

Shifting Patterns of BMI and Skinfold Fatness among US Children: 1985/87 vs. 2012

Yan Yang ⁽¹⁾, Weimo Zhu ⁽¹⁾, Songtao Wang ⁽²⁾

(1) Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, USA

(2) School of Physical Education & Sports Science, South China Normal University, P.R. China

CORRESPONDING AUTHOR: Yan Yang, Department of Kinesiology and Community Health - University of Illinois at Urbana-Champaign - Freer Hall 461A - 906 S Goodwin Avenue, Urbana, IL, USA 61801 - Telephone: 217-265-5264 - Fax: 217-244-7322 - E-mail: yanyang5@illinois.edu

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ABSTRACT

Background: Childhood obesity has been recognised as a major public health concern. The purpose of this study was to determine specific shifting patterns of BMI and skinfold fatness of the United States (U.S.) children across different age and sexes groups between 1985/87 and 2012.

Methods: The data of 9,366 children aged 8-15 years from two nationally representative surveys, i.e., 1985/87 National Children and Youth Fitness Study I & II and 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey, were analysed. Specifically, changes of BMI-based obesity prevalence and shifting patterns of measured anthropometric data including BMI, height, weight, skinfold body fat percentage (skinfold-fat%), subscapular skinfold and triceps skinfold from 1985/87 to 2012 were estimated by age and sex using the 1985/87 quartiles as the baseline.

Results: Significantly increased obesity prevalence were confirmed for both boys (increased by 159.06%, $P < 0.001$) and girls (increased by 49.79%, $P < 0.001$) from 1985/87 to 2012. Except for height, all other measures in 2012 experienced an unbalanced shifting pattern, mainly from other quartiles into the 4th quartile of 1985/87.

Conclusions: The shifting of both boys' and girls' BMI and skinfold-fat% in 2012 were all concentrated in the 4th quartile of 1985/87, indicating a significant increase in BMI and skinfold-fat% not only in U.S. children from 1985/87 to 2012, but also in the overweight and obese subgroups, which serves as a serious warning for the U.S. childhood obesity epidemic.

Keywords: Childhood Obesity; Skewed Change; Body Fat Percentage; Skinfold

INTRODUCTION

Childhood obesity is regarded as a major public health concern in both developed and developing

countries [1,2], with a predicted global estimation of a 9.1% prevalence of childhood overweight and obesity by 2020 year [3]. In the United States (U.S.), the prevalence of obesity was 17.0% with 5.8% morbid

obesity for 2 to 19-year-old children and adolescents in 2011-2014 [4]. Childhood obesity has been found to be positively associated with multiple health issues, including musculoskeletal pain [5], cardiovascular disease [6] and thyroid cancer [7]. Childhood obesity was also identified as a predictor for obesity in adulthood and becomes a major global public health concern [8]. Seeking accurate and comprehensive measurements of childhood obesity is essential to develop targeted and effective prevention actions and treatments.

There are numerous ways to measure body fat, including sophisticated laboratory methods, such as magnetic resonance imaging (MRI) and dual energy X-ray absorptiometry (DXA), or practical field measures, such as Body Mass Index (BMI) and skinfold-based body fat percentage (skinfold-fat%). Among the field measures, BMI, which is easily derived from height and weight, has been the most utilised in population based on surveillance and epidemiological studies [9,10]. Moreover, the Centers of Disease Control and Prevention (CDC) of U.S. established sex-age specific percentile standards using BMI to define children's normal weight, overweight and obese weight status [11]. BMI, however, has a limitation on the accuracy of body fatness assessment during childhood and can misclassify a muscular youngster as obese [12-14]. Fortunately, skinfold-based body fat percentage, a field measure which assesses percentage of body fat by measuring skinfold thicknesses of different specific sites on the body, has demonstrated a high accuracy for determining obesity even though it requires more training, time, cost and facilities [13]. Therefore, combining BMI and skinfold-fat%, measures should improve the accuracy of obesity prediction and provide more information on the changes of obesity prevalence.

So far, most childhood obesity studies [15,16] have only focused on obesity prevalence or trends of obesity prevalence estimated from either BMI or skinfold-fat%. For example, a significant linear increase of obesity prevalence from 1999-2000 to 2009-2010 was found for U.S. boys and adolescents (aged 2-19 years) using only BMI [17]. However, children with high fat but lean mass cannot be accurately categorised based on BMI only. Moreover, shifting patterns for obesity measures in the past decades are far from conclusive in that specifically, compared to children from decades ago, how are children getting fatter and is there any shifting that has occurred in their BMI and body fatness during the past decades? Thus, underlying shifting patterns of obesity measures based on BMI and skinfold-fat% should be investigated. Therefore, by comparing data from two nationally representative U.S. children and youth fitness surveys (i.e., the 1985/87 National Children and Youth Fitness Study [NCYFS] I & II and the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey [NNYFS]), the specific aims of this study were: 1) to examine the changes in obesity prevalence from 1985/87 to 2012; 2) to

investigate shifting patterns of BMI and skinfold-fat% from 1985/87 to 2012 and determine where the changes occurred; and 3) to analyse age and sex difference in terms of a shifting pattern.

METHODS

Surveys and participants

1985/87 NCYFS I & II. Both NCYFS I and NCYFS II are surveys of a nationally representative sample performed by the U.S. Department of Health and Human Services Offices for Disease Prevention and Health Promotion in 1985 and 1987, respectively, using a self-weighting sampling design to maximise the efficiency of national estimates. The NCYFS I study was designed to investigate the skinfold-fat% and obesity status of children aged 10 to 18 years. The NCYFS II study was launched to estimate the physical fitness and physical activity habits of children aged 6 to 9 years [18,19]. Detailed information regarding the NCYFS I & II sampling design, clinical measures and individual-level data are available through National Technical Information Services (<http://www.ntis.gov/>).

2012 NNYFS. The National Center for Health Statistics (NCHS) oversees the National Health and Nutrition Examination Survey (NHANES) program to assess the health and nutritional status of children and adults in the U.S. A multistage probability sampling design was used to select participants that would be representative of the civilian non-institutionalised U.S. population. The NCHS department conducted the 2012 NNYFS in conjunction with the NHANES to assess children and teens' physical activity and fitness levels (aged 3 to 15 years), through interviews administered in home and physical tests performed in state-of-the-art mobile examination centres. All children in the 2012 NNYFS survey were selected through a multistage probability sampling design and represent non-institutionalised children in the U.S. [20]. Detailed information regarding the NNYFS sampling design, clinical measures and individual-level data, can be found on its website (http://www.cdc.gov/nchs/nyfs/about_nnyfs.htm).

