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SYSTEMATIC REVIEW

Prevalence of metabolic dysfunction-associated steatotic liver disease among obese, overweight, and at-risk children and adolescents in Türkiye: A meta-analysis

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Points to Note

- **Synthesis of Current Evidence:** Pediatric MASLD prevalence among overweight/obese and at-risk children in Türkiye is high (44.6%), with a higher pooled prevalence in boys.
- **Major Controversies:** Substantial heterogeneity, reliance on ultrasonography, and inclusion of mainly high-risk populations limit generalizability to all children in Türkiye.
- **Future Directions:** Population-based epidemiological studies and improved pediatric screening strategies using reliable non-invasive methods are needed.

ABSTRACT

Background and Aim: Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly non-alcoholic fatty liver disease (NAFLD), is the most common chronic liver disease worldwide. Among children, the overall prevalence of MASLD is estimated at around 7%, and early manifestation is associated with a more severe prognosis. Despite this growing burden, no systematic analysis of pediatric MASLD prevalence in Türkiye has yet been conducted. Here, we aimed to estimate the pediatric MASLD prevalence among children with specific conditions in Türkiye.

Materials and Methods: A comprehensive literature search was conducted for studies published in English and/or Turkish between 2005 and 2023 using the databases MEDLINE, PubMed, EMBASE, and ULAKBIM. The search strategy included the following terms: "Türkiye AND NAFLD AND Pediatric" and "Türkiye AND NAFLD AND Prevalence AND Children AND Adolescent." The studies identified through this literature review were incorporated into the meta-analysis, which included either obese/overweight or at-risk children or adolescents with specific conditions such as increased transaminases.

Results: The pooled overall prevalence of MASLD was estimated as 44.6% (95% confidence interval [CI]: 39.5–49.7) among at-risk children and adolescents. Heterogeneity among studies was considerable, with an I2 value of 96%, indicating substantial variability. Subgroup analysis showed a pooled prevalence of 54.9% in boys (95% CI: 48.6–61.1) and 41.2% in girls (95% CI: 35.6–46.9). Regionally, the prevalence was 49.0% (95% CI: 41.2–57.1) in the Marmara and Aegean regions, and 42.2% (95% CI: 35.3–49.1) in the Black Sea, Mediterranean, and Central Anatolian regions.

Conclusion: The results of this study indicate a markedly high prevalence of MASLD among at-risk children and adolescents. These findings should serve as an alert for policymakers to adapt healthcare strategies aimed at preventing childhood obesity and MASLD.

Keywords: Adolescent, fibrosis, MASH, metabolic dysfunction-associated steatotic liver disease, non-alcoholic fatty liver disease, non-alcoholic steatohepatitis, pediatric.

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Introduction

Metabolic dysfunction-associated steatotic liver disease (MASLD), formerly known as non-alcoholic fatty liver disease (NAFLD), is the most prevalent chronic liver condition worldwide, affecting approximately 30% of the adult population.[1] MASLD is a significant public health concern not only among adults but also in children and adolescents – a trend that reflects the growing global obesity pandemic affecting younger populations as well.[2] Notably, not all children with obesity are expected to develop MASLD. It is estimated that approximately one-third of obese boys and one-quarter of obese girls are affected by the condition.[2] A meta-analysis estimated the overall prevalence of MASLD among children to be 7.6%, with rates exceeding 35% among those with obesity.[3] Childhood MASLD is associated with higher rates of comorbidities and a 40-fold increased risk of mortality in adulthood. These numbers are therefore highly concerning.[4] Moreover, a recent meta-analysis based on biopsy-confirmed cases reported pooled prevalence rates of 60% for metabolic dysfunction-associated steatohepatitis (MASH), 31% for significant fibrosis (FIB), and 12% for advanced fibrosis among pediatric MASLD patients, figures that approach the burden observed in adult populations.[5]

Despite the overall scarcity of data on pediatric MASLD, the evidence from Türkiye is particularly limited. To date, no systematic analysis has been conducted to determine the prevalence of MASLD among children and adolescents in the country. However, understanding this prevalence is essential for developing effective screening and treatment strategies aimed at preventing complications from an early age. Therefore, the aim of this meta-analysis was to estimate the prevalence of pediatric MASLD among either obese/overweight or at-risk children or adolescents with specific conditions, such as increased transaminases in Türkiye, and to examine its regional distribution.

Patients and Methods

Data Collection

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[6] A comprehensive literature search was performed for studies published in English and/or Turkish using the databases MEDLINE, PubMed, EMBASE, and ULAKBIM (Turkish medical index). The following search terms were used: "Türkiye AND NAFLD AND Pediatric" and "Türkiye AND NAFLD AND Prevalence AND Children AND Adolescent." All identified articles were reviewed, and the reference lists of included studies were examined to identify additional relevant publications. These additional sources were retrieved either manually or through subsequent electronic searches.

The meta-analysis covers studies published between 2005 and 2023. The primary inclusion criterion was the availability of a MASLD diagnosis. We used MASLD and NAFLD interchangeably, as the two terms have near-complete overlap and are globally accepted as synonymous.[7] To avoid duplication, we carefully screened for overlapping data by cross-checking study periods, sample sizes, study locations (e.g., centers or hospitals), and author names. We extracted the following data once the study was included: study author and year, study setting/region, type of diagnostic method, age (age-group), number tested (boy/girl), and number positive (boy/girl). Two authors (MT and CK) checked all studies used in the analysis. Eligible studies were observational studies, including cross-sectional, retrospective, and clinic- or hospital-based studies that enrolled children or adolescents and reported extractable data on MASLD/NAFLD prevalence. Studies were excluded if they were adult-only studies; reviews, editorials, letters, case reports, or conference abstracts without sufficient data; did not provide a clear MASLD/NAFLD diagnosis; did not report extractable numerator and denominator data; or represented duplicate reports or likely overlapping study populations. When multiple reports from the same center appeared to include overlapping populations, we retained the most complete or most relevant dataset based on study period, sample size, setting, and available outcome data. Interventional studies in which participants were selected due to treatment allocation rather than prevalence ascertainment, as well as studies with methods not comparable with the included observational studies, were also excluded.

