbreviations: BMI, body mass index; BP, blood pressure; SDS, s.d. score. [a]Basic models of ΔBMI SDS and ΔBP SDS were adjusted for the baseline values of BMI SDS and BP SDS. [b]All adjusted models were adjusted for sex, age, height SDS, socioeconomic status, and Tanner stage. Adjusted models of ΔBMI SDS and ΔBP SDS were further adjusted for baseline values of BMI SDS and BP SDS. [c]R^2, adjusted R-squared. Estimates (β) and 95% confidence intervals (CIs) are based upon simple regression models and covariance models.

Table 3. Changes in BMI SDS and BP SDS in the children with systolic and diastolic prehypertension or hypertension at entry

	Mean change	*95% CI*	*P-value*	*Time to follow-up median (range)*	N
Children with systolic prehypertension or hypertension at entry (N = 328)					
Mean changes in systolic BP SDS from baseline					
3–6 Months	− 0.42	− 0.59 to − 0.26	< 0.0001	5 Months (3–5)	125
6–12 Months	− 0.38	− 0.49 to − 0.27	< 0.0001	7 Months (6–11)	221
12–18 Months	− 0.32	− 0.50 to − 0.15	0.0003	13 Months (12–17)	123
18–24 Months	− 0.26	− 0.67 to 0.16	0.20	20 Months (18–23)	34
24–30 Months	− 0.02	− 1.12 to 1.07	0.90	24 Months (24–28)	7
Mean changes in BMI SDS from baseline					
3–6 Months	− 0.20	− 0.26 to − 0.14	< 0.0001	5 Months (3–5)	125
6–12 Months	− 0.27	− 0.32 to − 0.22	< 0.0001	7 Months (6–11)	221
12–18 Months	− 0.28	− 0.35 to − 0.21	< 0.0001	13 Months (12–17)	123
18–24 Months	− 0.25	− 0.42 to − 0.08	0.005	20 Months (18–23)	34
24–30 Months	− 0.46	− 0.93 to 0.00	0.05	24 Months (24–28)	7
Children with diastolic prehypertension or hypertension at entry (N = 139)					
Mean changes in diastolic BP SDS from baseline					
3–6 Months	− 0.68	− 0.91 to − 0.44	< 0.0001	4 Months (3–5)	52
6–12 Months	− 0.75	− 0.88 to − 0.62	< 0.0001	8 Months (6–11)	104
12–18 Months	− 1.05	− 1.27 to − 0.83	< 0.0001	13 Months (12–17)	54
18–24 Months	− 0.88	− 1.37 to − 0.40	0.001	21 Months (18–23)	17
24–30 Months	− 1.11	− 1.69 to − 0.53	0.001	24 Months (24–26)	4
Mean changes in BMI SDS from baseline					
3–6 Months	− 0.22	− 0.30 to − 0.15	< 0.0001	4 Months (3–5)	52
6–12 Months	− 0.25	− 0.32 to − 0.17	< 0.0001	8 Months (6–11)	104
12–18 Months	− 0.41	− 0.52 to − 0.30	< 0.0001	13 Months (12–17)	54
18–24 Months	− 0.17	− 0.40 to − 0.06	0.13	21 Months (18–23)	17
24–30 Months	− 0.42	− 0.82 to − 0.02	0.04	24 Months (24–26)	4

Abbreviations: BMI, body mass index; BP, blood pressure; SDS, s.d. score; N, number of children with a measure of BP during each time period. Pre-hypertension: BP ⩾ 90th and < 95th percentile; hypertension: BP ⩾ 95th percentile for sex, age and height. Mean changes from baseline values in BMI SDS and BP SDS were analysed using the paired Student's t-test.

Among the children and adolescents exhibiting systolic prehypertension or hypertension upon entry, the children and adolescents reducing BMI SDS by > 0.25 reduced their systolic BP SDS, while the children and adolescents reducing BMI SDS by < 0.25 did not reduce their systolic BP SDS (Table 4). Among the children and adolescents exhibiting diastolic prehypertension or hypertension at entry, the children and adolescents reducing their BMI SDSs by > 0.25 reduced their diastolic BP SDSs the most, but reductions in diastolic BP SDS occurred even in the children and adolescents who increased their BMI SDSs (Table 4).

The 663 children and adolescents included in this study reduced their BMI SDSs by a mean of 0.29 (95% CI: 0.26–0.33, $P < 0.0001$). The fraction of children and adolescents who developed prehypertension or hypertension ($n = 73$) reduced their BMI SDSs by a mean of 0.24 (95% CI: 0.14–0.34, $P < 0.0001$).

DISCUSSION

This study demonstrates that health benefits can be achieved during a community-based overweight and obesity treatment, as the majority of the children and adolescents exhibiting prehypertension or hypertension upon entry, reduced their BP, and 29% became normotensive. Prehypertension and hypertension were highly prevalent (52%) upon entry, and BP SDS was positively associated with age and BMI SDS. Changes in BMI SDSs were positively associated with changes in BP SDSs, but changes in BMI SDSs did not always reflect the changes in BP SDSs.