Measures

Children's height, weight, subscapular skinfold and triceps skinfold were all measured in both 1985/87 and 2012 surveys. Height was assessed by a stadiometer and weight was measured by a digital scale. According to standard anthropometry protocols and procedures, skinfold thicknesses measurements were conducted by well-trained anthropometrists. The subscapular skinfold was measured at the inferior angle of the right scapula and the triceps skinfold was assessed at the upper arm midpoint mark on

the posterior surface of the right arm. Both subscapular and triceps skinfolds were measured to the nearest whole millimetre (mm) using Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, MD) in 1985/87 NCYFS I/II and to a tenth of a mm using Holtain skinfold caliper (Holtain Ltd, Crosswell, Crymmych, Dyfed, Great Britain) in 2012 NNYFS. BMI was calculated by weight in kilograms divided by height in meters squared. The 2000 sex-specific BMI-for-age growth charts from the CDC were used to calculate age and sex specific BMI percentiles [11]. BMI-based obesity prevalence was assessed by a BMI value greater than or equal to the 95th percentile in the same age and sex [11,21]. Skinfold-fat% was estimated using Slaughter's sex and age specific equations [22] based on triceps and subscapular skinfolds thicknesses. Though the overlapping age range for both 1985/87 NCYFS I/II and 2012 NNYFS surveys is 6 to 15 years (yrs.), only boys and girls aged 8 to 15 years were included in this analysis due to Slaughter's equations, the only equations that employed subscapular and triceps skinfolds, being restricted to the age range of 8 to 15 years. (Sum = subscapular skinfold + triceps skinfold):

$$\text{Girls (8-15 yrs.): Skinfold-fat\%} = 1.33 * (\text{Sum})^2 - 0.013 * (\text{Sum})^2 - 2.5 \quad (1)$$

$$\text{Prepubertal Boys (8-10 yrs.): Skinfold-fat\%} = 1.21 * (\text{Sum}) - 0.008 * (\text{Sum})^2 - 1.7 \quad (2)$$

$$\text{Pubertal Boys (11-13 yrs.): Skinfold-fat\%} = 1.21 * (\text{Sum}) - 0.008 * (\text{Sum})^2 - 3.4 \quad (3)$$

$$\text{Post-pubertal Boys (14-15 yrs.): Skinfold-fat\%} = 1.21 * (\text{Sum}) - 0.008 * (\text{Sum})^2 - 5.5 \quad (4)$$

$$\text{Girls when (Sum) >35 mm (8-15 yrs.): Skinfold-fat\%} = 0.546 * (\text{Sum}) + 9.7 \quad (5)$$

$$\text{Boys when (Sum) >35 mm (8-15 yrs.): Skinfold-fat\%} = 0.783 * (\text{Sum}) + 1.7 \quad (6)$$

Comparability

In terms of comparability across the 1985/87 NCYFS I/II and 2012 NNYFS surveys, testing procedures for measuring height, weight and two skinfold thicknesses were the same. There were only two minor differences between the 1985/87 NCYFS I/II and 2012 NNYFS surveys. The first was the sample size, with 8,467 children from the 1985/1987 NCYFS I/II and 899 children from the 2012 NNYFS aged 8 to 15 years. The difference in the sample size can be ignored in this study since both the 1985/87 NCYFS I/II and 2012 NNYFS surveys used nationally representative samples, and taking into account that data from 2012 NNYFS were weighted according to sampling standard and data from 1985/87 NCYFS I/II survey applied a self-weighting sampling design to maximise the efficiency of national estimates. The second difference was that skinfold thicknesses in 1985/87 NCYFS I/II were rounded to the nearest whole mm, whereas skinfold thicknesses in 2012 NNYFS were

measured to the nearest tenth of a mm. This difference should not have a large influence on the comparability of the two datasets. Thus, the procedures in the 1985/87 NCYFS I/II and the 2012 NNYFS were considered to be sufficiently comparable [18-20].

Among a total of 9,738 participants, 369 (229 from 1985/87 NCYFS I & II) were excluded because of missing data and 3 were excluded due to extremely high values on skinfold-fat% (91.65%, 95.56%, and 95.56%). The remaining 9,366 children (8,467 children from the 1985/87 NCYFS I & II, 50.28% boys, and 899 children from the 2012 NNYFS, 49.39% boys) aged 8 to 15 years were included in the analysis.

Both 1985/87 NCYFS I/II and 2012 NNYFS studies were approved by their corresponding Research Ethics Review Board. This study used de-identified public data and was deemed exempt from human subjects review by the University of Illinois at Urbana-Champaign Institutional Review Board.

Statistical analyses

Descriptive statistics for BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold were computed. The prevalence of BMI-based obesity in 1985/87 and 2012 was analysed and compared. Shifting patterns of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold were examined by age and sex. Since those variables were not normally distributed across age and sex according to the Kolmogorov-Smirnov test, a nonparametric statistical test (i.e. Wilcoxon-Mann-Whitney test) was used to test the statistical significance on the mean differences of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold from 1985/87 and 2012. Since data of 1985/87 were self-weighted, to perform the mean difference tests and the BMI-based obesity prevalence changes tests, only unweighted data of 2012 were used. Since analyses of shifting patterns were conducted by age and sex separately, adjustments for age and sex were not necessary. Finally, using values of 25th, 50th and 75th percentiles of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold in 1985/87 NCYFS I/II as the baselines or cut-off reference standards, the corresponding measurement variables' distribution in the 2012 NNYFS, i.e., % of the participants in each of quartiles based on the 1985/87 percentile cut-off standards, were calculated. Statistical analyses were conducted using SAS version 9.3 software (SAS Institute Inc., Cary, North Carolina). All statistical tests were 2-tailed and used an alpha level of 0.05.

RESULTS

Of the overall 9,366 participants aged 8 to 15 years, their mean age was 11.5-year-old (SD = 2.34),

and 4,685 were girls and 4,681 were boys. Table 1 reports descriptive statistics on means and standard errors of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold on 1985/87 and 2012 years by age and sex. Overall, except for height, the mean values of BMI, weight, skinfold-fat%, subscapular skinfold and triceps skinfold had statistically increased from 1985/87 to 2012 for both boys and girls. Almost all boys' BMI and weight had notably increased from 1985/87 to 2012, the exceptions were boys ages 8 and 14 years old. Girls' BMI and weight were found to have remarkably increased at ages 8, 10 and 12 from 1985/87 to 2012. Boys ages 8 to 15 had substantially higher skinfold-fat% and

skinfold thicknesses in 2012 than boys in 1985/87. Additionally, girls ages 8, 10 to 13, and 15 had significantly higher skinfold-fat% and skinfold thicknesses in 2012 than girls in 1985/87.

Table 2 reports the comparison results of BMI-based obesity prevalence from 1985/87 to 2012 by age and sex. The overall BMI-based obesity prevalence in 1985/87 was 7.62% [95% CI = [6.82-8.42]] for boys and 7.09% (6.32-7.87) for girls. In contrast to boys' and girls' in 1985/87, the weighted BMI-based obesity prevalence was higher for both boys (19.74% [14.80-24.67]) and girls (10.62% [10.60-10.63]) in 2012. Among those, the prevalence of BMI-based obesity was substantially

TABLE 1. Descriptive statistics of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold by age and sex (Mean (SE))