The studies focused on children with specific conditions, including obesity or overweight, elevated transaminases, and polycystic ovary syndrome. Children and adolescents were considered overweight if their body mass index was between the 85th and 95th percentiles for their age and sex, and obese if it was at or above the 95th percentile.[8]

Statistical Analysis

Data were analysed using MetaXL version 5.3 software, an add-in for meta-analysis in Microsoft Excel for Windows (https://www.epigear.com/index_files/metaxl.html). A random-effects model using the DerSimonian–Laird method was applied to estimate the pooled prevalence and corresponding 95% confidence intervals (CIs), accounting for both within- and between-study variability. Where data permitted, pooled prevalence estimates were also stratified by region. For regional analysis, the following groupings were used: Region A (Marmara and Aegean) representing Western Türkiye; Region B (Black Sea, Central Anatolia, and Mediterranean) representing Central Türkiye; and Region C (Eastern and Southeastern Türkiye), based on geography, population size, and socioeconomic characteristics. Due to the limited number of studies available from Region C, pooled prevalence estimates were calculated only for Regions A and B. To account for the potential sources of heterogeneity in the data, we used two types of statistical models: A random-effects model and a quality effects model. The quality effects model allowed us to examine the effects of study quality on the prevalence estimate independently of other covariates, while the random-effects model accounted for both within-study and between-study heterogeneity and provided an estimate of the average effect size across studies. The quality effects model uses a quality score (Supplementary Table 1), which is essential as a safeguard score (risk of bias instrument). We scored each study that was used for the meta-analysis (Supplementary Table 2).

To explore whether prevalence estimates differed by publication period, we performed an exploratory descriptive stratification of studies included in the quality-effects analysis according to year of publication. Studies were grouped into four publication periods: 2005–2009, 2010–2014, 2015–2019, and 2020–2023. Quality-effect-weighted pooled prevalence estimates were calculated for each period. Because the number of studies was uneven across periods and the included populations were heterogeneous and primarily consisted of obese/overweight or otherwise high-risk pediatric cohorts, these analyses were considered descriptive and were not interpreted as formal temporal trend analyses.

Results

The results of the search strategy and the final selection of studies are summarized in the flow diagram (Fig. 1). The electronic database search identified 57 articles, with one additional study retrieved through manual screening, resulting in a total of 58 eligible studies. Among these, 38 studies reported MASLD prevalence stratified by sex[8–45] while others did not provide sex-specific data.[46–65] The age of participants across studies ranged from 2 months to 18 years.

A total of 9,600 participants were included across the 58 studies. Of these, 56 studies comprising 9,279 participants of both sexes contributed to the primary pooled prevalence analysis, yielding an overall MASLD prevalence of 44.6% (95% CI: 39.5–49.7) (Fig. 2). The remaining two studies included exclusively one sex: one study comprised 197 obese boys and the other comprised 124 girls with polycystic ovary syndrome. These two studies were excluded from the overall pooled prevalence estimate and contributed only to the sex-specific analyses. Of the 56 included studies, 52 focused on obese/overweight children, while the remaining studies were conducted in children with specific conditions, including elevated transaminases and polycystic ovary syndrome.[26,28,47,53,63,64] Ultrasonography was employed as the diagnostic method in 100% of the studies. In addition, transient elastography was used in one study, shear-wave elastography in another, and magnetic resonance imaging–proton density fat fraction was applied in one study as complementary diagnostic methods. A total of 14 studies were identified from the Marmara region, 10 from the Aegean region, 3 from the Black Sea region, 27 from Central Anatolia, 3 from the Mediterranean region, and 1 from the Southeastern Anatolian region. The heterogeneity among studies was substantial, with an I2 value of 96%, indicating significant variability.

The pooled prevalence results from the quality effects model were comparable; see the Supplementary material for the forest plots and study quality scores (Supplementary Figs. 1a and 2a; Supplementary Tables 3a and 4a).

Of the included studies, only 38 reported sex-specific outcomes. The pooled prevalence was 54.9% in boys (95% CI: 48.6–61.1) (Fig. 3a) and 41.2% in girls (95% CI: 35.6–46.9) (Fig. 3b). The pooled prevalence results from the quality effects model were comparable; see the Supplementary material for the forest plots and study quality scores (Supplementary Fig. 1b and c; Supplementary Tables 3b and c and 4b and c).

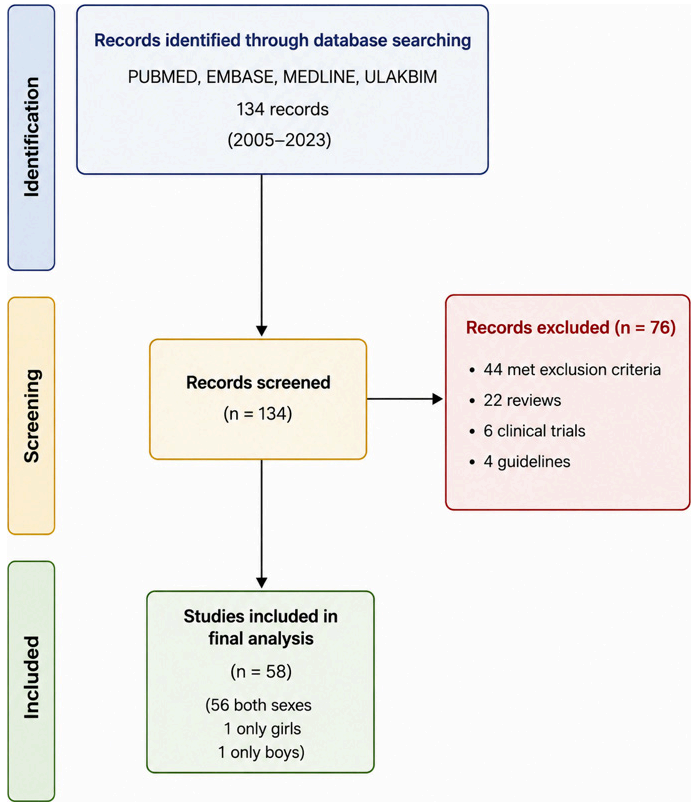


Figure 1. Literature search strategy.

