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Temporal Trends of the Prevalence of Abdominal Obesity and Metabolic Syndrome in Korean Children and Adolescents between 2007 and 2020

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Background: The prevalence of obesity in children and adolescents is increasing worldwide, which is of concern because obesity can lead to various complications such as metabolic syndrome (MS). Waist circumference (WC) and waist-height ratio (WHtR) are useful indicators of abdominal obesity and MS. In this study, we investigate trends in the prevalence of abdominal obesity and MS using two different references.
Methods: Data from the Korea National Health and Nutrition Examination Survey (2007 to 2020) were used. In total, 21,652 participants aged 2 to 18 years and 9,592 participants aged 10 to 18 years were analyzed for abdominal obesity and MS, respectively. The prevalence of abdominal obesity and that of MS were compared using the Korean National Growth Chart in 2007 (REF2007) and the newly published WC and WHtR reference values in 2022 (REF2022).
Results: Both WC and WHtR showed an increasing trend. The prevalence of abdominal obesity was 14.71% based on REF2022, 5.85% points higher than that of 8.86% based on REF2007. MS based on REF2022 had a higher prevalence for both the National Cholesterol Education Program definition (3.90% by REF2007, 4.78% by REF2022) and the International Diabetes Federation definition (2.29% by REF2007, 3.10% by REF2022). The prevalence of both abdominal obesity and MS increased over time.
Conclusion: The prevalence of abdominal obesity and MS increased in Korean children and adolescents from 2007 to 2020. When analyzed by REF2022, both abdominal obesity and MS showed higher prevalence rates than when using REF2007, indicating that previous reports were underestimated. Follow-up for abdominal obesity and MS using REF2022 is needed.

Key words: Trend, Abdominal obesity, Metabolic syndrome, Child, Adolescent, Korea

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INTRODUCTION

Obesity in children and adolescents is on the rise worldwide and is emerging as an important public health problem.[1-3] Obesity causes various complications including metabolic syndrome (MS)[4] and is a risk factor for adulthood obesity and cardiovascular disease.[5,6] Although body mass index (BMI) is widely used to evaluate these problems in children and adolescents, waist circumference

(WC) and waist-height ratio (WHtR) are considered better indicators of abdominal obesity and MS because they reflect visceral fat more directly.[7-9]

In Korea, new WC and WHtR references were recently published. The formerly used WC reference published in the 2007 Korean National Growth Charts (REF2007)[10] had drawbacks of no standardized measurements for WC, few percentile values, no graphs, and no exclusion of children and adolescents with extreme weight.

To compensate for these disadvantages, the newly published WC and WHtR reference (REF2022)[11] uses an updated statistical methodology. The advantages of REF2022 include that it is age- and sex-specific; furthermore, lambda-mu-sigma (LMS) values for WC and WHtR have been added to the calculated z-scores or percentiles for the corresponding sex and age.

The curves are lower for both boys and girls in REF2022 than in REF2007, and in the meantime, the prevalence of abdominal obesity may have been underestimated in Korean children and adolescents.[11] Therefore, MS, for which abdominal obesity is an important diagnostic criterion, seems to have been underestimated.

In this study, using data from the Korea National Health and Nutrition Examination Survey (KNHANES), we investigated the prevalence of abdominal obesity and MS from 2007 to 2020 in Korean children and adolescents using REF2007 and REF2022.

METHODS

Study population

Data were obtained from the KNHANES performed from 2007 to 2020. The KNHANES is an ongoing cross-sectional survey that collects nationally representative data. Although it has been conducted since 1998 by the Korea Centers for Disease Control and Prevention (renamed the Korea Disease Control and Prevention Agency in 2020), only data collected from 2007 to 2020 were included in the present study because the survey design and detailed methods were updated in 2007. The KNHANES used a stratified multi-stage clustered probability method to sample non-institutionalized citizens in Korea. The KNHANES consists of a health interview, examination, and a nutritional survey. Detailed procedures for data collection have been described elsewhere.[12]

Among the 113,091 individuals enrolled in the KNHANES from 2007 to 2020, 23,595 individuals aged 2 to 18 years were considered candidates for the present study. Among them, 21,652 participants aged 2 to 18 years (11,379 boys and 10,273 girls) were finally included in the analysis of the trends in prevalence of abdominal obesity after excluding participants without anthropometric data (n = 1,943). For trends in the prevalence of MS, a total of 9,592 subjects aged 10 to 18 years (5,118 boys and 4,474 girls) was included in the analysis after excluding participants without anthropometric data, data on the components of MS, or who did not fast for at least 8 hours before biochemical parameter testing (Supplementary Figure 1).