		BOYS						
Year	Age (yr.)	n	BMI (kg/m ²)	Height (mm)	Weight (kg)	Skinfold-fat% (%)	Subscapular (mm)	Triceps (mm)
1985/87	8	560	17.00 (0.12)	132.24 (0.27)	29.93 (0.28)	17.10 (0.33)	7.48 (0.21)	10.84 (0.22)
	9	578	17.60 (0.13)	137.30 (0.25)	33.39 (0.31)	18.81 (0.36)	8.34 (0.24)	12.01 (0.24)
	10	252	18.05 (0.21)	143.21 (0.52)	37.13 (0.53)	18.97 (0.53)	8.23 (0.34)	12.24 (0.37)
	11	544	18.82 (0.13)	147.22 (0.32)	41.01 (0.39)	18.33 (0.41)	8.86 (0.27)	12.73 (0.27)
	12	565	19.34 (0.14)	153.15 (0.37)	45.61 (0.45)	18.22 (0.41)	8.94 (0.26)	12.52 (0.27)
	13	582	19.77 (0.13)	160.26 (0.38)	51.09 (0.46)	16.96 (0.35)	8.55 (0.21)	11.38 (0.25)
	14	575	20.88 (0.15)	166.83 (0.36)	58.37 (0.54)	15.15 (0.41)	9.40 (0.26)	10.68 (0.25)
	15	581	21.55 (0.15)	172.01 (0.33)	63.87 (0.52)	15.04 (0.39)	9.49 (0.21)	10.42 (0.26)
	Overall	4237	19.22 (0.06)	152.29 (0.24)	45.76 (0.24)	17.19 (0.14)	8.70 (0.09)	11.54 (0.09)
Unweighted 2012	8	57	18.19 (0.47)*	132.48 (0.81)	32.23 (1.06)	20.77 (1.15)*	9.60 (0.77)*	13.18 (0.80)*
	9	48	18.63 (0.48)*	132.19 (0.92)	33.05 (1.25)*	22.63 (0.92)*	11.19 (0.78)*	15.09 (0.74)*
	10	55	19.58 (0.68)*	137.52 (1.04)	37.53 (1.65)*	23.02 (1.47)*	10.72 (0.97)*	14.93 (1.03)*
	11	48	18.83 (0.69)*	136.93 (1.23)*	35.79 (1.65)*	23.53 (1.32)*	12.22 (1.08)*	15.90 (1.11)*
	12	72	20.03 (0.61)*	142.78 (0.97)*	41.33 (1.60)*	24.45 (1.40)*	11.76 (0.96)*	15.72 (0.96)*
	13	54	19.54 (0.51)*	144.18 (0.99)*	41.21 (1.45)*	24.22 (0.96)*	12.77 (0.91)*	15.99 (0.69)*
	14	57	20.36 (0.56)	150.80 (1.19)	46.92 (1.76)	22.05 (1.18)*	11.49 (0.82)*	14.49 (0.73)*
	15	53	20.41 (0.57)*	151.31 (0.91)	47.20 (1.62)*	24.26 (0.90)*	12.91 (0.77)*	15.72 (0.73)*
	Overall	444	20.92 (0.22)*	153.55 (0.75)	50.74 (0.85)*	22.03 (0.49)*	11.64 (0.32)*	14.35 (0.32)*
Weighted 2012	8	57	18.23 (0.45)	132.82 (0.73)	32.42 (1.02)	20.76 (1.06)	9.34 (0.71)	13.35 (0.75)
	9	48	19.95 (0.72)	137.95 (1.08)	38.53 (1.76)	24.44 (1.66)	11.41 (1.07)	16.22 (1.19)
	10	55	19.90 (0.65)	142.62 (0.99)	41.05 (1.72)	24.33 (1.47)	11.80 (0.99)	15.60 (1.01)
	11	48	20.21 (0.59)	150.75 (1.19)	46.62 (1.89)	22.15 (1.23)	11.47 (0.86)	14.66 (0.78)
	12	72	21.62 (0.52)	156.38 (0.97)	53.33 (1.55)	24.85 (1.38)	13.25 (0.92)	16.38 (0.89)
	13	54	21.99 (0.64)	164.81 (1.07)	59.77 (1.89)	21.86 (1.53)	11.73 (0.98)	14.17 (1.00)
	14	57	21.44 (0.57)	168.63 (0.86)	61.39 (2.00)	18.45 (1.31)	11.04 (0.84)	12.74 (0.75)
	15	53	22.99 (0.57)	173.67 (1.10)	69.65 (2.01)	20.51 (1.33)	12.62 (0.84)	13.44 (0.78)
	Overall	444	20.83 (0.22)	153.51 (0.74)	50.44 (0.83)	22.34 (0.50)	11.68 (0.33)	14.69 (0.33)

Notes: Individual-level data (N = 9,633) came from 1985/87 NCYFS I/II and 2012 NNYFS. Standard errors (SE) are in parentheses; Means and SE were weighted to the US population for weighted 2012 NNYFS; * P < 0.05

varied across different ages for both boys and girls. The BMI-based obesity prevalence in 1985/87 ranged from 5.50% to 10.38% for boys and from 4.02% to 9.14% for girls. The weighted BMI-based obesity prevalence in 2012 year ranged from 16.96% to 25.25% for boys and 7.08% to 14.80% for girls. Among all ages and sexes, 9-year-old boys (increased by 143.26% relatively which was calculated by $(25.25-10.38)/10.38$) and 15-year-old girls (increased by 200.20%) had the significantly highest increase from 1985/87 to 2012. Overall, more boys (increased by 159.06%) are becoming obese than girls (increased by 49.79%) from 1985/87 to 2012.

Table 3 reports the descriptive values of 25th, 50th and 75th percentiles of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold in 1985/87 by age and sex, which were applied to the 2012 survey as

cut-off reference standards to estimate shifting patterns of measures from 1985/87 to 2012.

Table 4 reports the percentages of BMI, height and weight in 2012 by age and sex according to the quartiles of the cut-off standards in 1985/87. If there is no change/shifting, all distributions of the four quartiles in 2012 should be 25% as they were in the 1985/87 survey. If there is a shifting, but a balanced one, then, there should be a decreased or increased percentage in the 1st quartile, no change in the 2nd and 3rd quartiles, but a corresponding increased or decreased percentage in the 4th quartile. However, Table 4 illustrates unbalanced shifting patterns from the lower quartiles to the higher quartiles. For example, BMI in the 4th quartile had the highest percentage compared with the other three quartiles for both boys and girls (44.15% [39.94-48.36]; 39.16%

TABLE 1. Descriptive statistics of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold by age and sex (Mean (SE))

