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Prevalence of and factors associated with lipid screening in young people aged 16– to 21 years in the United States: analysis of nationwide cross-sectional data

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Abstract

Background & Aims There is no consensus on whether it is worthwhile for young people to undergo lipid screening. An estimate of the national prevalence of lipid screening in this population can serve as a basic parameter in analyses of the utilization and cost-effectiveness of health care services. Previous studies were mostly based on electronic health records or insurance claims data or were restricted to adolescents at younger ages. This study aimed to investigate the prevalence of lipid screening and the factors associated with it in young people aged 16– to 21 years in the United States based on a nationally representative sample.

Methods A cross-sectional study of 16- to 21-year-old participants from the National Health and Nutrition Examination Survey (NHANES), 2013–March 2020 (four cycles), was conducted. The prevalence of lipid screening uptake was calculated for each cycle as well as for all four cycles combined, and the associations of lipid screening uptake with the covariates were analysed by logistic regression. An appropriate sample weight was incorporated into the analysis as recommended.

Results A total of 3,600 participants were included in the analysis, and 32.02% of them had ever received lipid screening at the time of the survey, with no statistically significant secular changes observed over the four cycles. Among the participants, 28.83% received lipid screening within the past 5 years. In multivariable regression analysis adjusted for all covariates, non-Hispanic black ethnicity (adjusted odds ratio [AOR]: 1.43), having health insurance (AOR: 1.54), obesity (AOR: 1.65) and sufficient physical activity (AOR: 1.36) were significantly associated with a greater chance of ever receiving lipid screening.

Conclusions Nearly one-third of young people aged 16– to 21 years in the United States have received lipid screening. Ethnicity, health insurance, weight problems, and physical activity level were associated with the likelihood of lipid screening uptake. These findings could help people understand the current situation of lipid screening in young people in the United States and may serve as fundamental parameters in the assessment of the utilization and cost-effectiveness of related health care services.

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Introduction
Background
Dyslipidaemia in children and adolescents is associated with premature atherosclerosis, cardiovascular disease and death in adulthood [1, 2]. Familial hypercholesterolemia and multifactorial dyslipidaemia are the two main types of dyslipidaemia in this population. According to the evidence reported by the United States Preventive Services Task Force (USPSTF), in children and adolescents in the United States (US), the prevalence of familial hypercholesterolemia ranges from 0.2 to 0.4%, and that of multifactorial dyslipidaemia ranges from 7.1 to 9.4% [3]. Screening is widely implemented to detect and treat diseases early, with the ultimate goal of preventing severe outcomes such as mortality. However, several randomized controlled trials conducted in adults have shown that many screening programs are ineffective in this regard [4–7], and no randomized trials have evaluated the effects of lipid screening on long-term outcomes in children and young people.

There are different recommendations for lipid screening in children and adolescents. The National Heart, Lung, and Blood Institute (NHLBI) recommends universal lipid screening once in children aged 9– to 11 years and again when they are 17– to 21 years old to identify those with elevated lipid levels, especially those with familial hypercholesterolemia. Selective lipid screening is recommended for children aged 2 to 8 years and those aged 12 to 16 years if they have risk factors such as a family history of cardiovascular diseases or dyslipidaemia, diabetes, hypertension, a body mass index (BMI)≥85th percentile, and smoking cigarettes [1]. The American Academy of Pediatrics also recommends a selective screening strategy [8]. In contrast, the USPSTF guidelines [2, 9, 10] have consistently suggested that there is insufficient evidence for universal lipid screening in asymptomatic children and adolescents aged≤20 years and that whether to order a lipid screening test for young patients is at the discretion of clinicians [2]. Given the discrepancy of recommendations by different entities, it is of interest to know the actual rate of lipid screening in children and young people. This information can serve as a basic parameter in analyses of the utilization and cost-effectiveness of health care services.

The screening rates reported by previous studies varied considerably from 2 to 46.8% [11–18]. Older age, overweight or obesity, nonwhite ethnicity, and the presence of some comorbidities have been reported to be associated with higher screening rates [3, 11–13]. However, most of the previous studies were based on electronic health records or insurance claims data from one or several states [13–17]. Furthermore, some studies included only well-child visit records [12, 14, 16, 18] or focused on 9- to 11-year-old children [11, 14–16]. These issues undermined their representativeness of the national population of children and young people, particularly the older children within this population, among whom the prevalence rates of overweight/obesity and dyslipidaemia are higher [19–21].