Anthropometric measurements and laboratory tests

Height, weight, and WC were measured by trained medical personnel. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 225; Seca). Weight was measured to the nearest 0.1 kg using an electronic balance (GL-6000-20; G-tech). BMI was calculated as weight (kg) divided by height squared (m^2) and was transformed into a z-score using the 2017 Korean National Growth Chart.[13] WC was measured using a flexible tape (Seca 220) to the nearest 0.1 cm at the midpoint between the lowest margin of the rib and the highest margin of the iliac crest during expiration. WHtR was calculated as WC (cm) divided by height (cm). WC and WHtR were transformed into z-score using REF2022 data. Blood pressure (BP) was measured three times on the right arm using a mercury sphygmomanometer with a cuff appropriate for arm circumference after the participant had rested for at least 5 minutes in a sitting position (Baumanometer Desk Model 0320 in 2007 to 2012 and Baumanometer Wall Unit 33 [0850] 2013 to 2019; W.A. Baum). The mean values of the second and third systolic and diastolic BP measurements were used for analyses in this study.

Blood samples were collected by trained medical personnel. Fasting blood samples obtained from venipuncture were transported to a central laboratory for analysis within 24 hours. Plasma glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol, and triglyceride levels were measured using a Hitachi Automatic Analyzer 7600 (Hitachi). The glycated hemoglobin level was measured via high-performance liquid chromatography (HPLC-723G7; Tosoh), which is the method certified by the National Glycohemoglobin Standardization Program.

Definitions of abdominal obesity and metabolic syndrome

Abdominal obesity was defined as WC equal or greater than the 90th percentile by sex and age, respectively, based on REF2007[10] and REF2022.[11] MS was defined according to the modified criteria of the National Cholesterol Education Program-Adult Treatment Panel III (MS_{NCEP}) as a combination of any three of the five following criteria: central obesity (WC ≥90th percentile), hyperglycemia (fasting glucose ≥110 mg/dL), hypertriglyceridemia (fasting triglycerides ≥110 mg/dL), low HDL-C (≤40 mg/dL), and elevated BP (≥90th percentile or receiving treatment for hypertension).[14] MS was defined by the criteria of the International Diabetes Federation (MS_{IDF}) as a combination of central obesity with the presence of two or more of the other four risk factors.[15] For children 10 to 15 years of age, the following cutoffs were used: WC ≥90th percentile, systolic BP ≥130 mmHg or diastolic BP ≥85 mmHg, triglycerides ≥150 mg/dL, HDL-C <40 mg/dL, and fasting glucose ≥100 mg/dL. For adolescents older than 15 years, the IDF recommended the same criteria for diagnosis of MS as used in adults: central obesity (WC ≥90 cm for male, ≥80 cm for female), as well as at least two of the following risk factors: high BP (systolic BP ≥130 mmHg or diastolic BP ≥85 mmHg or treatment of previously diagnosed hypertension), fasting glucose ≥100 mg/dL or known type 2 diabetes, triglycerides ≥150 mg/dL or specific treatment for high triglycerides, HDL-C <40 mg/dL in males and <50 mg/dL in females, or specific treatment for low HDL-C.[15-17]

Statistical analysis

All statistical analyses were performed using Stata version 17.0 (StataCorp LP). Multivariate linear regression analysis was applied to evaluate the correlation between the WC z-score and the WHtR z-score. Logistic regression analysis was performed to evaluate the associations between cardio-metabolic risk factors and the z-scores of WC, WHtR, and BMI, and the results were presented as odds ratio (OR) and 95% confidence interval (CI). A *P*-value <0.05 was considered to indicate statistical significance.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board of Seoul National University Bundang Hospital (approval No. X-2206-761-901). Informed consent was submitted by all subjects at enrollment.

RESULTS

Trends in waist circumference and waist-to-height ratio z-scores

Based on REF2022, the WC z-score and WHtR z-score in 2007 to 2020 were 0.09 (95% CI, 0.07 to 0.11) and –0.06 (95% CI, –0.08 to –0.04), respectively (Table 1). The WC z-score was higher in girls ($P=0.004$), but there was no significant difference in the WHtR z-score between boys and girls ($P=0.248$).

Age- and sex-adjusted linear regression analysis showed that WC and WHtR increased in recent years (coefficient = 0.014, standard error [SE] = 0.003, $P<0.001$ for WC; coefficient = 0.012, SE = 0.003, $P<0.001$ for WHtR) (Figure 1). Similar results were shown in age- and sex-specific analyses (Supplementary Figure 2).