		GIRLS						
1985/87	8	569	17.18 (0.13)	131.57 (0.26)	29.94 (0.29)	20.13 (0.31)	9.29 (0.26)	13.57 (0.23)
	9	597	17.75 (0.14)	137.27 (0.27)	33.74 (0.34)	21.41 (0.34)	10.32 (0.29)	14.48 (0.26)
	10	289	18.12 (0.19)	143.93 (0.47)	37.70 (0.51)	20.25 (0.39)	9.26 (0.30)	13.57 (0.32)
	11	551	19.23 (0.15)	149.14 (0.32)	43.03 (0.44)	21.41 (0.31)	10.46 (0.25)	14.13 (0.25)
	12	551	19.92 (0.16)	154.60 (0.32)	47.79 (0.46)	22.06 (0.30)	10.87 (0.24)	14.49 (0.26)
	13	533	20.53 (0.16)	158.43 (0.30)	51.61 (0.46)	23.22 (0.32)	11.57 (0.26)	15.51 (0.27)
	14	572	20.99 (0.14)	161.22 (0.27)	54.49 (0.38)	24.17 (0.29)	12.19 (0.25)	16.20 (0.25)
	15	568	21.79 (0.15)	162.16 (0.29)	57.28 (0.45)	25.36 (0.28)	12.87 (0.24)	17.30 (0.26)
	Overall	4230	19.50 (0.06)	150.01 (0.20)	44.76 (0.21)	22.38 (0.11)	10.95 (0.09)	14.99 (0.09)
Unweighted 2012	8	64	21.69 (0.57)*	156.10 (0.95)	53.35 (1.67)*	24.36 (1.41)*	13.18 (0.94)*	15.86 (0.90)*
	9	47	21.53 (0.52)	154.52 (1.07)	51.82 (1.52)	26.28 (1.04)	14.54 (0.88)*	17.58 (0.88)
	10	62	22.32 (0.69)*	164.84 (1.11)	60.84 (2.12)*	22.13 (1.52)*	12.02 (0.97)*	14.24 (1.00)*
	11	61	21.43 (0.49)	159.93 (0.92)*	55.03 (1.49)*	26.62 (0.91)*	14.32 (0.79)*	17.89 (0.80)*
	12	60	22.01 (0.60)*	168.82 (0.85)	63.11 (2.05)*	19.36 (1.37)*	11.59 (0.87)*	13.23 (0.79)*
	13	60	22.14 (0.47)	161.50 (0.81)	57.97 (1.51)	27.17 (0.78)*	14.47 (0.75)*	18.50 (0.69)*
	14	65	22.81 (0.57)*	173.01 (1.13)	68.66 (2.06)	19.60 (1.32)*	12.25 (0.83)*	12.79 (0.78)*
	15	36	22.67 (0.74)	160.93 (1.07)	58.64 (1.97)	27.49 (1.09)*	15.20 (0.95)*	18.37 (0.97)
	Overall	455	20.59 (0.20)*	149.94 (0.60)	47.30 (0.69)*	25.20 (0.35)*	13.38 (0.31)*	16.82 (0.29)*
Weighted 2012	8	64	18.03 (0.44)	131.67 (0.86)	31.63 (1.10)	21.73 (0.86)	10.37 (0.75)	14.50 (0.65)
	9	47	18.58 (0.60)	135.95 (1.20)	34.80 (1.50)	23.55 (1.26)	11.86 (1.00)	16.19 (1.07)
	10	62	19.29 (0.51)	143.69 (0.95)	40.33 (1.39)	23.74 (0.97)	12.12 (0.86)	15.96 (0.72)
	11	61	19.94 (0.51)	151.00 (0.90)	45.88 (1.49)	24.27 (0.88)	12.65 (0.76)	15.95 (0.71)
	12	60	21.28 (0.49)	154.33 (1.11)	51.15 (1.50)	26.39 (1.05)	14.42 (0.86)	17.90 (0.92)
	13	60	21.71 (0.48)	160.30 (0.98)	56.09 (1.54)	27.20 (0.91)	14.46 (0.78)	18.69 (0.82)
	14	65	22.09 (0.47)	161.55 (0.78)	57.88 (1.50)	27.40 (0.77)	14.47 (0.74)	18.87 (0.68)
	15	36	22.76 (0.79)	161.23 (1.11)	59.17 (2.21)	27.50 (1.10)	15.30 (0.97)	18.29 (0.96)
	Overall	455	20.38 (0.20)	149.78 (0.61)	46.81 (0.70)	25.15 (0.35)	13.12 (0.30)	17.00 (0.29)

Notes: Individual-level data (N = 9,633) came from 1985/87 NCYFS I/II and 2012 NNYFS. Standard errors (SE) are in parentheses; Means and SE were weighted to the US population for weighted 2012 NNYFS; * P < 0.05

TABLE 2. The comparison of BMI-based obesity prevalence in 1985/87 and 2012 by age and sex.

AGE (YR.)	BOYS OBESITY, % (95% CI)				GIRLS OBESITY, % (95% CI)			
	1985/87	2012 UNWEIGHTED	2012 WEIGHTED	P VALUE	1985/87	2012 UNWEIGHTED	2012 WEIGHTED	P VALUE
8	9.64 (7.20-12.09)	21.05 (10.47-31.64)	22.18 (12.40-31.96)	0.008	9.14 (6.77-11.51)	14.06 (5.55-22.58)	9.81 (9.77-9.85)	0.206
9	10.38 (7.89-12.87)	20.83 (9.34-32.32)	25.25 (6.28-44.23)	0.027	8.88 (6.60-11.16)	14.89 (4.72-25.07)	10.17 (10.13-10.22)	0.172
10	7.54 (4.28-10.80)	21.82 (10.90-32.73)	18.88 (10.26-27.50)	0.002	6.57 (3.72-9.43)	16.13 (6.97-25.28)	14.38 (14.34-14.43)	0.013
11	7.35 (5.16-9.55)	12.50 (3.14-21.86)	12.25 (0.70-23.81)	0.205	7.99 (5.72-10.25)	14.75 (5.85-23.65)	10.36 (10.32-10.40)	0.075
12	8.14 (5.89-10.40)	25.00 (15.00-35.00)	21.11 (6.10-36.11)	<0.001	8.53 (6.20-10.86)	16.67 (7.24-26.10)	12.63 (12.58-12.68)	0.040
13	5.50 (3.65-7.35)	22.22 (11.13-33.31)	19.23 (8.33-30.13)	<0.001	6.38 (4.30-8.45)	6.67 (0.35-12.98)	7.08 (7.05-7.12)	0.931
14	6.78 (4.73-8.84)	24.56 (13.39-35.74)	20.61 (6.64-34.58)	<0.001	4.02 (2.41-5.63)	7.69 (1.21-14.17)	7.57 (7.54-7.61)	0.171
15	5.68 (3.80-7.56)	16.98 (6.87-27.09)	16.96 (6.96-26.96)	0.002	4.93 (3.15-6.71)	16.67 (4.49-28.84)	14.80 (14.74-14.87)	0.003
Overall	7.62 (6.82-8.42)	20.95 (17.16-24.73)	19.74 (14.80-24.67)	<0.001	7.09 (6.32-7.87)	13.19 (10.08-16.30)	10.62 (10.60-10.63)	<0.001

Notes: Individual-level data (N = 9,633) came from 1985/87 NCYFS I & II and 2012 NNYFS. 95% confidence intervals are in parentheses

TABLE 3. The 25th, 50th, 75th percentiles of BMI, height, weight, skinfold-fat%, subscapular skinfold and triceps skinfold for boys and girls in 1985/87