Region-specific pooled prevalence was calculated for Regions A and B. The prevalence in Region A was 49.0% (95% CI: 41.2–57.1), and in Region B, 42.2% (95% CI: 35.3–49.1) (Fig. 4a and b). Due to an insufficient number of studies from Region C, a pooled prevalence estimate could not be calculated. However, a single study from this region reported a prevalence of 63.2%.[41]

In an exploratory stratification by publication period, three studies were published in 2005–2009, 24 studies in 2010–2014, 16 studies in 2015–2019, and 15 studies in 2020–2023. The corresponding quality-effect-weighted prevalence estimates were 31.2%, 43.2%, 41.4%, and 45.8%, respectively. The characteristics of the included studies according to study population and publication period are summarized in Table 1. These findings suggest broadly comparable prevalence estimates across the later publication periods, although the earliest period included only three studies.

Discussion

In this study, we reported for the first time the prevalence of MASLD among Turkish children and adolescents with obesity or specific conditions that make them at risk for MASLD. Our meta-analysis revealed a pooled prevalence of approximately 45% among predominantly overweight/obese and other at-risk children, with rates exceeding 50% in boys and with broadly comparable pooled estimates in Regions A and B. These findings underscore the alarming prevalence of MASLD in our country and its projected growing burden.

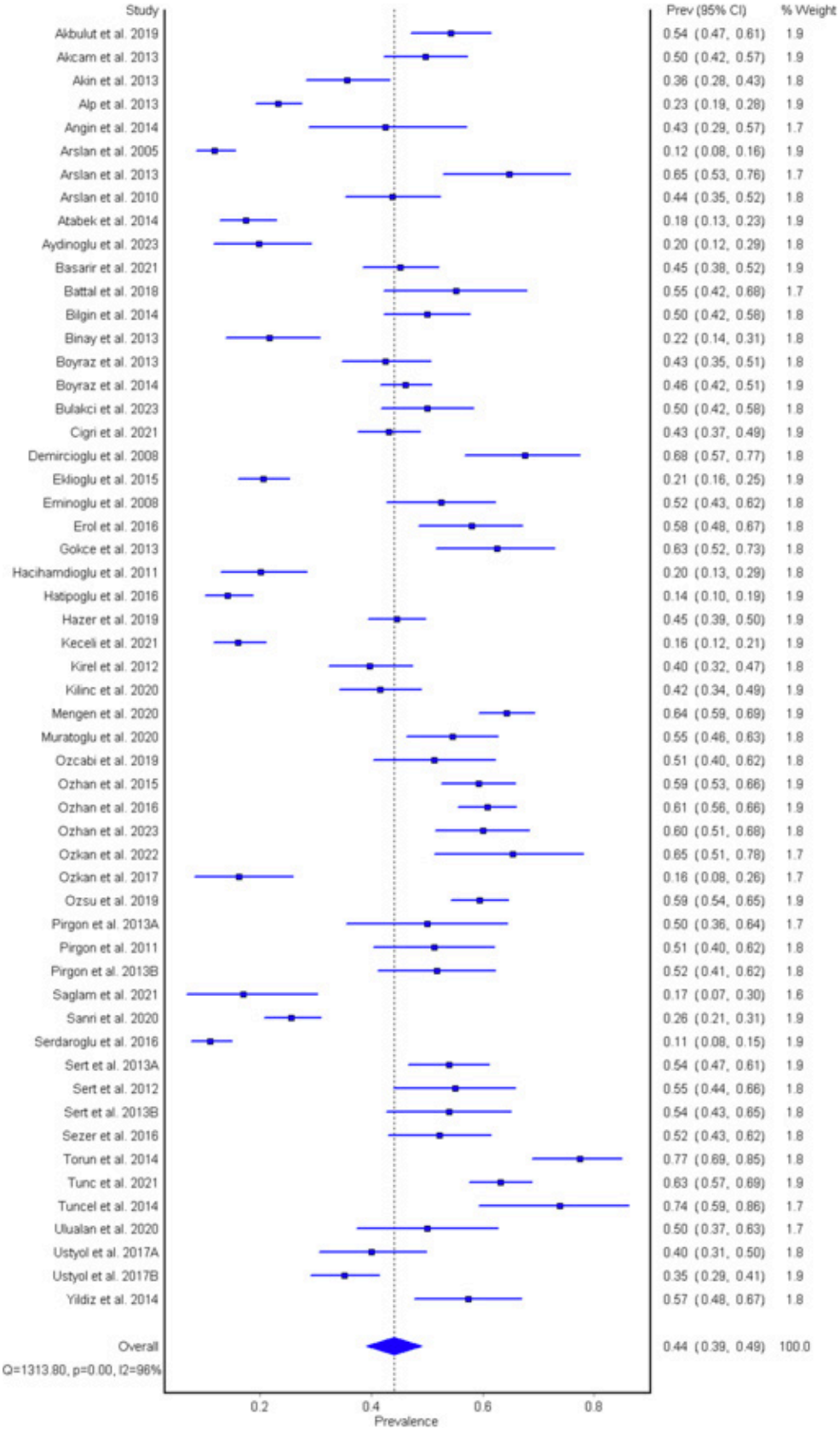
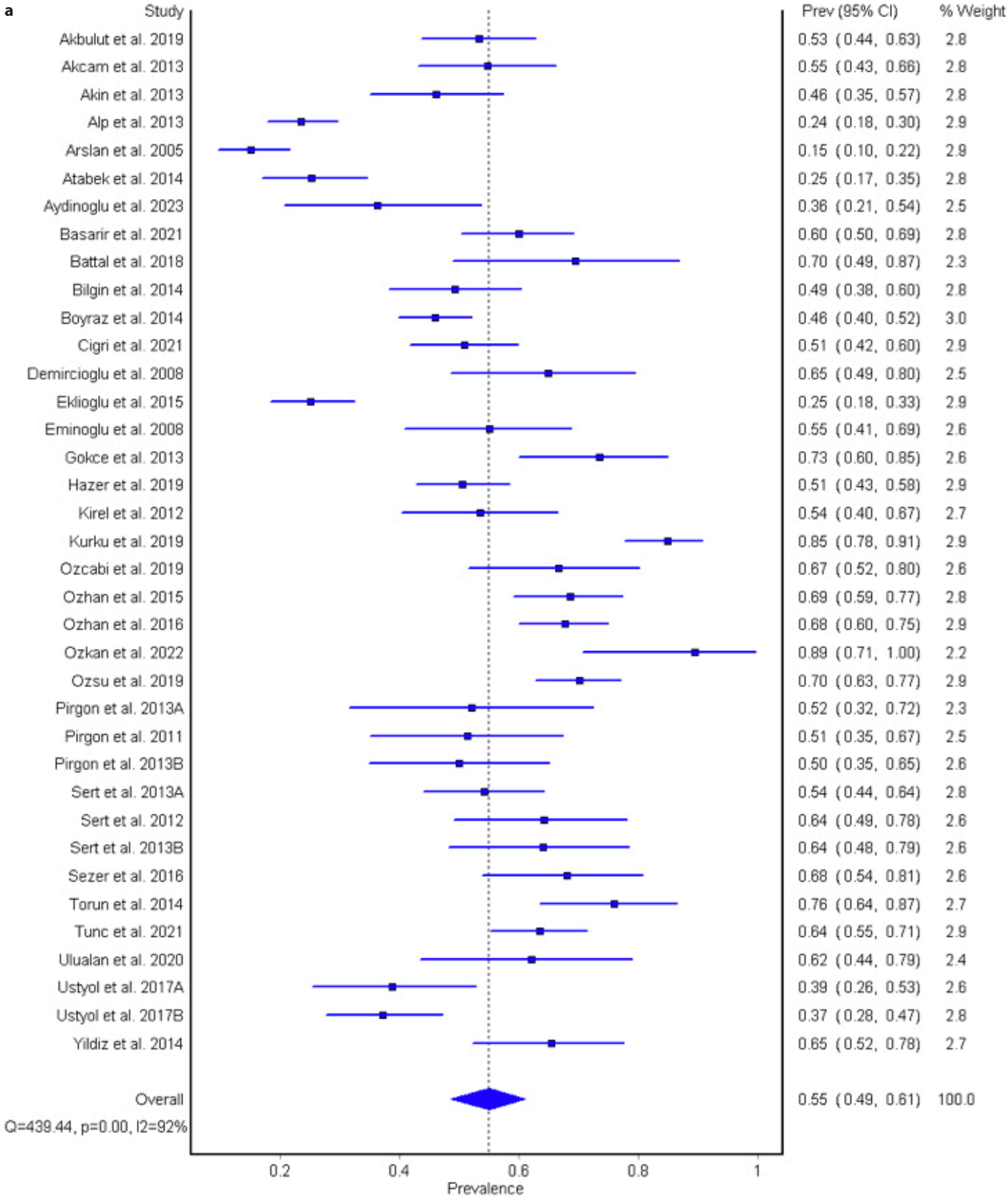


Figure 2. The pooled prevalence of pediatric metabolic dysfunction-associated steatotic liver disease across all studies.