Trends in abdominal obesity

In 2007 to 2020, the prevalence of abdominal obesity was 8.86% (boys 8.85%, girls 8.86%) based on REF2007 and 14.71% (boys 14.81%, girls 14.60%) based on REF2022 (Table 2). No significant difference between sexes was found with either reference.

When age- and sex-adjusted logistic regression analysis was performed, abdominal obesity increased when using the more recent reference (OR, 1.045; 95% CI, 1.029 to 1.062; $P<0.001$ for REF2007) (OR, 1.027; 95% CI, 1.014 to 1.040; $P<0.001$ for REF2022). Similar results were shown in analyses by sex and age, but the increase was greater in boys (Figure 2 and Supplementary Figure 3).

Trends in metabolic syndrome

The MS_{NCEP} in 2007 to 2020 was 3.90% (4.41% for boys and 3.32% for girls) according to REF2007 and 4.78% (5.47% for boys, 4.00% for girls) according to REF2022, a difference of 0.88% (Table 3). The MS_{IDF} in 2007 to 2020 was 2.29% (2.22% for boys and 2.38% for girls) using REF2007 and 3.10% (3.19% for boys and 3.00% for girls) using REF2022, an increase of 0.81% (Table 3). There was no significant difference between the sexes.

When age- and sex-adjusted logistic regression analysis was performed, MS increased in recent years (OR, 1.044; 95% CI, 1.011 to 1.077; $P=0.008$ for MS_{NCEP} by REF2022) (OR, 1.042; 95% CI,

Table 1. Temporal trends in z-scores of waist circumference and waist-height ratio in children and adolescents aged 2 to 18 years using the reference updated in 2022

Year	Waist circumference			Waist-height ratio		
	Total	Boys	Girls	Total	Boys	Girls
2007	0.23 (0.13 to 0.32)	0.19 (0.08 to 0.31)	0.26 (0.13 to 0.39)	0.04 (–0.06 to 0.14)	0.03 (–0.08 to 0.14)	0.05 (–0.09 to 0.19)
2008	0.10 (0.04 to 0.16)	0.10 (0.03 to 0.17)	0.10 (0.01 to 0.19)	–0.03 (–0.10 to 0.04)	–0.03 (–0.10 to 0.05)	–0.04 (–0.13 to 0.06)
2009	–0.01 (–0.07 to 0.05)	–0.01 (–0.09 to 0.07)	–0.01 (–0.09 to 0.08)	–0.16 (–0.22 to –0.10)	–0.15 (–0.23 to –0.07)	–0.16 (–0.25 to –0.08)
2010	0.02 (–0.05 to 0.09)	0.00 (–0.09 to 0.10)	0.04 (–0.07 to 0.15)	–0.10 (–0.18 to –0.02)	–0.11 (–0.21 to 0.00)	–0.10 (–0.22 to 0.01)
2011	0.03 (–0.04 to 0.11)	–0.04 (–0.13 to 0.06)	0.11 (0.02 to 0.21)	–0.10 (–0.18 to –0.02)	–0.17 (–0.27 to –0.07)	–0.01 (–0.11 to 0.09)
2012	–0.03 (–0.10 to 0.05)	–0.07 (–0.18 to 0.04)	0.02 (–0.09 to 0.13)	–0.19 (–0.26 to –0.12)	–0.20 (–0.30 to –0.11)	–0.17 (–0.29 to –0.05)
2013	–0.07 (–0.15 to 0.01)	–0.09 (–0.19 to 0.01)	–0.04 (–0.13 to 0.05)	–0.23 (–0.32 to –0.14)	–0.25 (–0.36 to –0.14)	–0.20 (–0.30 to –0.10)
2014	0.05 (–0.02 to 0.13)	0.01 (–0.09 to 0.10)	0.10 (–0.01 to 0.21)	–0.09 (–0.17 to –0.01)	–0.13 (–0.23 to –0.03)	–0.04 (–0.16 to 0.07)
2015	0.28 (0.20 to 0.36)	0.20 (0.10 to 0.30)	0.37 (0.25 to 0.48)	0.13 (0.05 to 0.22)	0.05 (–0.05 to 0.16)	0.22 (0.10 to 0.34)
2016	0.12 (0.04 to 0.20)	0.08 (–0.01 to 0.18)	0.16 (0.06 to 0.26)	–0.04 (–0.12 to 0.04)	–0.06 (–0.16 to 0.05)	–0.03 (–0.13 to 0.08)
2017	0.05 (–0.02 to 0.12)	0.02 (–0.08 to 0.11)	0.09 (–0.01 to 0.18)	–0.12 (–0.20 to –0.04)	–0.14 (–0.24 to –0.04)	–0.09 (–0.19 to 0.01)
2018	0.12 (0.05 to 0.20)	0.11 (0.01 to 0.21)	0.14 (0.05 to 0.23)	–0.05 (–0.12 to 0.02)	–0.03 (–0.14 to 0.08)	–0.07 (–0.17 to 0.02)
2019	0.27 (0.17 to 0.36)	0.29 (0.18 to 0.40)	0.24 (0.12 to 0.37)	0.12 (0.02 to 0.22)	0.17 (0.05 to 0.30)	0.06 (–0.07 to 0.20)
2020	0.35 (0.24 to 0.46)	0.42 (0.32 to 0.53)	0.27 (0.11 to 0.43)	0.21 (0.10 to 0.32)	0.33 (0.20 to 0.45)	0.08 (–0.07 to 0.24)
Total	0.09 (0.07 to 0.11)	0.07 (0.04 to 0.09)	0.12 (0.09 to 0.15)	–0.06 (–0.08 to –0.04)	–0.07 (–0.10 to –0.04)	–0.05 (–0.08 to –0.02)