Baseline

Hypertension in children and adolescents is defined as a BP ⩾ 95th percentile for sex, age and height on at least three occasions,[4] and a high BP upon entry may be due to white coat hypertension (hypertension at office only).[29] However, prevalence rates of white coat hypertension in children and adolescents ranging from 10 to 60% have been reported[29] depending on the methodology, definitions and reference values used for diagnosis. Likewise, masked hypertension (normal blood pressure at office, but hypertension elsewhere) may occur as well, but for the same reasons, the prevalence in children and adolescents is unclear.[30,31] White coat hypertension[32] and masked hypertension[30] may be associated with increased left ventricular mass, but the clinical significance of both conditions is still unclear.[29,31,32] Thus, the occurrence of both white coat hypertension and masked hypertension may have impacted our results, but the size and significance of this impact is unknown. Nonetheless, our results are consistent with the results of a European study reporting that 35% of 63 025 children and adolescents with overweight or obesity exhibited hypertension, and the prevalence of hypertension increased as the degree of obesity increased, reaching 45% in children and adolescents with severe obesity (BMI > 99.5th percentile).[33]

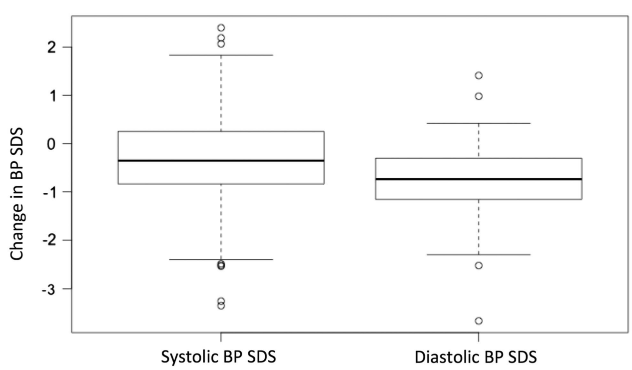

Figure 1. Mean changes in systolic and diastolic BP SDSs at the latest follow-up measurement in children and adolescents exhibiting systolic or diastolic prehypertension/hypertension upon entry. Tukey boxplot with boxes marking the second quartiles and medians, and whiskers marking the lowest and highest data within 1.5 times the interquartile range.

Follow-up

The reductions in BP SDSs after this overweight and obesity treatment may be due to a reduction of anxiety or a regression towards the mean.[4,31] As 23% of the children and adolescents who were normotensive upon entry developed prehypertension or hypertension, the regression towards the mean phenomenon may be of considerable significance. However, despite reductions in BMI SDSs, the majority of the children and adolescents in this study were still obese at follow-up, and thus were still at high risk of developing hypertension.[1]

Changes in BMI SDS and BP SDS

Consistent with previous studies,[6] we found that changes in BMI SDSs were positively associated with changes in BP SDSs, and the children and adolescents who increased their BMI SDSs did not reduce their systolic BP SDSs. Diastolic BP SDS was, however, reduced in children and adolescents who increased their BMI SDSs, and we found a tendency towards reductions in systolic BP SDSs in those attaining only moderate reductions in BMI SDSs. This may be due to reductions in the degree of obesity not reflected by reductions in BMI SDSs; an increased lean body mass with a concomitant reduction in fat mass can result in a stable or increased BMI SDSs due to the higher relative muscle mass.[34] Introducing high levels of physical activity and low levels of sedentary behaviours is central in this overweight and obesity treatment approach,[14] and these behaviours are associated with reductions in BP regardless of changes in the degree of obesity.[34] Further, reductions in BP caused by an increased level of physical activity or by reductions in the degree of obesity, may be greater in children and adolescents with overweight or obesity exhibiting hypertension than in children and adolescents with overweight or obesity exhibiting a normal BP.[34] These effects may have occurred in our study, and hence changes in BMI SDSs may not always reflect the changes in BP SDSs.

Community-based overweight and obesity treatment

Other studies investigating the changes in BP attained during community-based childhood overweight and obesity programs have yielded mixed results with unclear long-term changes.[8–11] As examples, Sacher *et al.*[8] evaluated a 9-week community-based obesity treatment program in 116 children aged 8–12 years, and found significant reductions of 5.0 and 4.3 mm Hg in systolic and diastolic BP, respectively, accompanying a 0.30 reduction in BMI SDSs. However, at a 2.4-year follow-up, BMI SDS was not

Table 4. Changes in BP SDSs in children and adolescents exhibiting systolic or diastolic prehypertension or hypertension upon entry, stratified by the changes in BMI SDSs at their latest follow-up