Age (yr.)	BMI (KG/M ²)						HEIGHT (MM)						WEIGHT (KG)					
	BOYS PERCENTILE			GIRLS PERCENTILE			BOYS PERCENTILE			GIRLS PERCENTILE			BOYS PERCENTILE			GIRLS PERCENTILE		
	25 th	50 th	75 th	25 th	50 th	75 th	25 th	50 th	75 th	25 th	50 th	75 th	25 th	50 th	75 th	25 th	50 th	75 th
8	15.30	16.30	17.80	15.10	16.37	18.60	127.00	132.08	137.16	127.00	132.08	127.00	25.40	28.58	32.21	25.40	28.58	25.40
9	15.60	16.83	18.67	15.47	16.83	19.13	132.08	137.16	142.24	132.08	137.16	132.08	28.12	32.21	36.29	27.67	31.75	28.12
10	15.89	17.36	19.38	16.01	17.61	19.43	137.16	142.24	147.32	139.70	143.51	137.16	31.30	35.38	41.73	32.21	36.29	31.30
11	16.60	18.20	20.16	16.62	18.56	21.03	142.24	147.32	152.40	143.51	149.20	142.24	34.47	39.01	45.81	35.83	41.73	34.47
12	17.04	18.44	20.83	17.50	19.18	21.37	147.32	152.40	157.48	149.86	154.94	147.32	38.10	43.54	51.71	40.82	45.81	38.10
13	17.51	19.23	21.17	17.89	19.95	22.51	153.67	160.02	166.37	153.67	158.75	153.67	43.09	49.90	58.06	44.00	50.80	43.09
14	18.59	20.20	22.30	18.83	20.53	22.48	161.29	167.64	172.72	157.48	161.29	161.29	50.80	57.15	63.96	48.53	53.52	50.80
15	19.29	20.86	22.89	19.43	21.28	23.39	166.37	172.72	177.80	157.48	162.56	166.37	56.25	62.14	69.40	49.90	55.79	56.25
	SKINFOLD-FAT% (%)						SUBSCAPULAR (MM)						TRICEPS (MM)					
8	11.67	14.65	18.85	14.53	18.08	23.93	5.00	6.00	7.00	6.00	7.00	10.00	7.00	9.00	12.00	9.00	12.00	17.00
9	12.68	16.56	21.90	15.45	19.70	25.14	5.00	6.00	9.00	6.00	8.00	12.00	8.00	10.00	15.00	10.00	13.00	18.00
10	13.67	16.56	21.90	15.45	18.90	23.93	5.00	6.00	9.00	6.00	8.00	10.00	8.00	11.00	15.00	10.00	12.00	16.00
11	11.97	15.79	21.85	16.35	19.70	25.70	5.00	6.00	10.00	6.00	8.00	13.00	8.00	11.00	16.00	10.00	13.00	17.00
12	11.97	14.86	21.03	17.23	21.21	25.14	6.00	7.00	10.00	7.00	9.00	12.00	8.00	11.00	15.00	10.00	13.00	17.00
13	10.98	13.91	19.35	18.08	21.93	26.75	6.00	7.00	9.00	8.00	10.00	14.00	7.00	10.00	14.00	11.00	14.00	18.00
14	8.88	11.81	17.25	19.70	23.29	27.69	6.00	7.00	10.00	8.00	11.00	14.00	7.00	9.00	12.00	12.00	15.31	19.00
15	9.87	12.76	17.25	21.21	24.55	28.13	7.00	8.00	10.00	9.00	12.00	15.00	7.00	9.00	12.00	13.00	16.00	20.00

Notes: Individual-level data (N = 8,467) came from 1985/87 NCYFS I & II.

[33.95-44.38], respectively). Regarding boys, the higher percentages in the 4th quartile were contributed to mainly from the 1st and 2nd quartiles and for girls mainly from the 2nd and 3rd quartiles. Subgroup variations in age, with the exception of 14-year-old boys, were also observed, e.g., both boys and girls at age 12 had the highest percentages in the 4th BMI quartile (59.63% [48.12-71.13]; 49.55%

[41.28-57.82], respectively). Shifting patterns among different measures were distinct from each other, e.g., while major shifting patterns were found in both boys' and girls' weight, the changes in height were relatively small.

Table 5 reports the percentages of skinfold-fat%, subscapular skinfold and triceps skinfold in 2012 by age and sex according to the quartiles of the cut-off standards

TABLE 4. Boys' and girls' percentages of BMI, height and weight in 2012 year across 1985/87 quartiles