a
Study
Prev (95% CI)
% Weight
Akbulut et al. 2019 0.53 (0.44, 0.63) 2.8
Akcam et al. 2013 0.55 (0.43, 0.66) 2.8
Akin et al. 2013 0.46 (0.35, 0.57) 2.8
Alp et al. 2013 0.24 (0.18, 0.30) 2.9
Arslan et al. 2005 0.15 (0.10, 0.22) 2.9
Atabek et al. 2014 0.25 (0.17, 0.35) 2.8
Aydinoglu et al. 2023 0.36 (0.21, 0.54) 2.5
Basarir et al. 2021 0.60 (0.50, 0.69) 2.8
Battal et al. 2018 0.70 (0.49, 0.87) 2.3
Bilgin et al. 2014 0.49 (0.38, 0.60) 2.8
Boyraz et al. 2014 0.46 (0.40, 0.52) 3.0
Cigri et al. 2021 0.51 (0.42, 0.60) 2.9
Demircioglu et al. 2008 0.65 (0.49, 0.80) 2.5
Eklioglu et al. 2015 0.25 (0.18, 0.33) 2.9
Eminoglu et al. 2008 0.55 (0.41, 0.69) 2.6
Gokce et al. 2013 0.73 (0.60, 0.85) 2.6
Hazer et al. 2019 0.51 (0.43, 0.58) 2.9
Kirel et al. 2012 0.54 (0.40, 0.67) 2.7
Kurku et al. 2019 0.85 (0.78, 0.91) 2.9
Ozcabi et al. 2019 0.67 (0.52, 0.80) 2.6