Therefore, this study was conducted to evaluate the nationwide prevalence of lipid screening among 16- to 21-year-old young people in the US. As a secondary objective, the factors associated with the uptake of lipids in this population were also explored. The novelty of this study, compared with previous studies, lies in the age range of the study participants, which was less examined, and the national representativeness of the participants, which was rarely achieved.

Methods
Study design and population
This was a cross-sectional study based on data from the National Health and Nutrition Examination Survey (NHANES). The NHANES is a national survey that collects data every 2 years. A complex, multistage and probability sampling strategy is adopted to make the data representative of noninstitutionalized US civilians. The data can be downloaded directly from the NHANES website for free. The sample for the present study was selected from those who participated in any of the four NHANES cycles conducted from 2013–March 2020 before the pandemic. All participants between 16 and 21 years of age were eligible to be included in the study population. Because the questions about lipid screening ("BPQ080" and "BPQ060") were only asked of those who were aged 16 years or above since 2013, those under 16 years old were not considered in this study. The oldest age recommended for lipid screening in the current guidelines is 21 years [1, 2, 8], and the vast majority of previous studies did not include participants above 21 years of age; therefore, the upper age limit was set at 21 years in this study. The participants who did not answer the two questions were also excluded. NHANES was approved by the National Center for Health Statistics ethics review board, and written informed consent was obtained from all participants or their parents or guardians. This study was approved by the Survey and Behavioural Research Ethics Committee of The Chinese University of Hong Kong (reference no. SBRE-23-0967).

Measurements of lipid screening uptake
The questions about lipid screening history in the NHANES interviews included "Have you ever been told by a doctor that your blood cholesterol level was high?" (question BPQ080) and "Have you ever had your blood cholesterol checked?" (question BPQ060). Those who answered "Yes" to question BPQ080 were not asked question BPQ060. The participants who answered

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"Yes" to either of the two questions were considered "ever received lipid screening". For these people, their responses to "How long has it been since you last had your blood cholesterol checked?" (question BPQ070) were also analysed and reported in this study.

Measurements of covariates

The following factors were collected from the NHANES and considered potentially associated with the uptake of lipid screening: age, gender, race, physical activity level, health insurance status, diagnosed hypertension, diagnosed diabetes, BMI category, and lipid profile (including total cholesterol [TC], high-density lipoprotein cholesterol [HDL-C], and non-HDL-C). Among them, BMI and lipid profiles were collected at the Mobile Examination Center, whereas the other data were self-reported by participants or their parents or guardians during the questionnaire survey.

There were four BMI categories, i.e., underweight, normal weight, overweight, and obese. The cut-off points used for defining the four categories differ between those≥20 and <20, according to the World Health Organization and the US Centers for Disease Control and Prevention [22, 23]. For those≥20, the definitions were as follows: BMI<18.5 (unit: kg/m^2), underweight; 18.5≤BMI<25, normal weight; 25≤BMI<30, overweight; BMI≥30, obese. For those under 20, the BMI categories were age- and sex-specific and were expressed as percentiles: <5th percentile, underweight; 5th to 85th percentile, normal weight; 85th to 95th percentile, overweight; and ≥95th percentile, obese. For those under 20 years, the BMI categories they fell into could be obtained directly from the response to the question BMDBMIC in the NHANES, whereas for those≥20 years, the original values of BMI were provided by the NHANES dataset and were divided into different categories by the authors of this study according to the abovementioned definitions.

According to the recommendations of the Physical Activity Guidelines for Americans and the World Health Organization [24, 25], children and adolescents aged 5–17 years should perform at least 60 min of moderate-to-vigorous physical activities per day, whereas adults aged 18–64 years should perform at least 150 min of moderate-intensity or 75 min of vigorous-intensity or an equivalent combination of moderate- and vigorous-intensity physical activities per week. For those under 18 years of age, physical activities were categorized into "sufficient" (7 days of ≥60 min of moderate-to-vigorous physical activities during the past week) or "insufficient" (less than 7 days of ≥60 min of moderate-to-vigorous physical activities during the past week) directly based on their reporting. For those aged 18 years or above, first, the suggested metabolic equivalent (MET) scores from the NHANES were used to calculate their weekly physical activity level, which was equal to the "suggested MET × weekly frequency × minutes of each physical activity" [26, 27]. The physical activity level was then categorized into "sufficient" (≥600 MET-minutes/week) or "insufficient" according to the World Health Organization standards [25].