Values are presented as weighted mean (95% confidence interval).

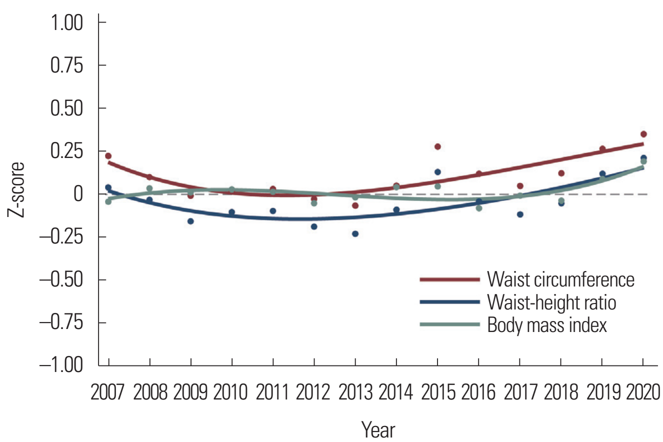

Figure 1. Temporal trends in z-scores of waist circumference, waist-height ratio, and body mass index among children and adolescents aged 2 to 18 years using the reference updated in 2022.

1.001 to 1.008; $P=0.045$ for MS_{IDF} by REF2022) (Figure 3). In analysis by sex, only the increase in boys was significant (Supplementary Figure 4).

DISCUSSION

This is the first study investigating whether application of the recently published WC and WHtR reference values[11] leads to a difference in prevalence of abdominal obesity and MS compared to values derived using the previous reference (REF2007).[10]

Several studies have reported results for the prevalence of abdominal obesity in children and adolescents, varying from 10% to 30%. As examples from other countries, the prevalence of abdominal obesity in children 2 to 18 years was 18.87% in the United States (2011 to 2012),[18] 10.6% in 14- to 19-year-old Brazilian adolescents,[19] 26% in 9- to 17-year-old girls in Bangladesh,[20] 27.8% in Iranian children and adolescents (6 to 18 years),[21] 9.4% in 6- to 11-year-old children in Spain, and 9.6% in 12- to 17-year-old adolescents in Spain (1998 to 2000).[22] In Korea, the prevalence of abdominal obesity in children and adolescents has been reported to range from 9.7% to 11.5%.[23-25] The present study found a prevalence of 8.86% for abdominal obesity in 2- to 18-year-old children and adolescents based on REF2007 and of 14.71% based on REF2022, and it showed a continually increasing trend from 2007 to 2020.