AGE (YR.)	BOYS				GIRLS			
	1 ST QUARTILE (%)	2 ND QUARTILE (%)	3 RD QUARTILE (%)	4 TH QUARTILE (%)	1 ST QUARTILE (%)	2 ND QUARTILE (%)	3 RD QUARTILE (%)	4 TH QUARTILE (%)
BMI								
8	17.22 (5.51-28.93)	16.13 (6.50-25.76)	26.45 (14.05-38.85)	40.20 (25.97-54.43)	16.34 (0.00-32.86)	23.23 (8.77-37.70)	27.53 (10.99-44.07)	32.89 (19.08-46.70)
9	16.63 (1.99-31.27)	10.66 (2.79-18.53)	25.15 (4.46-45.84)	47.56 (28.84-66.28)	21.88 (5.12-38.63)	22.51 (6.22-38.79)	21.97 (6.66-37.28)	33.65 (9.29-58.01)
10	18.23 (5.22-31.25)	15.54 (6.10-24.98)	22.16 (10.31-34.01)	44.07 (26.11-62.03)	24.02 (7.65-40.40)	18.61 (12.17-25.05)	9.54 (0.74-18.35)	47.83 (32.95-62.70)
11	24.58 (8.49-40.67)	11.35 (0.92-21.79)	19.47 (5.28-33.67)	44.59 (34.88-54.31)	27.40 (11.90-42.91)	14.50 (6.06-22.93)	21.57 (6.19-36.94)	36.53 (24.62-48.44)
12	15.82 (9.86-21.77)	7.19 (0.72-13.67)	17.36 (7.55-27.18)	59.63 (48.12-71.13)	20.71 (6.00-35.43)	12.91 (5.61-20.22)	16.83 (4.16-29.49)	49.55 (41.28-57.82)
13	8.11 (0.64-15.57)	32.82 (14.67-50.97)	15.83 (5.27-26.40)	43.24 (30.62-55.87)	18.01 (5.47-30.56)	17.68 (6.56-28.80)	25.37 (14.69-36.06)	38.94 (19.71-58.17)
14	24.38 (10.36-38.40)	21.67 (10.03-33.31)	29.66 (15.56-43.75)	24.30 (10.04-38.55)	18.19 (3.26-33.12)	23.32 (9.50-37.15)	25.22 (9.69-40.75)	33.27 (23.92-42.61)
15	16.03 (2.85-29.22)	14.57 (5.05-24.09)	26.59 (14.78-38.41)	42.80 (28.46-57.14)	27.43 (7.94-46.91)	13.95 (0.00-28.28)	17.97 (4.60-31.34)	40.66 (21.23-60.08)
Overall	17.53 (12.27-22.79)	15.67 (11.69-19.65)	22.64 (19.09-26.20)	44.15 (39.94-48.36)	21.43 (15.61-27.24)	18.55 (12.12-24.98)	20.86 (16.44-25.28)	39.16 (33.95-44.38)
Height								
8	10.70 (0.33-21.07)	33.79 (21.85-45.74)	31.51 (15.26-47.76)	23.99 (14.02-33.97)	19.23 (3.48-34.98)	35.23 (21.41-49.06)	17.72 (5.68-29.77)	27.81 (17.85-37.77)
9	22.82 (9.64-35.99)	19.05 (5.25-32.85)	31.74 (16.06-47.42)	26.39 (6.20-46.58)	39.27 (27.95-50.60)	18.65 (10.94-26.37)	20.33 (7.69-32.97)	21.74 (5.43-38.06)
10	27.88 (17.47-38.30)	20.36 (6.51-34.20)	21.93 (10.76-33.11)	29.82 (16.99-42.66)	32.51 (17.44-47.58)	17.69 (9.94-25.44)	26.00 (8.91-43.08)	23.80 (13.35-34.25)
11	10.73 (2.24-19.22)	36.27 (20.80-51.74)	7.94 (1.76-14.12)	45.06 (29.82-60.30)	14.66 (2.01-27.31)	24.13 (10.10-38.17)	31.94 (20.79-43.09)	29.27 (13.55-44.99)
12	11.77 (1.45-22.09)	17.23 (3.08-31.38)	28.16 (7.11-49.20)	42.84 (31.74-53.95)	26.46 (16.94-35.98)	18.07 (4.01-32.13)	20.69 (6.14-35.24)	34.79 (18.78-50.81)
13	10.68 (0.73-20.64)	18.49 (4.34-32.63)	32.60 (22.61-42.60)	38.23 (21.23-55.22)	16.48 (6.25-26.71)	34.14 (23.62-44.66)	15.50 (5.48-25.51)	33.88 (18.40-49.37)
14	14.86 (1.76-27.97)	30.98 (14.66-47.30)	31.79 (14.86-48.72)	22.37 (13.74-31.00)	25.03 (14.31-35.76)	22.03 (15.49-28.57)	20.97 (11.06-30.88)	31.97 (24.55-39.39)
15	12.52 (1.10-23.94)	32.92 (21.59-44.25)	24.33 (10.15-38.51)	30.23 (12.14-48.32)	25.10 (5.04-45.16)	40.46 (19.80-61.13)	5.16 (0.00-11.74)	29.27 (11.29-47.25)
Overall	15.35 (12.48-18.23)	25.48 (20.23-30.72)	26.50 (20.40-32.59)	32.67 (26.58-38.76)	24.51 (19.13-29.88)	25.51 (20.86-30.16)	20.76 (16.44-25.07)	29.22 (23.00-35.44)
Weight								
8	16.83 (3.69-29.97)	18.49 (8.79-28.19)	28.39 (15.35-41.43)	36.29 (25.05-47.52)	20.88 (5.86-35.90)	21.24 (8.02-34.45)	20.29 (9.12-31.46)	37.60 (23.11-52.09)
9	20.71 (8.09-33.34)	12.54 (4.37-20.71)	21.36 (2.58-40.14)	45.38 (23.84-66.93)	21.86 (4.93-38.78)	27.73 (14.23-41.24)	22.38 (11.90-32.87)	28.03 (9.95-46.10)
10	15.66 (4.33-26.98)	19.57 (6.91-32.22)	27.79 (12.43-43.16)	36.98 (22.22-51.73)	29.07 (15.73-42.42)	15.66 (6.28-25.04)	9.47 (0.77-18.18)	45.80 (31.22-60.38)
11	20.76 (4.95-36.57)	21.11 (5.00-37.23)	9.42 (0.00-19.36)	48.70 (34.83-62.58)	16.36 (0.00-33.08)	22.42 (6.35-38.49)	23.71 (7.67-39.75)	37.51 (22.55-52.47)
12	14.56 (8.87-20.25)	11.04 (2.11-19.97)	17.97 (6.05-29.89)	56.43 (44.02-68.84)	16.63 (4.58-28.67)	19.60 (10.52-28.69)	17.00 (4.73-29.28)	46.77 (36.53-57.00)
13	5.02 (0.00-10.88)	11.68 (3.19-20.18)	39.55 (23.24-55.85)	43.76 (28.10-59.41)	16.71 (1.68-31.73)	24.85 (13.02-36.68)	18.84 (6.27-31.42)	39.60 (19.38-59.81)
14	26.74 (7.70-45.77)	24.36 (11.37-37.36)	20.86 (8.70-33.01)	28.05 (13.14-42.95)	16.08 (4.15-28.01)	30.99 (15.83-46.15)	28.02 (13.49-42.55)	24.91 (18.11-31.70)
15	18.89 (1.44-36.34)	8.91 (0.71-17.11)	27.74 (16.11-39.38)	44.45 (30.52-58.39)	20.44 (5.67-35.22)	26.29 (13.51-39.07)	18.90 (0.81-36.99)	34.37 (12.83-55.90)
Overall	17.30 (12.25-22.36)	15.71 (11.90-19.53)	23.90 (20.40-27.40)	43.08 (38.70-47.47)	19.66 (13.26-26.07)	23.39 (17.99-28.80)	19.89 (13.88-25.90)	37.05 (31.63-42.46)

Notes: Individual-level data (N = 9,633) came from 1985/87 NCIYFS I & II and 2012 NNIYFS. 95% confidence intervals are in parentheses.

of 1985/87. Similarly with BMI, unbalanced shifting patterns in skinfold-fat% were found. Skinfold-fat% in the 4th quartile had the highest percentage compared to other quartiles for both boys and girls (49.06% [43.69-54.44]; 42.56% [35.10-50.01], respectively). The unbalanced shifting patterns for boys' and girls' skinfold-fat% mainly occurred from the 1st and 2nd quartiles to the 4th quartile and these patterns differed slightly across different ages as well. For example, boys age 15 (53.92% [39.35-68.48]) and girls age 12 (59.53% [46.29-72.78]) had the highest percentages in the 4th skinfold-fat% quartile, but the highest percentage in the 4th skinfold-fat% quartile was not found for girls ages 8, 11 and 14. Similarly, the higher percentages in the 4th quartile of subscapular and triceps skinfold were also found mostly to have shifted from the 1st and 2nd quartiles.

Table 6 reports the BMI-based overweight/obese and obese percentages in the 4th quartile by age, sex and year. The reason to only report the statistics in the 4th quartile is because all overweight/obese children, according to the CDC cut-off standards, were falling into the 4th quartile for both 1985/87 and 2012. Regarding boys, the percentage of overweight/obese in the 4th quartile had changed from 81.10% to 90.88% from 1985/87 to 2012 and corresponding changes for obese were 30.67% to 59.93%, respectively. Similarly, for girls, overweight/obese percentages in the 4th quartile had changed from 84.35% to 86.09% from 1985/87 to 2012 and corresponding changes for obese were 28.46% to 37.77%, respectively. Boys age 14 (76.22% to 94.28%) and girls age 15 (71.63% to 87.58%) had the highest increase in overweight/obese percentages from 1985/87 to 2012 compared to other age subgroups. Generally, especially for boys, the percentages in overweight/obese and obese subgroups were notably higher for the children in 2012 compared to 1985/87.

DISCUSSION

Using data from two nationally representative surveys, the 1985/87 NCYFS I & II and the 2012 NNYFS, this study examined the changes of BMI-based obesity prevalence and investigated the shifting patterns of BMI and skinfold-fat% among children age 8 to 15 from 1985/87 to 2012. From 1985/87 to 2012, the BMI-based obesity prevalence of boys and girls had increased by 159.06% and 49.79%, respectively, which shows more boys were becoming obese than girls over the past decades. A similar study [17] reported a significant increase in BMI from 1999-2000 to 2009-2010 in adolescent males, but not in females. The higher observed increased BMI-based obesity prevalence for boys compared to girls was consistent with similar finding from previous studies in other countries, such as China [23], India [24] and other European countries [25].