The data on low-density lipoprotein cholesterol and triglycerides were available for less than half of the study population in the NHANES, whereas those on TC and HDL-C were available for approximately 90% of the study population. Therefore, only TC, HDL-C, and non-HDL-C (defined by TC minus HDL-C) were included as covariates in this study. For those aged 19 years or younger, according to the National Cholesterol Education Program Expert Panel on Cholesterol Levels in Children and NHLBI report [1, 28], HDL-C>40 mg/dL was considered "normal" and ≤40 mg/dL was considered "low"; TC<200 mg/dL was considered "normal" and ≥200 mg/dL was considered "high"; and non-HDL-C<145 mg/dL was considered "normal" and ≥145 mg/dL was considered "high". For those aged 20 years or above, according to the NHLBI report [1], TC<225 mg/dL was considered "normal" and ≥225 mg/dL was considered "high"; non-HDL-C<190 mg/dL was considered "normal" and ≥190 mg/dL was considered "high"; and the cut-off point for HDL-C was the same as that for those≤19 years of age.

A family history of diseases, education level, smoking status, and drinking status may also be associated with the use of lipid screening. However, in the NHANES, questions about the family history of young people focused on diabetes only and did not include dyslipidaemia or cardiovascular diseases. The questions about education level were only asked to those aged 20 years or above. The data concerning young people's smoking and drinking status can only be accessed on site through the Research Data Center of the National Center for Health Statistics. Therefore, these covariates were not included in this study.

Data analysis

For each variable, the frequencies and percentages are presented. The prevalence of lipid screening was calculated for each cycle as well as for all four cycles combined. The appropriate sample weight was applied to combine different cycles according to the analysis guidelines of the NHANES. Binary logistic regression analysis was conducted to explore the factors that may be associated with the use of lipid screening. Both unadjusted and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported for each covariate. In the multivariable regression analysis, all the covariates mentioned above were included in the model. The potential

multicollinearity among TC, HDL-C, and non-HDL-C was examined by variance inflation factors, which were 1.10, 1.91, and 1.99, respectively, far below the widely adopted rule-of-thumb cut-off of 10. Thus, it was considered appropriate to include the three lipid measures in the same model. All the statistical analyses were performed with SAS v9.4 (SAS Institute, Cary, North Carolina), with a *P* value < 0.05 indicating statistical significance.

Results

Characteristics of the study population

A total of 44,960 people participated in the four NHANES cycles between 2013 and March 2020. Among them, 3,600 participants aged 16– to 21 years answered questions BPQ080 and/or BPQ060 and were thus included in the estimation of the prevalence of lipid screening. The numbers of participants from the 2013–2014, 2015–2016, 2017–2018, and 2017–March 2020 cycles were 901, 753, 735, and 1211, respectively. The characteristics of the participants are presented in Table 1. The weighted proportions of participants were similar across different ages and genders. Approximately half of the participants were non-Hispanic white, and more than 80% of them were covered by health insurance. The weighted percentages of overweight/obese, diagnosed hypertension, diagnosed diabetes, high TC, and high non-HDL-C individuals were 42.44%, 3.68%, 0.79%, 6.90%, and 7.46%, respectively.

Prevalence of lipid screening uptake

Among the 3,600 eligible participants, 1,178 reported a history of lipid screening when they participated in the survey, and the weighted prevalence was 32.02%. The weighted prevalences were 30.79% for 2013–2014, 33.10% for 2015–2016, 30.65% for 2017–2018, and 33.74% for 2017–March 2020 (*P* for trend: 0.97). Among the 1,178 participants with a history of lipid screening, 449 (weighted prevalence 11.53%) were screened "less than 1 year ago", 353 (9.27%) were screened "1 year but less than 2 years ago", 287 (8.03%) were screened "2 years but less than 5 years ago", and 71 (2.70%) were screened "5 years or more ago"; the other 18 (0.49%) did not recall this information.