One study has reported the prevalence of MS at 2.8% in children (6 to 12 years) and 4.8% in adolescents (13 to 18 years), with some variation across countries and regions.[26] In other studies, the prevalence of MS in children and adolescents was reported to be 0.3% to 26.4% depending on the definition of MS.[27] In other countries, the prevalence of MS in children and adolescents was 3.1% to 5.4% in the United States,[27-29] 9.5% in Chile,[27,30] 1.1% to 7.6% in China,[27,31] 7.6% in Iran,[21,27] and 3.8% in Spain.[27,32] In recent papers in Korea, the prevalence was 2.1% in KNHANES 2010 to 2012 (10 to 18 years),[23] 2.5% in KNHANES 2016 to 2017 (10 to 18 years),[24] and 2.2% in

Table 2. Temporal trends of abdominal obesity according to references in children and adolescents aged 2 to 18 years

Year	Abdominal obesity (REF2007)			Abdominal obesity (REF2022)		
	Total	Boys	Girls	Total	Boys	Girls
2007	9.84 (7.88–12.22)	10.67 (8.18–13.82)	8.88 (6.34–12.29)	17.58 (15.13–20.34)	18.29 (15.30–21.71)	16.77 (12.78–21.70)
2008	8.41 (7.16–9.85)	7.94 (6.40–9.81)	8.94 (7.09–11.21)	14.82 (12.97–16.87)	15.61 (13.30–18.25)	13.91 (11.46–16.78)
2009	6.39 (5.31–7.66)	5.94 (4.56–7.71)	6.88 (5.42–8.70)	11.59 (10.13–13.22)	12.08 (10.21–14.25)	11.04 (9.07–13.37)
2010	7.51 (6.00–9.41)	7.39 (5.40–10.03)	7.65 (5.51–10.54)	12.83 (10.86–15.10)	13.14 (10.68–16.07)	12.47 (9.64–15.98)
2011	9.23 (7.49–11.34)	8.24 (6.30–10.69)	10.37 (7.88–13.53)	14.34 (12.25–16.71)	13.34 (10.94–16.16)	15.48 (12.43–19.11)
2012	6.97 (5.41–8.95)	6.28 (4.33–9.03)	7.74 (5.35–11.07)	12.62 (10.49–15.12)	12.67 (9.60–16.53)	12.57 (9.73–16.10)
2013	7.28 (5.85–9.02)	7.53 (5.60–10.06)	7.00 (5.06–9.61)	11.90 (10.15–13.89)	11.75 (9.56–14.36)	12.06 (9.65–14.97)
2014	8.01 (6.56–9.76)	8.41 (6.30–11.14)	7.57 (5.63–10.11)	13.17 (11.27–15.34)	12.00 (9.45–15.05)	14.49 (11.64–17.90)
2015	10.66 (8.85–12.80)	10.25 (7.96–13.10)	11.12 (8.39–14.60)	17.55 (15.24–20.12)	16.16 (13.33–19.44)	19.09 (15.72–22.99)
2016	10.96 (9.00–13.28)	10.20 (7.81–13.23)	11.76 (9.07–15.12)	16.21 (13.90–18.83)	15.46 (12.61–18.81)	17.02 (13.71–20.94)
2017	8.57 (6.98–10.48)	8.86 (6.85–11.38)	8.26 (6.21–10.90)	13.19 (11.22–15.46)	13.40 (10.88–16.41)	12.96 (10.39–16.06)
2018	9.30 (7.65–11.26)	11.14 (8.69–14.17)	7.36 (5.49–9.79)	14.97 (12.78–17.46)	16.16 (13.27–19.54)	13.71 (10.85–17.18)
2019	12.41 (10.03–15.26)	12.25 (9.51–15.65)	12.58 (9.38–16.66)	19.68 (16.66–23.11)	20.73 (16.60–25.57)	18.56 (14.62–23.27)
2020	16.22 (13.35–19.55)	18.19 (14.87–22.05)	14.05 (10.22–19.00)	21.09 (17.86–24.73)	23.42 (19.45–27.91)	18.54 (14.19–23.84)
Total	8.86 (8.38–9.36)	8.85 (8.23–9.51)	8.86 (8.18–9.59)	14.71 (14.11–15.33)	14.81 (14.03–15.62)	14.60 (13.74–15.50)

Values are presented as weighted percentage (95% confidence interval).

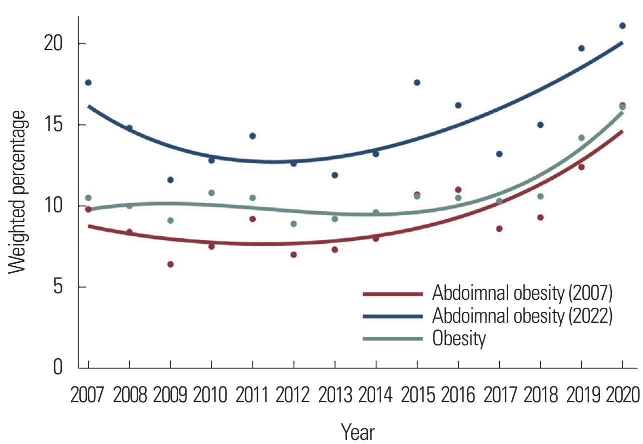

Figure 2. Temporal trends in the prevalence of obesity and abdominal obesity among children and adolescents aged 2 to 18 years according to different references.