Ozhan et al. 2015 0.69 (0.59, 0.77) 2.8
Ozhan et al. 2016 0.68 (0.60, 0.75) 2.9
Ozkan et al. 2022 0.89 (0.71, 1.00) 2.2
Ozsu et al. 2019 0.70 (0.63, 0.77) 2.9
Pirgon et al. 2013A 0.52 (0.32, 0.72) 2.3
Pirgon et al. 2011 0.51 (0.35, 0.67) 2.5
Pirgon et al. 2013B 0.50 (0.35, 0.65) 2.6
Sert et al. 2013A 0.54 (0.44, 0.64) 2.8
Sert et al. 2012 0.64 (0.49, 0.78) 2.6
Sert et al. 2013B 0.64 (0.48, 0.79) 2.6
Sezer et al. 2016 0.68 (0.54, 0.81) 2.6
Torun et al. 2014 0.76 (0.64, 0.87) 2.7
Tunc et al. 2021 0.64 (0.55, 0.71) 2.9
Ulualan et al. 2020 0.62 (0.44, 0.79) 2.4
Ustyol et al. 2017A 0.39 (0.26, 0.53) 2.6
Ustyol et al. 2017B 0.37 (0.28, 0.47) 2.8
Yildiz et al. 2014 0.65 (0.52, 0.78) 2.7
Overall 0.55 (0.49, 0.61) 100.0
Q=439.44, p=0.00, I2=92%
0.2
0.4
0.6
0.8
1
Prevalence

Cont →

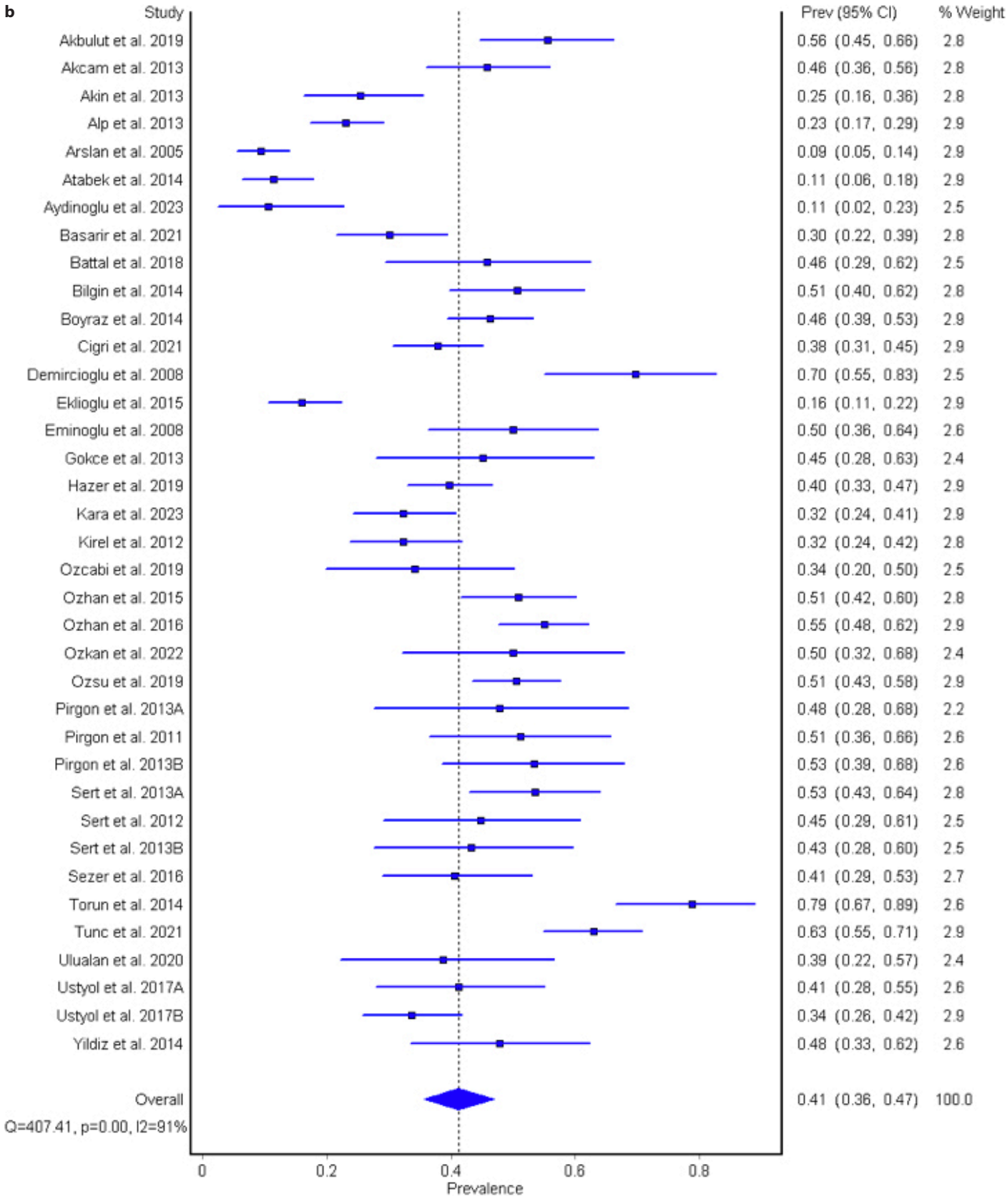
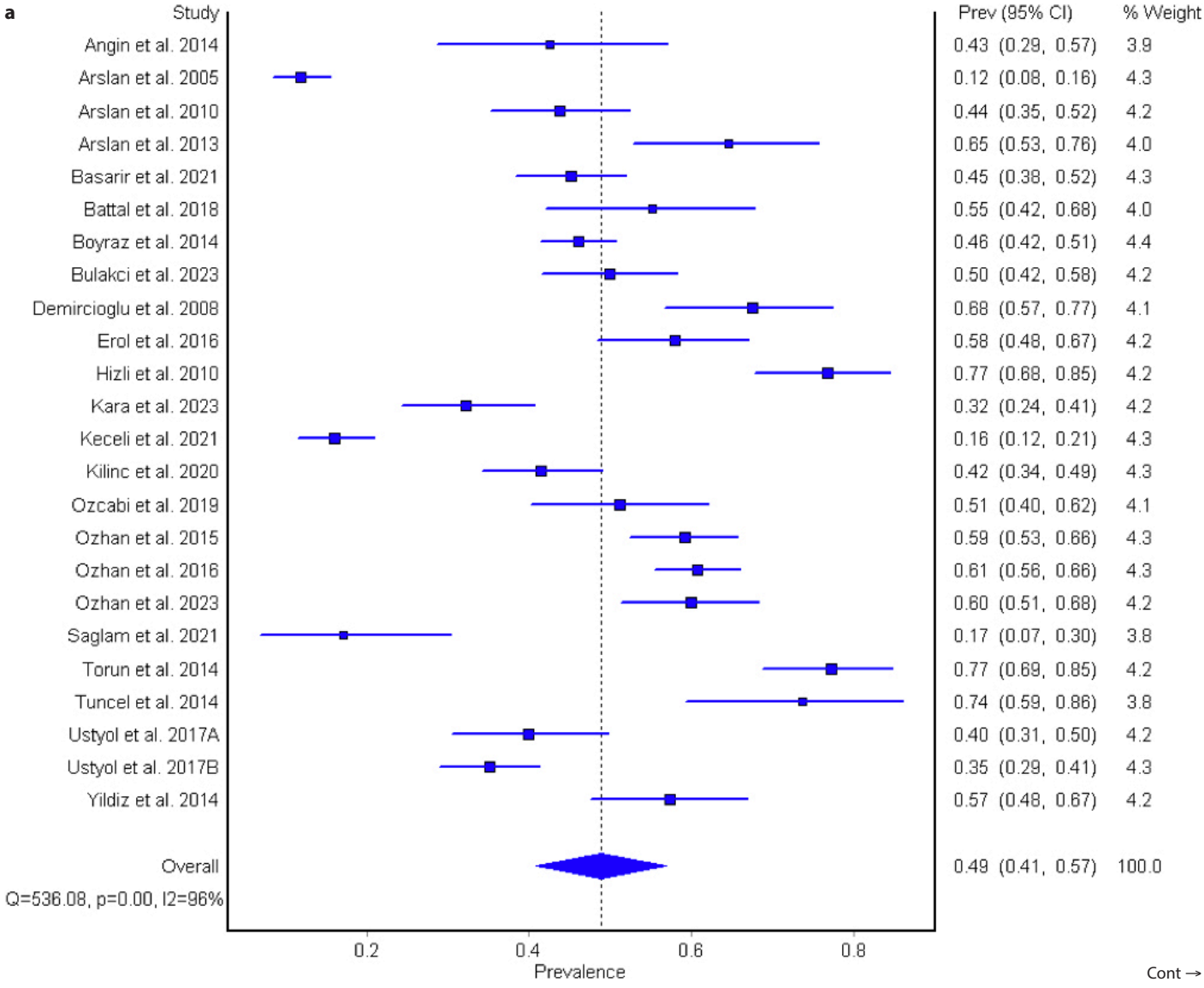