Associations between lipid screening uptake and covariates

The univariable analysis revealed that all covariates were associated with the use of lipid screening (Table 2). However, multivariable regression analysis, which included 3,282 participants with complete data on all covariates, revealed that only ethnicity, health insurance status, BMI category, and physical activity level were significantly associated with the use of lipid screening. Specifically, non-Hispanic black people (adjusted OR: 1.43; *P* = 0.007;

non-Hispanic white people as the reference), people with health insurance (adjusted OR: 1.54; *P* < 0.001; people without health insurance as the reference), obese people (adjusted OR: 1.65; *P* < 0.001; normal weight people as the reference) and people with sufficient physical activity (adjusted OR: 1.36; *P* = 0.01; people with insufficient physical activity as the reference) were more likely to have a history of lipid screening uptake.

Discussion

This study evaluated the nationwide prevalence of lipid screening in young people aged 16– to 21 years in the US. Nearly one-third of this population had ever received lipid screening, and 28.83% had received lipid screening in the past 5 years. Non-Hispanic black ethnicity, having health insurance, obesity (BMI ≥ 30), and sufficient physical activity were associated with a greater chance of ever receiving lipid screening.

The prevalence of lipid screening in this study was higher than those reported by most previous studies (2–27.2%) [11–17], which might be explained by several factors. First, this study was based on a nationally representative sample, whereas previous studies mostly used electronic health records (EHRs) or insurance claims data from one or several states in the US [11–18]. Furthermore, some studies analysed well-child visit records only [12, 14, 16, 18], which may have led to underestimation of the prevalence. Second, the present study focused on young people aged 16– to 21 years, whereas previous studies focused mostly on younger populations, especially 9- to 11-year-old children [11, 14–16]. As some health problems (e.g., obesity) that may prompt the use of lipid screening are more prevalent in older adolescents [19], it is not surprising that the prevalence of lipid screening was higher in the present study. This finding was consistent with those of previous studies, which showed that older age is associated with a greater likelihood of receiving lipid screening [3, 11–13, 29]. The third possible reason was that in the present study, "lipid screening" included any such screening ever received by participants, whereas previous studies mostly counted the screening received within particular age ranges (e.g., 9–11 years) only. The two have slightly different implications.

Our finding that non-Hispanic black people were more likely to have their blood lipids checked is consistent with the findings of previous studies [3, 14, 15]. One possible explanation for this finding is that the obesity rate is significantly higher in non-Hispanic black youth [19]. As it is well known to the general public that obesity increases the risk of high blood cholesterol, those with a higher incidence of obesity (i.e., non-Hispanic black people) are more likely to have their blood lipids checked, as evidenced by our analysis (Table 2). The findings concerning

Table 1 Characteristics of participants stratified by history of lipid screening uptake