KNHANES 2016 to 2018 (12 to 18 years).[25] Compared to the present study, the results of these previous studies reflect underestimations compared to the prevalence of MS determined based on REF2022.

The present study showed that the prevalence of abdominal obesity and MS in children and adolescents in Korea has been underestimated. The increase in prevalence of abdominal obesity was greater in boys, and prevalence of MS showed a significant increase only in boys. This is thought to be related to the steeper increase in WC in boys than in girls (Supplementary Figure 2), as with WHtR and BMI. To explain this phenomenon, further research will be needed to identify factors affecting changes in body composition in boys and girls over the last decade.

Based on REF2007 and REF2022, both abdominal obesity and MS showed an increasing trend from 2007 to 2020. The prevalence of abdominal obesity in children and adolescents in Korea is similar to the prevalence of obesity and has increased over time as has the prevalence of obesity.[33]

As mentioned, abdominal obesity and MS were likely underestimated in studies before REF2022 was published because abdominal obesity is one of the main diagnostic criteria for MS, and underestimation of abdominal obesity causes an underestimation of MS.[11] REF2022 presented reference values for both WC and WHtR, which is calculated by dividing WC by height and is known to reflect body fat better than WC in children and adolescents.[8] Therefore, WHtR has been used with WC as an indicator of abdominal obesity.[9] However, criteria for defining abdominal obesity based on WHtR in children and adolescents have not been established. Several studies have reported that it is not appropriate to apply the 0.5 cutoff of adult WHtR to children and adolescents, who are still growing.[7,34,35] Instead, it would be better to use WHtR percentiles that are specific for age and sex. However, these criteria have not been clearly defined. Although WC is currently the most widely used indicator for abdominal obesity, it has a positive correlation

Table 3. Temporal trends of metabolic syndrome by modified NCEP-ATP III criteria according to abdominal obesity references in children and adolescents aged 10 to18 years