Figure 3. (a) Prevalence of pediatric metabolic dysfunction-associated steatotic liver disease (MASLD) among boys; **(b)** prevalence of pediatric MASLD among girls.



Worldwide, the prevalence of MASLD increased from 25.3% in 1990–2006 to 38.0% in 2016–2019.[1] Accumulating data from Türkiye, primarily derived from adult populations over the past decade, also consistently demonstrated a significantly high prevalence of MASLD. The most recent multicenter study, conducted mainly among patients presenting to tertiary care centers with dyspeptic complaints, reported a prevalence of 50%.[66] Another study conducted in the Central Anatolian region reported a MASLD prevalence of 60% based on ultrasonography. Remarkably, within this cohort, 40% of the participants were obese, and 36% were overweight.[67] However, the most striking prevalence rates were reported in studies conducted among apparently healthy young individuals. One study, carried out among medical students using transient elastography, which is a highly sensitive tool, demonstrated a prevalence of 23%.[68] A study conducted in a military hospital among apparently healthy young men, using ultrasonography, reported a prevalence of 10%.[69] The discrepancy between these two studies may be explained by differences in nutrition, physical activity, and the diagnostic methods used to assess hepatic steatosis.[68,69] In our study, we report an alarming prevalence of MASLD among children and adolescents, approaching the rates observed in the adult population. The higher prevalence compared with that in apparently healthy young individuals is primarily attributable to the predominance of children with obesity in our analysis. In obese patients, prevalence rates of at least 60% have been reported in Türkiye, increasing to as high as 85% with higher classes of obesity.[70] Among children with obesity, however, we found a lower prevalence of MASLD than that reported in adults. Notably, one study from 2006, which we excluded due to methodological differences, investigated the prevalence of NAFLD in children aged 2–10 years who had undergone autopsy. In that study, the prevalence was 10% among obese children and 5% among non-obese children, with an overall prevalence of 6%.[71] Given the increasing prevalence of obesity among children today, higher rates would be expected. Indeed, obesity affected <1% of the pediatric population in the 1970s, whereas today its prevalence exceeds 7% worldwide.[72]