Characteristics	Total (n = 3600)	Lipid screening uptake	
		Screened (n = 1178)	Never screened (n = 2422)
	n (weighted %)	n (weighted %)	n (weighted %)
Age			
16	786 (19.19)	234 (15.81)	552 (20.79)
17	707 (16.76)	190 (14.39)	517 (17.87)
18	707 (16.75)	251 (17.67)	456 (16.32)
19	658 (14.77)	230 (15.30)	428 (14.53)
20	392 (17.23)	147 (19.00)	245 (16.40)
21	350 (15.29)	126 (17.83)	224 (14.09)
Gender			
Male	1770 (49.81)	558 (49.08)	1212 (50.15)
Female	1830 (50.19)	620 (50.92)	1210 (49.85)
Ethnicity			
Non-Hispanic white	1060 (52.43)	306 (49.17)	754 (53.96)
Non-Hispanic black	827 (13.59)	302 (16.29)	525 (12.32)
Non-Hispanic Asian	419 (5.32)	139 (5.63)	280 (5.17)
Mexican American	705 (15.72)	213 (14.98)	492 (16.07)
Other Hispanic	347 (7.82)	123 (8.65)	224 (7.43)
Other races, including multiracial	242 (5.13)	95 (5.29)	147 (5.05)
Health insurance			
Not covered	642 (16.85)	176 (13.69)	466 (18.33)
Covered	2958 (83.15)	1002 (86.31)	1956 (81.67)
BMI category			
Normal weight	1752 (51.68)	490 (46.17)	1262 (54.25)
Underweight	177 (5.89)	54 (4.73)	123 (6.42)
Overweight	643 (19.63)	209 (20.60)	434 (19.17)
Obese	796 (22.81)	337 (28.50)	459 (20.15)
Physical activity level			
Insufficient	1875 (47.45)	551 (41.70)	1324 (50.16)
Sufficient	1713 (52.55)	623 (58.30)	1090 (49.84)
Diagnosed hypertension			
No	3467 (96.32)	1121 (95.45)	2346 (96.73)
Yes	133 (3.68)	57 (4.55)	76 (3.27)
Diagnosed diabetes			
No	3571 (99.21)	1166 (98.64)	2405 (99.49)
Yes	29 (0.79)	12 (1.36)	17 (0.51)
HDL-C level			
Normal	2540 (73.83)	809 (74.37)	1731 (73.58)
Low	896 (26.17)	308 (25.63)	588 (26.42)
TC level			
Normal	3168 (93.10)	1012 (91.49)	2156 (93.86)
High	268 (6.90)	105 (8.51)	163 (6.14)
Non-HDL-C level			
Normal	3126 (92.54)	989 (90.54)	2137 (93.47)
High	310 (7.46)	128 (9.46)	182 (6.53)

Abbreviations: BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol

health insurance status and BMI category are consistent with those of most previous studies [3, 11–13, 29]. It is easy to understand that people covered with health insurance are more likely to receive lipid screening and other health checkups because the insurance can cover some of or all the bills. Given that people with sufficient physical activity are more likely to receive lipid screening, these people may be more health conscious and thus more willing to take any potentially beneficial actions to improve or maintain their health.

Table 2 Associations between covariates and the use of lipid screening

Variable	Univariable model		Multivariable model	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Age				
≤ 19	1.00 (ref.)		1.00 (ref.)	
> 19	1.329 (1.327, 1.332)	< 0.001	1.266 (0.959, 1.670)	0.09
Gender				
Male	1.00 (ref.)		1.00 (ref.)	
Female	1.044 (1.042, 1.045)	< 0.001	1.036 (0.802, 1.337)	0.78
Ethnicity				
Non-Hispanic white	1.00 (ref.)		1.00 (ref.)	
Non-Hispanic black	1.451 (1.448, 1.455)	< 0.001	1.432 (1.106, 1.855)	0.007
Mexican American	1.022 (1.020, 1.025)	< 0.001	0.982 (0.732, 1.317)	0.90
Other races*	1.216 (1.213, 1.219)	< 0.001	1.227 (0.932, 1.615)	0.14
Health insurance				
Not covered	1.00 (ref.)		1.00 (ref.)	
Covered	1.416 (1.412, 1.419)	< 0.001	1.541 (1.213, 1.958)	< 0.001
BMI category				
Normal weight	1.00 (ref.)		1.00 (ref.)	
Underweight	0.866 (0.862, 0.869)	< 0.001	0.904 (0.622, 1.313)	0.59
Overweight	1.263 (1.260, 1.265)	< 0.001	1.250 (0.941, 1.660)	0.12
Obese	1.662 (1.658, 1.665)	< 0.001	1.653 (1.276, 2.140)	< 0.001
Physical activity level				
Insufficient	1.00 (ref.)		1.00 (ref.)	
Sufficient	1.407 (1.405, 1.410)	< 0.001	1.362 (1.071, 1.732)	0.01
Diagnosed hypertension				
No	1.00 (ref.)		1.00 (ref.)	
Yes	1.409 (1.403, 1.415)	< 0.001	1.122 (0.692, 1.818)	0.64
Diagnosed diabetes				
No	1.00 (ref.)		1.00 (ref.)	
Yes	2.677 (2.653, 2.701)	< 0.001	2.768 (0.530, 14.444)	0.22
HDL-C level				
Normal	1.00 (ref.)		1.00 (ref.)	
Low	0.960 (0.958, 0.962)	< 0.001	0.871 (0.668, 1.135)	0.30
TC level				
Normal	1.00 (ref.)		1.00 (ref.)	
High	1.421 (1.416, 1.426)	< 0.001	1.034 (0.605, 1.766)	0.90
Non-HDL-C level				
Normal	1.00 (ref.)		1.00 (ref.)	
High	1.497 (1.493, 1.502)	< 0.001	1.314 (0.849, 2.034)	0.22