Year	Metabolic syndrome by modified NCEP-ATP III criteria						Metabolic syndrome by IDF criteria					
	Abdominal obesity REF2007			Abdominal obesity REF2022			Abdominal obesity REF2007			Abdominal obesity REF2022		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
2007	3.74 (1.99–6.95)	4.17 (2.24–7.65)	3.22 (1.31–7.69)	5.56 (3.33–9.25)	5.41 (3.29–8.77)	5.82 (2.68–12.19)	2.30 (1.25–4.20)	2.29 (0.87–5.90)	2.32 (1.01–5.24)	3.61 (2.04–6.29)	2.60 (1.10–6.03)	4.85 (2.50–9.20)
2008	3.67 (2.53–5.30)	3.72 (2.29–5.99)	3.62 (2.15–6.01)	5.15 (3.76–7.02)	6.18 (4.13–9.14)	3.99 (2.47–6.39)	1.83 (1.11–3.01)	1.49 (0.67–3.28)	2.23 (1.14–4.29)	3.14 (2.20–4.46)	3.31 (1.97–5.51)	2.95 (1.71–5.02)
2009	2.84 (1.89–4.23)	3.26 (2.03–5.21)	2.35 (1.09–5.00)	3.80 (2.59–5.53)	4.08 (2.66–6.23)	3.49 (1.71–6.99)	1.58 (0.94–2.64)	1.14 (0.47–2.70)	2.07 (1.08–3.93)	2.60 (1.77–3.81)	2.57 (1.46–4.49)	2.64 (1.52–4.54)
2010	2.84 (1.73–4.64)	3.26 (1.73–6.05)	2.35 (1.24–4.39)	3.84 (2.57–5.69)	4.41 (2.64–7.29)	3.15 (1.83–5.37)	1.44 (0.68–2.99)	1.55 (0.65–3.63)	1.30 (0.41–4.07)	2.69 (1.67–4.30)	2.91 (1.54–5.44)	2.42 (1.19–4.86)
2011	3.01 (1.80–4.97)	3.47 (1.75–6.77)	2.48 (1.12–5.39)	3.81 (2.41–5.97)	4.11 (2.27–7.35)	3.46 (1.65–7.13)	2.08 (1.04–4.10)	1.24 (0.38–3.90)	3.03 (1.33–6.77)	2.57 (1.43–4.57)	1.80 (0.75–4.25)	3.44 (1.61–7.21)
2012	2.88 (1.60–5.12)	2.80 (1.21–6.35)	2.97 (1.25–6.92)	3.71 (2.10–6.48)	4.10 (2.13–7.75)	3.24 (1.44–7.14)	1.67 (0.77–3.57)	1.85 (0.61–5.51)	1.45 (0.52–3.95)	2.08 (1.09–3.93)	2.39 (0.98–5.70)	1.71 (0.69–4.22)
2013	3.11 (1.91–5.01)	3.27 (1.74–6.05)	2.93 (1.43–5.90)	3.61 (2.33–5.54)	3.86 (2.17–6.77)	3.33 (1.73–6.30)	1.77 (0.98–3.17)	1.58 (0.62–3.96)	1.98 (0.94–4.11)	2.44 (1.49–3.96)	2.27 (1.05–4.84)	2.62 (1.37–4.93)
2014	3.39 (1.91–5.97)	3.72 (1.83–7.42)	3.02 (1.23–7.22)	3.48 (1.98–6.05)	3.88 (1.96–7.55)	3.02 (1.23–7.22)	1.90 (0.91–3.92)	2.52 (1.01–6.17)	1.18 (0.37–3.71)	2.22 (1.15–4.24)	2.68 (1.13–6.26)	1.69 (0.63–4.45)
2015	3.60 (2.26–5.68)	4.10 (2.36–7.03)	3.02 (1.36–6.58)	4.32 (2.85–6.50)	4.95 (3.02–8.01)	3.61 (1.80–7.11)	3.18 (1.85–5.41)	3.51 (1.66–7.29)	2.80 (1.24–6.19)	3.80 (2.36–6.07)	4.36 (2.31–8.10)	3.16 (1.49–6.58)
2016	5.39 (3.58–8.03)	5.56 (3.34–9.12)	5.18 (2.55–10.23)	5.86 (4.00–8.50)	5.98 (3.69–9.56)	5.71 (2.98–10.67)	3.18 (1.85–5.42)	2.45 (1.22–4.89)	4.03 (1.83–8.64)	3.56 (2.15–5.84)	2.94 (1.52–5.63)	4.29 (2.04–8.82)
2017	3.84 (2.51–5.83)	4.61 (2.74–7.66)	3.00 (1.46–6.07)	4.79 (3.27–6.97)	5.57 (3.50–8.76)	3.94 (2.02–7.57)	1.73 (0.96–3.08)	1.92 (0.93–3.91)	1.52 (0.59–3.87)	2.72 (1.73–4.26)	3.49 (2.03–5.92)	1.89 (0.81–4.36)
2018	4.70 (3.18–6.89)	5.39 (3.27–8.77)	3.94 (2.13–7.19)	5.48 (3.84–7.77)	6.90 (4.49–10.46)	3.94 (2.13–7.19)	1.76 (0.97–3.17)	1.92 (0.83–4.35)	1.58 (0.67–3.71)	2.64 (1.58–4.35)	3.26 (1.77–5.95)	1.95 (0.88–4.29)
2019	4.66 (2.94–7.30)	5.53 (3.35–9.02)	3.72 (1.81–7.52)	6.09 (4.06–9.03)	7.45 (4.77–11.45)	4.63 (2.47–8.53)	3.83 (2.13–6.80)	3.56 (2.07–6.12)	4.10 (1.71–9.50)	4.77 (2.73–8.23)	5.40 (3.02–9.49)	4.10 (1.71–9.50)
2020	8.47 (5.96–11.89)	10.84 (7.20–16.01)	5.57 (3.24–9.42)	9.18 (6.64–12.56)	11.65 (7.97–16.74)	6.16 (3.71–10.05)	4.86 (2.96–7.91)	5.41 (2.87–9.94)	4.20 (2.22–7.82)	5.70 (3.57–9.00)	5.77 (3.15–10.32)	5.62 (3.23–9.61)
Total	3.90 (3.45–4.41)	4.41 (3.79–5.12)	3.32 (2.73–4.02)	4.78 (4.28–5.34)	5.47 (4.80–6.24)	4.00 (3.34–4.77)	2.29 (1.94–2.70)	2.22 (1.78–2.76)	2.38 (1.89–3.00)	3.10 (2.70–3.56)	3.19 (2.67–3.82)	3.00 (2.46–3.66)

Values are presented as weighted percentage (95% confidence interval).
NCEP-ATP III, National Cholesterol Education Program-Adult Treatment Panel III; IDF, International Diabetes Federation.