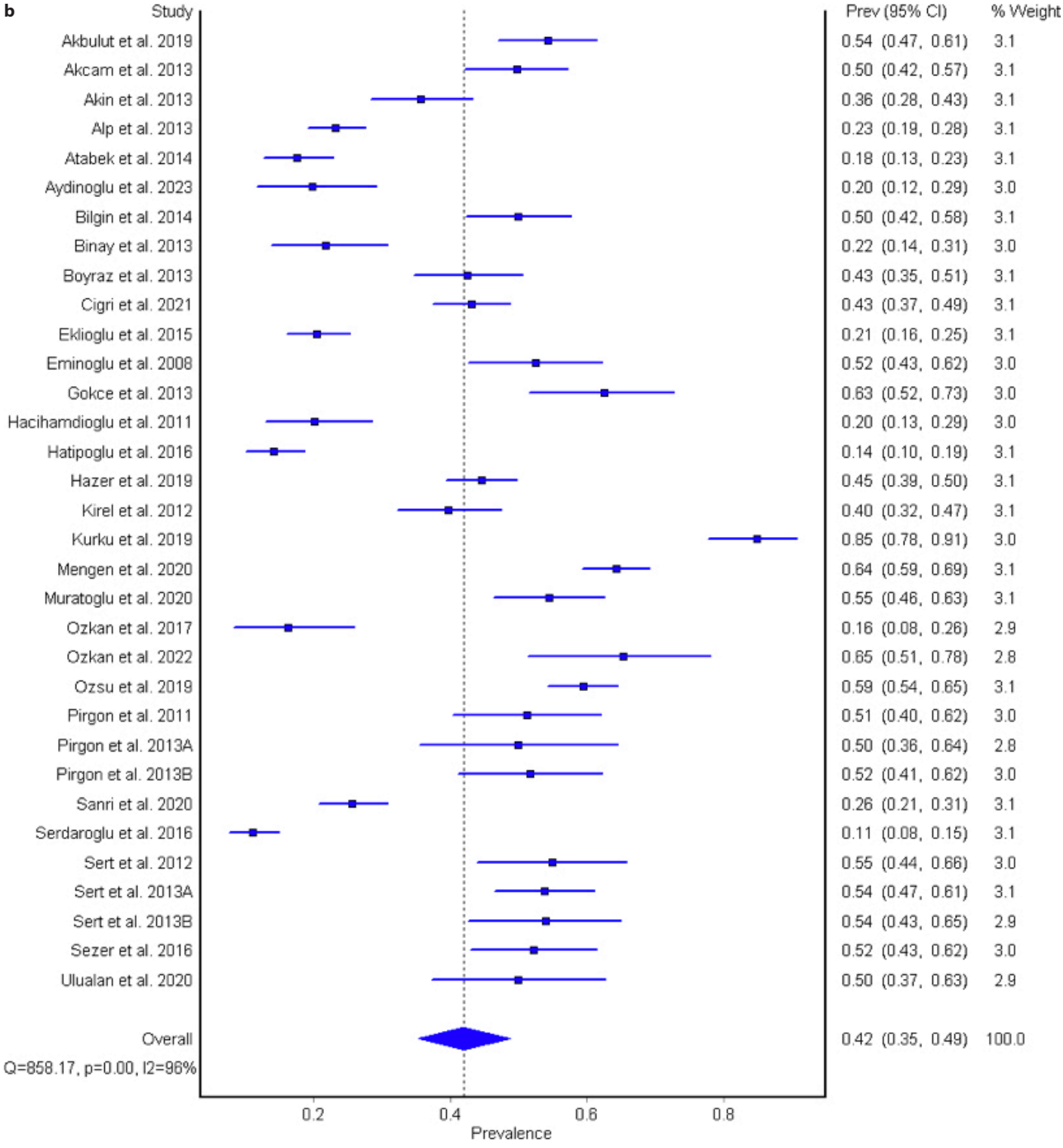


Figure 4. (a) Prevalence of pediatric MASLD in the Marmara and Aegean regions; **(b)** Prevalence of pediatric MASLD in the Black Sea, Mediterranean and Central Anatolia regions.

The metabolic burden originating in childhood often persists into adulthood and is associated with a more severe prognosis compared to acquiring these comorbidities later in life. Patients with pediatric MASLD have a significantly higher likelihood of requiring liver transplantation compared to the general population.[73,74] The trajectory may, in fact, be determined before birth, as even gestational

Table 1. Distribution of included studies and participants by population and publication period

Group	Study population	Subgroup	2005–2009		2010–2014		2015–2019		2020–2023		Total	
			Stu. (n)	Par. (n)	Stu. (n)	Par. (n)	Stu. (n)	Par. (n)	Stu. (n)	Par. (n)	Stu. (n)	Par. (n)
Group 1	Obese	—	3	503	23	3,182	14	2,568	9	1,922	49	8,175
Group 2	Overweight and obese	—	—	—	1	99	1	68	2	184	4	351
Group 3	Other/PCOS	PCOS	—	—	—	—	—	—	1	124	1	124
Group 3	Other/enzyme elevation	Enzyme elevation	—	—	—	—	1	281	3	669	4	950
Overall			3	503	24	3,281	16	2,917	15	2,899	58	9,600

Stu: Studies; Par: Participants; PCOS: Polycystic ovary syndrome. For the Other population, subgroups are displayed explicitly. Participant counts represent the total number of participants reported in the included studies within each population and publication-period category. Counts are presented as number of studies and total participants.