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol; ref., reference group

*: "Other races" include non-Hispanic Asian, other Hispanic except Mexican American, and other races, including multiracial

Strengths and limitations

The strength of this study is that it was based on the NHANES database, which ensures the national representativeness of the sample and, consequently, the generalizability of the results. Nevertheless, the findings of this study should be interpreted with the following issues borne in mind. First, recall bias may exist. For example, the general public may not be able to recall the exact tests or procedures they underwent during a health checkup or hospital visit. This may have led to the underestimation of the prevalence of lipid screening. Second, although attempts have been made to explore the factors potentially associated with the uptake of lipid screening, data on family history of high blood cholesterol, education level, smoking status, and drinking status were not available for most or all the participants in this study, which precluded us from examining their influence on the outcome.

Conclusions

In conclusion, this study provides an estimate of the national prevalence of lipid screening uptake in young people aged 16– to 21 years in the US. Several factors associated with screening uptake were identified. These

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findings could help people understand the current situation of lipid screening in young people in the US and may serve as basic parameters in the assessment of the utilization and cost-effectiveness of related health care services.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Author contributions
Zuyao Yang contributed to the conception, supervision and funding acquisition; Zuyao Yang and Nianyan Li developed the methodology; Nianyan Li conducted the formal analysis; Nianyan Li and Zuyao Yang wrote the original manuscript text; All authors reviewed and edited the manuscript.

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Data availability
The data utilized for this study has been deposited into a publicly available repository, which can be found on the National Health and Nutrition Examination Survey (NHANES) website: https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethical approval
The study was approved by the Survey and Behavioral Research Ethics Committee of The Chinese University of Hong Kong (reference no. SBRE-23-0967, and date of approval: 19 Jul 2024), and it was conducted in accordance with the Declaration of Helsinki.

Competing interests
The authors declare no competing interests.

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I. references

1. Expert Panel on Integrated Guidelines for Cardiovascular Health Risk Reduction in Children and Adolescents, National Heart, Lung, and Blood Institute. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: summary report. Pediatrics. 2011;128(Suppl 5):S213–56.

2. US Preventive Services Task Force; Barry MJ, Nicholson WK, Silverstein M, Chelmow D, Coker TR, et al. Screening for lipid disorders in Children and adolescents: US Preventive Services Task Force Recommendation Statement. JAMA. 2023;330(3):253–60.

3. Guirguis-Blake JM, Evans CV, Coppola EL, Redmond N, Perdue LA. Screening for lipid disorders in Children and adolescents: updated evidence report and systematic review for the US Preventive Services Task Force. JAMA. 2023;330(3):261–74.

4. Saquib N, Saquib J, Ioannidis JP. Does screening for disease save lives in asymptomatic adults? Systematic review of meta-analyses and randomized trials. Int J Epidemiol. 2015;44(1):264–77.

5. Simmons RK, Echouffo-Tcheugui JB, Sharp SJ, Sargeant LA, Williams KM, Prevost AT, et al. Screening for type 2 diabetes and population mortality over 10 years (ADDITION-Cambridge): a cluster-randomised controlled trial. Lancet. 2012;380(9855):1741–8.

6. Menon U, Gentry-Maharaj A, Burnell M, Singh N, Ryan A, Karpinskyj C, et al. Ovarian cancer population screening and mortality after long-term follow-up in the UK Collaborative Trial of Ovarian Cancer Screening (UKCTOCS): a randomised controlled trial. Lancet. 2021;397(10290):2182–93.

7. Lindholt JS, Sogaard R, Rasmussen LM, Mejldal A, Lambrechtsen J, Steffensen FH, et al. Five-year outcomes of the Danish Cardiovascular Screening (DAN-CAVAS) Trial. N Engl J Med. 2022;387(15):1385–94.