The unique aspect of this study was to examine the obesity shifting patterns of 2012 NNYFS by using the quartiles of the 1985/87 NCYFS I & II as the baselines. If the increase is "balanced", one should see a percentage decrease in the first quartile, no percentage change in the 2nd and 3rd quartiles and the same percentage increase in the 4th quartiles since the moved-out percentages to the upper quartile should be filled by the moved-in percentages from the lower quartiles. The findings were that the unbalanced shifting patterns occurred with two interesting features: 1) there is a skewed shifting mainly to the 4th quartile subgroups of overweight and obese and 2) there is a slight sex difference in terms of shifting, with the higher percentages in the 4th quartile contributed mostly from 1st and 2nd quartiles for boys, but from the 2nd and 3rd quartiles for girls. The observed results of shifting patterns from the lower quartiles to the highest quartile were supported by similar findings that decreased prevalence of underweight and increased prevalence of overweight in the past decades were found for children and adolescents in the U.S. [26], China [26], Italy [27] and Indonesia [28].

Another distinctive aspect of this study is that the reason for BMI shifting was examined simultaneously. Except for height, children's other measures (including weight, subscapular skinfold and triceps skinfold) in 2012 experienced an unbalanced shifting mainly into the 4th quartile compared with children in 1985/87. Thus, it is the weight, not the height, which made the BMI skewed shifting happened. This is consistent with the finding of an earlier study that children and adolescents' weight had increased 9 pounds from 1963/65 to 1999-2002 [17].

Moreover, the skewed shifting of BMI is further confirmed or cross-validated by skinfolds, another fatness measure employed in this study. Both boys and girls were found to have the highest percentages in the 4th quartile of skinfold-fat% and skinfold thicknesses in this study. The skewed shifting patterns of skinfold-fat% and skinfold thicknesses mostly contributed from the 1st and 2nd quartiles, which indicates the number of boys and girls that are overweight or obese substantially increased from 1985/87 to 2012. These findings are consistent with results from Olds et al. [13] that U.S. children and adolescents had a constant increasing rate trend of 1.02% body fatness, 0.6 mm on subscapular skinfold, and 0.38 mm on triceps skinfold per decade from 1956 to 2000. It should be noted that skinfold-fat% values varied considerably between boys and girls across all the ages (8 to 15). Boys aged 9 to 12 years and girls aged 10 to 12 years had higher increments in skinfold-fat% from 1985/87 to 2012. These results are consistent with studies [29,30] that boys around age 12 had the highest skinfold fatness during their growth and development stage, and girls around age 10 gained more skinfold fatness compared with younger girls. Additionally, the finding of boys' higher percentages than girls in the 4th quartile of skinfold-fat%

TABLE 5. Boys' and girls' percentages of skinfold-fat%, subscapular skinfold and triceps skinfold in 2012 year across 1985/87 quartiles

AGE (YR.)	BOYS				GIRLS			
	1 ST QUARTILE (%)	2 ND QUARTILE (%)	3 RD QUARTILE (%)	4 TH QUARTILE (%)	1 ST QUARTILE (%)	2 ND QUARTILE (%)	3 RD QUARTILE (%)	4 TH QUARTILE (%)
Skinfold-fat%								
8	4.08 (0.00-9.59)	21.13 (10.35-31.90)	21.35 (7.52-35.18)	53.45 (36.99-69.90)	11.74 (1.11-22.37)	16.98 (5.26-28.70)	36.78 (25.30-48.26)	34.50 (19.94-49.06)
9	11.81 (0.59-23.03)	12.89 (3.69-22.10)	24.82 (8.71-40.92)	50.48 (32.05-68.90)	19.63 (5.06-34.20)	23.64 (13.78-33.50)	13.51 (3.32-23.70)	43.22 (22.83-63.61)
10	19.09 (5.76-32.42)	12.78 (6.67-18.89)	17.96 (6.67-29.25)	50.17 (33.98-66.36)	12.11 (5.06-19.16)	20.09 (4.20-35.99)	19.91 (9.80-30.03)	47.88 (30.98-64.78)
11	12.84 (0.38-25.29)	15.44 (5.19-25.69)	25.71 (11.49-39.93)	46.02 (31.86-60.18)	14.42 (4.06-24.77)	11.62 (1.74-21.49)	39.40 (23.56-55.25)	34.56 (21.87-47.25)
12	7.24 (1.15-13.33)	19.53 (8.85-30.22)	20.58 (10.46-30.69)	52.65 (39.18-66.12)	17.18 (6.31-28.04)	16.01 (4.91-27.11)	7.28 (0.05-14.50)	59.53 (46.29-72.78)
13	4.42 (0.00-10.17)	22.45 (6.25-38.66)	29.52 (11.90-47.14)	43.61 (24.67-62.55)	6.44 (0.00-16.73)	17.05 (7.21-26.90)	28.92 (11.49-46.36)	47.58 (25.28-69.88)
14	2.13 (0.00-6.45)	28.99 (16.80-41.18)	28.91 (15.59-42.22)	39.98 (24.85-55.11)	5.27 (0.00-10.68)	27.07 (12.90-41.24)	37.25 (23.04-51.46)	30.41 (17.60-43.21)
15	11.93 (0.79-23.06)	12.30 (5.26-19.35)	21.85 (10.80-32.91)	53.92 (39.35-68.48)	17.43 (0.00-34.86)	16.12 (0.00-34.32)	20.67 (6.46-34.87)	45.79 (26.98-64.61)
Overall	9.22 (5.40-13.04)	18.20 (14.29-22.10)	23.52 (19.82-27.23)	49.06 (43.69-54.44)	12.51 (8.18-16.84)	18.70 (15.50-21.90)	26.23 (21.05-31.42)	42.56 (35.10-50.01)
Subscapular skinfold								
8	12.05 (3.63-20.47)	17.89 (5.80-29.98)	9.93 (0.06-19.80)	60.13 (47.94-72.32)	20.00 (8.62-31.37)	15.32 (3.97-26.67)	28.43 (16.15-40.71)	36.26 (20.79-51.73)
9	11.57 (0.00-25.16)	8.36 (0.59-16.14)	33.60 (16.25-50.94)	46.47 (28.35-64.59)	10.34 (0.00-21.69)	39.58 (23.34-55.82)	14.31 (2.47-26.14)	35.78 (12.01-59.54)
10	4.58 (0.00-11.03)	18.16 (3.65-32.67)	28.36 (15.41-41.32)	48.90 (34.17-63.62)	14.88 (3.55-26.22)	23.12 (7.80-38.45)	14.03 (1.86-26.19)	47.97 (29.70-66.24)
11	5.72 (0.00-14.61)	15.11 (2.84-27.38)	34.33 (20.75-47.91)	44.84 (33.24-56.44)	5.89 (0.02-11.77)	22.10 (8.39-35.81)	31.43 (18.50-44.37)	40.57 (26.20-54.94)
12	11.90 (4.64-19.17)	11.63 (4.42-18.83)	27.29 (16.54-38.04)	49.18 (35.76-62.60)	14.11 (1.43-26.79)	14.74 (3.49-25.98)	16.82 (5.57-28.06)	54.34 (41.43-67.24)
13	19.03 (12.32-25.73)	8.96 (0.00-18.27)	31.83 (16.69-46.96)	40.19 (24.72-55.65)	10.07 (1.13-19.01)	12.85 (6.82-18.88)	37.68 (23.18-52.19)	39.40 (22.97-55.83)
14	5.65 (0.00-11.90)	20.55 (8.68-32.42)	35.57 (19.12-52.02)	38.23 (22.10-54.36)	6.82 (0.79-12.84)	22.21 (9.10-35.31)	32.59 (17.44-47.73)	38.39 (25.69-51.10)
15	13.08 (0.00-27.29)	12.43 (2.14-22.72)	21.32 (11.30-31.34)	53.17 (38.36-67.97)	6.14 (0.00-15.55)	36.72 (11.49-61.94)	17.64 (0.54-34.74)	39.50 (20.32-58.68)
Overall	10.43 (8.23-12.63)	14.08 (9.66-18.50)	27.72 (23.90-31.53)	47.78 (42.92-52.63)	11.25 (7.34-15.17)	22.18 (17.42-26.94)	24.80 (19.49-30.11)	41.77 (35.39-48.14)
Triceps skinfold								
8	9.38 (2.38-16.37)	15.73 (5.96-25.49)	30.21 (17.17-43.25)	44.68 (28.98-60.39)	8.23 (1.03-15.43)	27.19 (15.89-38.48)	40.72 (29.43-52.02)	23.87 (10.06-37.67)
9	13.34 (2.16-24.51)	14.55 (3.63-25.48)	27.14 (8.53-45.74)	44.97 (23.37-66.58)	21.67 (6.91-36.43)	20.17 (11.12-29.22)	20.74 (10.50-30.98)	37.42 (16.98-57.85)
10	8.01 (0.00-18.45)	28.81 (11.83-45.79)	18.78 (4.59-32.97)	44.40 (27.17-61.63)	10.79 (3.18-18.41)	25.04 (10.97-39.12)	14.99 (6.46-23.51)	49.18 (33.12-65.25)
11	11.37 (0.00-23.50)	20.10 (6.96-33.25)	34.03 (21.35-46.71)	34.50 (17.33-51.67)	12.08 (0.82-23.34)	17.81 (8.62-27.00)	34.32 (18.01-50.63)	35.79 (22.19-49.39)
12	11.85 (5.03-18.66)	21.21 (11.71-30.72)	16.43 (9.04-23.82)	50.51 (36.59-64.44)	16.62 (5.05-28.18)	11.98 (3.68-20.28)	17.08 (4.93-29.23)	54.32 (36.78-71.86)
13	11.32 (0.00-22.69)	28.30 (8.20-48.40)	19.89 (6.97-32.81)	40.49 (20.77-60.21)	12.64 (1.95-23.33)	7.31 (1.78-12.84)	31.98 (14.26-49.70)	48.07 (24.32-71.82)
14	7.57 (0.99-14.16)	30.21 (11.78-48.65)	17.21 (4.45-29.97)	45.00 (27.75-62.24)	6.01 (0.92-11.10)	29.05 (13.01-45.08)	26.90 (14.68-39.13)	38.04 (20.57-55.51)
15	10.21 (0.00-21.20)	24.41 (17.33-31.48)	10.27 (2.39-18.15)	55.12 (37.97-72.26)	20.65 (4.50-36.80)	16.66 (4.58-28.74)	22.98 (6.58-39.37)	39.72 (16.74-62.69)
Overall	10.41 (6.62-14.19)	22.93 (18.22-27.64)	21.22 (18.69-23.75)	45.45 (38.87-52.02)	12.85 (8.04-17.67)	19.72 (16.34-23.11)	26.49 (21.08-31.90)	40.94 (32.88-48.99)