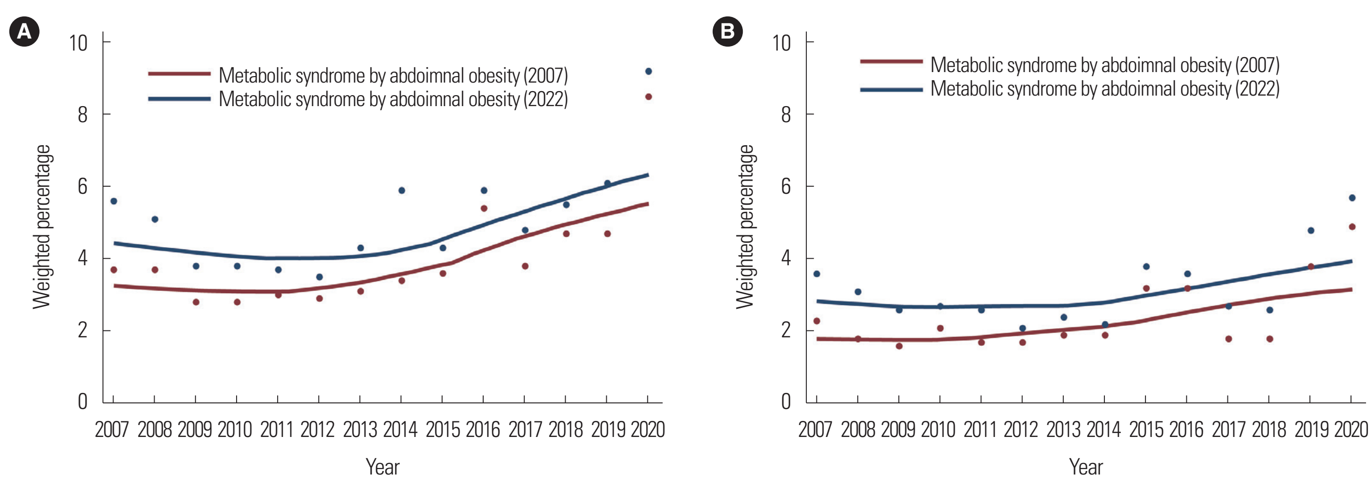

Figure 3. Temporal trends in the prevalence of metabolic syndrome among children and adolescents aged 10 to 18 years according to different references for abdominal obesity. (A) The modified National Cholesterol Education Program-Adult Treatment Panel III and (B) the International Diabetes Federation.

with height.[11] Therefore, using WHtR is more accurate to define abdominal obesity, but further research is required to determine the optimal cutoff point before WHtR can be used in real-world clinical practice.[11]

Interestingly, the rapid increases in abdominal obesity and MS in 2020 are thought to be due to changes in the living environment due to the coronavirus disease 2019 (COVID-19) pandemic. Abdominal obesity and MS may have increased as obesity increased due to a decrease in physical activity and an increase in sedentary time due to social distancing during the COVID-19 period along with an increase in calorie intake due to increased consumption of delivery and instant food.[36-39] Further studies on the increases of obesity and MS during the COVID-19 pandemic (specifically, the 2-year period during which strong social distancing measures were implemented) analyzing up-to-date data will be needed.

In this study, children younger than 10 years were not included in analysis of the prevalence of MS. Though data on WC, WHtR, and BMI are collected in children aged 2 to 10 years, it is generally recommended not to diagnose MS before age 10 because of lack of age-specific reference values for MS components.[17,40]

Nevertheless, this study is the first to analyze the prevalence of abdominal obesity and MS in Korean children and adolescents based on the newly published REF2022[11] and to confirm that abdominal obesity and MS in children and adolescents in Korea have been underestimated based on a comparison of these values with those derived using REF2007.

In conclusion, abdominal obesity and MS showed increasing trends in Korean children and adolescents from 2007 to 2020. Use of REF2022 showed higher prevalence of abdominal obesity and MS than when using REF2007; thus, studies that used REF2007 presented underestimated values. In the future, it will be necessary to follow up on abdominal obesity and MS based on the newly published REF2022.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found online at https://doi.org/10.7570/jomes22059.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Study concept and design: HWC and JK; acquisition of data: JK; analysis and interpretation of data: JK; drafting of the manuscript: JL and JK; critical revision of the manuscript: SCK, OK, SSH, and JSM; statistical analysis: JK; administrative, technical, or material support: JK; and study supervision: HWC and JK.

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