diabetes has been associated with an increased rate of hepatic steatosis among neonates.[75] One important finding from a large retrospective study involving more than 50,000 children identified the ages of 2–6 years as the critical period for weight gain. Beyond this window, the likelihood of obesity persisting into adulthood increases significantly.[76] In line with these data, MASLD in the pediatric age group should be screened among obese children or children at high risk with specific conditions, as indicated.[77,78] Among adults, the recommended target population for MASLD screening is largely similar to that in the pediatric population. However, in adults, the screening strategy relies on the application of the FIB-4 index, which allows for the exclusion of patients at low risk for advanced fibrosis, who can then be followed in primary care settings.[79] FIB-4 has been well validated among adult MASLD patients, including in the Turkish population, across different settings such as diabetes, obesity, and both normal and abnormal liver function profiles. Indeed, lean and morbidly obese patients appear to be less suitable for screening with FIB-4 or NAFLD fibrosis score-based algorithms. Nevertheless, the conclusion from these studies was that such scoring systems are valuable in excluding high risk for advanced fibrosis, due to their strong negative predictive value.[80–82] In contrast, screening in pediatric patients primarily relies on alanine transaminase (ALT)-based algorithms, applied in the presence of cardiometabolic risk factors or obesity, beginning at 10 years of age or earlier.[83] Such an approach may not be suitable for the pediatric population, as abnormal ALT thresholds are not universally valid across different populations. Defining what constitutes an abnormal value is therefore challenging, and this limitation may result in missing some children at high risk for MASLD.[84] At present, there is growing interest in screening children with imaging modalities. However, there is also a need for non-invasive diagnostic algorithms that can be applied in primary care settings to enable timely and targeted intervention.[83] In our meta-analysis, ultrasonography was almost universally used as the diagnostic method for MASLD. In two studies, transient elastography–based methods/algorithms were also applied. This approach may be particularly useful in children, as FibroScan is easy to perform and has higher sensitivity for detecting hepatic steatosis compared with ultrasonography. Moreover, its ability to identify increased liver fibrosis provides an important advantage in detecting children at high risk of developing severe liver-related outcomes.[68] A recent analysis of National Health and Nutrition Examination Survey data reported a MASLD prevalence of 20% among adolescents aged 12–17 years, increasing to as high as 70% in adults.[85] These findings suggest that FibroScan can also be feasibly applied in children, where its high sensitivity may allow for the detection of a greater number of cases of hepatic steatosis. Although imaging-based algorithms are associated with higher costs, the vulnerability of obese children and the projected long-term burden of untreated disease often leading to more severe outcomes in adulthood suggest that these approaches should be more strongly encouraged in pediatric practice.

Another significant challenge is the treatment of patients with MASLD, particularly regarding who should be treated and at what stage. Until recently, no pharmacological treatment options were available for MASLD. The recent approvals of resmetirom and semaglutide have opened a new era in the medical management of MASLD. For MASH, both have been approved only for adults.[86–88] However, glucagon-like peptide-1 receptor agonists are also being considered for the treatment of obesity in children aged 12 years and older.[77] A recent clinical trial conducted in children aged 6–12 years compared liraglutide with placebo, with both groups receiving lifestyle modification counseling. The study revealed that the liraglutide group achieved significant weight loss without adversely affecting development, whereas the placebo group continued to gain weight.[89] Interestingly, the success rate was even higher compared to the adolescent trial of liraglutide.[89,90] After discontinuation of the medication, weight regain remained a considerable problem, and the prospect of lifelong use of these agents in children requires careful evaluation. Nevertheless, these results indicate that intervening in childhood obesity as early as possible enhances treatment effectiveness and reduces the burden in adulthood, including the risk of MASLD.

This study should be interpreted in light of its strengths and limitations. To the best of our knowledge, this is the first meta-analysis to demonstrate the burden of MASLD among Turkish children and adolescents. We were able to include a large number of studies spanning a considerable period of time. However, all included studies were conducted in children and adolescents with specific conditions such as obesity and increased transaminases. Therefore, the prevalence of MASLD in the general pediatric population could not be

estimated. Moreover, ultrasonography was the most commonly used method for the detection of hepatic steatosis, with only a few studies employing additional methods such as transient elastography. The low sensitivity of ultrasonography for detecting mild steatosis, as well as its operator dependency and inter-observer variability, may have affected our results. Also, the high degree of heterogeneity (I2 = 96%) indicates marked clinical and methodological diversity among the included studies, including differences in patient selection, underlying risk conditions, and diagnostic approaches. Consequently, the pooled prevalence should not be viewed as a universal estimate for all children in Türkiye, but rather as a summary measure reflecting the burden of MASLD across heterogeneous at-risk pediatric populations. These findings also warrant consideration alongside additional limitations, including possible cohort overlap among included studies, group sizes potentially driven by study design rather than true prevalence, restrictions in search language and terminology, and diagnostic heterogeneity arising from the transition from the NAFLD to the MASLD nomenclature. Although we conducted an exploratory analysis by publication period, these results should be interpreted cautiously. The number of studies was uneven across periods, particularly in 2005–2009, and differences in study populations, clinical settings, and diagnostic approaches limited our ability to draw robust conclusions about temporal changes in pediatric MASLD prevalence in Türkiye.

Conclusion

This study is the first to systematically demonstrate the alarming prevalence of MASLD among overweight/obese and at-risk children and adolescents in Türkiye. This high prevalence underscores the increasing burden and severity of the disease as affected children transition into adulthood. Early intervention and timely diagnosis should therefore be critically evaluated and integrated into routine pediatric care. There is a need for epidemiological studies in the general pediatric population to better estimate prevalence and to inform the development of appropriate screening policies for children.

Online Appendix Link: https://file.paplino.com/hepatologyforum/files/1786537058-appendix-en.pdf

Ethics Committee Approval: As this study was a systematic review and meta-analysis based exclusively on previously published data, ethics committee approval and informed consent were not required.

Conflict of Interest: The authors declare no conflicts of interest.

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Peer-review: Externally peer-reviewed.

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