8. Committee on Practice & Ambulatory Medicine, American Academy of Pediatrics. 2024 Recommendations for Preventive Pediatric Health Care: Policy Statement. Pediatrics. 2024;154(1):e2024067201.

9. US Preventive Services Task Force. Screening for lipid disorders in Children and adolescents: US Preventive Services Task Force Recommendation Statement. JAMA. 2016;316(6):625–33.

10. US Preventive Services Task Force. Screening for lipid disorders in children: US Preventive Services Task Force recommendation statement. Pediatrics. 2007;120(1):e215–9.

11. Berger JH, Chen F, Faerber JA, O'Byrne ML, Brothers JA. Adherence with lipid screening guidelines in standard- and high-risk children and adolescents. Am Heart J. 2021;232:39–46.

12. Herrington L, Susi A, Gorman G, Nylund CM, Hisle-Gorman E. Factors affecting Pediatric Dyslipidemia Screening and Treatment. Clin Pediatr (Phila). 2019;58(5):502–10.

13. Margolis KL, Greenspan LC, Trower NK, Daley MF, Daniels SR, Lo JC, et al. Lipid screening in children and adolescents in community practice: 2007 to 2010. Circ Cardiovasc Qual Outcomes. 2014;7(5):718–26.

14. Mihalopoulos NL, Stipelman C, Hemond J, Brown LL, Young PC. Universal lipid screening in 9- to 11-Year-Olds before and after 2011 guidelines. Acad Pediatr. 2018;18(2):196–9.

15. Allen-Tice C, Steinberger J, Murdy K, Zierhut H. Pediatric cholesterol screening practices in 9- to 11-year-olds in a large midwestern primary care setting. J Clin Lipidol. 2020;14(2):224–30.

16. Valle CW, Binns HJ, Quadri-Sheriff M, Benuck I, Patel A. Physicians' lack of adherence to National Heart, Lung, and Blood Institute Guidelines for Pediatric lipid screening. Clin Pediatr (Phila). 2015;54(12):1200–5.

17. Zachariah JP, McNeal CJ, Copeland LA, Fang-Hollingsworth Y, Stock EM, Sun F, et al. Temporal trends in lipid screening and therapy among youth from 2002 to 2012. J Clin Lipidol. 2015;9(5 Suppl):S77–87.

18. DeSantes K, Dodge A, Eickhoff J, Peterson AL. Improving Universal Pediatric lipid screening. J Pediatr. 2017;188:87–90.

19. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015–2016. NCHS Data Brief. 2017;288:1–8.

20. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999–2016. Pediatrics. 2018;141(3):e20173459.

21. Kit BK, Kuklina E, Carroll MD, Ostchega Y, Freedman DS, Ogden CL. Prevalence of and trends in dyslipidemia and blood pressure among US children and adolescents, 1999–2012. JAMA Pediatr. 2015;169(3):272–9.

22. Obesity and overweight. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed 1 Aug 2024.

23. Child, Teen BMI, Categories. Aug. Centers for Disease Control and Prevention. https://www.cdc.gov/bmi/child-teen-calculator/bmi-categories.html. Accessed 1 2024.

24. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The physical activity guidelines for americans. JAMA. 2018;320(19):2020–8.

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25. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451–62.

26. Liang J, Huang S, Jiang N, Kakaer A, Chen Y, Liu M, et al. Association between Joint Physical Activity and Dietary Quality and Lower Risk of Depression symptoms in US Adults: cross-sectional NHANES Study. JMIR Public Health Surveill. 2023;9:e45776.

27. Chen L, Cai M, Li H, Wang X, Tian F, Wu Y, et al. Risk/benefit tradeoff of habitual physical activity and air pollution on chronic pulmonary obstructive disease: findings from a large prospective cohort study. BMC Med. 2022;20(1):70.

28. National Cholesterol Education Program (NCEP). Highlights of the report of the Expert Panel on blood cholesterol levels in children and adolescents. Pediatrics. 1992;89(3):495–501.

29. de Ferranti SD, Rodday AM, Parsons SK, Cull WL, O'Connor KG, Daniels SR, et al. Cholesterol Screening and Treatment Practices and preferences: a Survey of United States pediatricians. J Pediatr. 2017;185:99–105. e2.

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