Notes: Individual-level data (N = 9,633) came from 1985/87 NCYFS I & II and 2012 NNYFS. 95% confidence intervals are in parentheses.

TABLE 6. The BMI-based overweight/obese and obese percentages in the 4th quartile by age, sex and year.

Age (yr.)	BOYS (%)				GIRLS (%)			
	OVERWEIGHT/OBESE		OBESE		OVERWEIGHT/OBESE		OBESE	
	1985/87	2012	1985/87	2012	1985/87	2012	1985/87	2012
8	83.94	93.50	39.42	59.54	98.59	100.00	36.62	44.68
9	93.71	90.43	41.96	52.13	93.96	95.34	35.57	50.33
10	87.30	87.36	30.16	53.11	72.22	74.53	26.39	38.29
11	86.03	93.20	29.41	31.18	92.70	92.57	32.12	45.20
12	82.27	89.16	32.62	50.74	82.48	85.15	34.31	34.97
13	68.28	93.15	22.07	54.66	84.96	92.00	25.56	21.99
14	76.22	94.28	27.27	89.16	72.03	72.26	16.08	30.70
15	75.17	88.24	22.76	46.63	71.63	87.58	19.86	47.84
Overall	81.10	90.88	30.67	53.93	84.35	86.09	28.46	37.77

and skinfold thicknesses demonstrated that boys' skinfold fatness had noticeably increased more than girls' skinfold fatness from 1985/87 to 2012. The finding of higher fat accumulation in boys compared to girls over the past decades was also supported by the Olds et al. study [13] that increased rates in body fat percentage were greater for boys than for girls.

The findings on the changes of BMI-based obesity prevalence for boys and for girls from 1985/87 to 2012 revealed that there is a significant increase in childhood obesity from 1985/87 to 2012 especially for boys. Furthermore, the skewed shifting patterns on weight, BMI and skinfold-fat% in the 4th quartile suggest that the significant increase in overweight and obese prevalence from 1985/87 to 2012 was accompanied with the decrease in underweight and normal weight prevalence, which should serve as a serious warning that the current childhood obesity epidemic continues and that its prolonged impact on public health must be considered. It is commonly believed that less physical activity and more sedentary behaviour played significant roles in the observed high BMI, body fatness and obesity trends [31-33]. Increases in television viewing, computer/video game playing and the lack of daily physical activity may have further negative impacts on exercise motivation and trigger a higher obesity prevalence [34]. Therefore, wellness programs are urgently needed to better address the current shifting trend in childhood obesity.

Finally, two limitations of this study need to be noted. First, only two time points' data were compared to estimate changing patterns of BMI and skinfold-fat% from 1985/87 to 2012, which cannot assess a comprehensive trend in the past decades. Second, although they were validated, only the field measures of fatness, i.e., weight, BMI and skinfold, were employed.

In summary, this study examined changes of BMI-based obesity prevalence and shifting patterns of weight,

BMI and skinfold fatness among children aged 8 to 15 years from 1985/87 to 2012. Significantly increased BMI-based obesity prevalence was found for both boys (increased by 159.06%) and girls (increased by 49.79%) from 1985/87 to 2012. Except for height, all other measures (including BMI, weight, skinfold-fat%, subscapular skinfold and triceps skinfold) in 2012 experienced a skewed shifting, mainly into the 4th quartile established in 1985/87, indicating a significant increase in BMI and skinfold-fat% not only in U.S. children from 1985/87 to 2012, but also into the overweight and obese subgroups, which serves as a warning concerning the on-going childhood obesity epidemic.

Conflict of interest

The authors declare that there is no conflict of interest.

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