	N	*Estimate*	*95% CI*	P-*value*
Δ Systolic BP SDSs				
Δ BMI SDS less than − 0.25	152	− 0.51	− 0.64 to − 0.37	< 0.0001
Δ BMI SDS − 0.25 to 0.00	97	− 0.15	− 0.32 to 0.00	0.05
Δ BMI SDS greater than 0.00	79	0.12	− 0.36 to 0.12	0.32
Δ Diastolic BP SDSs				
Δ BMI SDS less than − 0.25	65	− 1.06	− 1.23 to − 0.89	< 0.0001
Δ BMI SDS − 0.25 to 0.00	35	− 0.55	− 0.34 to − 0.76	< 0.0001
Δ BMI SDS greater than 0.00	39	− 0.51	− 0.73 to −0.29	< 0.0001

Abbreviations: BMI, body mass index; BP, blood pressure; CI, confidence interval; SDS, s.d. score. Changes in BMI SDSs and BP SDSs were analysed using the paired Student's *t*-test.

significantly lower that at entry, and BP was not measured.[9] Further, Nguyen *et al.*[10,11] evaluated a 2-year community-based overweight and obesity treatment program in 128 adolescents aged 13–16 years, and found 0.09 and 0.13 reductions in BMI SDSs at the 1- and 2-year follow-ups, respectively, but found no reductions in the absolute BP at the 1-year follow-up and significant increases at the 2-year follow-up. Both studies reported absolute values of BP, not BP SDSs, and therefore the results are not directly comparable to our results. Nonetheless, since BP increases with age and height during childhood,[5] the initial reductions in BP reported by Sacher *et al.*[8] are likely to represent reductions in BP SDSs.

Strengths and limitations

The strengths of this study are the large number of children included, the long period of follow-up and the use of SDSs for BMI and BP, which take into account the changes during childhood growth and development. Hence, the SDSs reflect the BMI and BP relative to the mean values in a reference population with the same sex and age (BMI) or the same sex, age and height (BP).

A number of children and adolescents were ineligible for inclusion in this study, and these children were older, exhibited a higher BMI SDS, and had a lower socioeconomic status. Consequently, we adjusted for these factors in the subsequent analyses. Nonetheless, age and BMI SDSs were positively associated with BP SDSs, and this may have led to an under-estimation of the prevalence of prehypertension and hypertension in the present study.

A validated oscillometric devise was used for the measurements of BP, and the applied references were obtained using the auscultatory method,[4] which may provide slightly lower results for systolic BP.[5] Hence, using the oscillometric device may lead to an overestimation of the prevalence of systolic hypertension but it also has the advantage of minimizing the inter-observer variability.[4] We used American references to calculate the BP SDSs[4] and despite differences between European and American populations, these references are recommended by the European Society of Hypertension[5] and the Danish Group for Pediatric Hypertension,[24] due to the large population of 70 000 children and adolescents on which these references are based.[4]

Assessment of pubertal development stage was self-reported using a non-validated questionnaire, and this method may be less accurate than a clinical examination by a pediatrician.[35] However, the healthcare centres did not employ pediatricians, so assessment by a pediatrician was not possible.

The present study is prospective and longitudinal, and due to this non-randomized design we do not know if the same changes would occur in children and adolescents not undergoing overweight and obesity treatment. However, the choice of this non-randomized design was due to a lack of community-based child and adolescent overweight and obesity standard care treatment centres in Denmark. Due to the multitude of obesity-related complications,[19,20] it was found unethical to randomize to no treatment or to a waiting list.[17,21] For the same reasons, no exclusion criteria for entering treatment were applied. Thus, this study evaluates the changes during a community-based child and adolescent overweight and obesity treatment modality setup to continue beyond this study period without prior exclusion of children and adolescents and thus the results reflect actual clinical practice.

In conclusion, the high prevalence rates of prehypertension and hypertension demonstrated in this study highlight the importance of prevention and treatment of overweight and obesity in children and adolescents. The majority of children and adolescents exhibiting prehypertension or hypertension reduced their BP SDSs and 29% became normotensive, suggesting that community-based overweight and obesity treatment can serve as a first-line treatment option for children and adolescents with obesity-related prehypertension or hypertension, which may help accommodate the need for improvements in treatment availability and accessibility. Nonetheless, not all children and adolescents with prehypertension or hypertension reduced their BP SDSs or became normotensive, and other treatment options may be necessary for these children and adolescents. Changes in BMI SDSs were associated with changes in BP SDSs, but changes in BMI SDSs may not adequately reflect the impact of overweight and obesity treatment on BP SDSs. Hence, evaluations of child and adolescent overweight and obesity treatment programs should aim to provide a thorough evaluation of the degree of overweight and obesity as well as the related comorbidities.

What is known about the topic?

- Due to the pandemic of childhood obesity, obesity-related hypertension has become a considerable health issue in children and adolescents.
- Hospital-based overweight and obesity treatment programs can reduce blood pressure in children and adolescents with overweight or obesity exhibiting hypertension.
- Improvements in treatment availability and accessibility are needed.

What this study adds?

- Blood pressure was reduced during a community-based overweight and obesity treatment in children and adolescents with overweight or obesity exhibiting prehypertension or hypertension.
- Community-based overweight and obesity treatment programs may help accommodate the need for improvements in treatment availability and accessibility.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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