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Headache and Obesity in the Pediatric Population

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Abstract

Childhood obesity and headache are both significant health concerns that often have a marked impact both personally and socially, that if not addressed can carry over into adulthood. For many individuals, these effects may be magnified when obesity and headache are seen in conjunction. It is this overlap between obesity and headache in children, as well as similarities in the known mechanism of action for feeding and headache, which led to a suspected association between the two. Unfortunately, although recent studies have supported this association, only a limited number have been conducted to directly address this. Furthermore, despite rising rates of childhood obesity and headache, the associated medical comorbidities, and the significant financial cost for these conditions, there is a relative void in studies investigating treatment options that address both underlying conditions of obesity and headache in children.

Keywords

Migraine; Headache; Pediatric; Adolescents; Obesity; BMI

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Compliance with Ethics Guidelines

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Introduction

Individually, as well as collectively, obesity and headache are significant health concerns in children; both are frequently associated with marked personal and societal impact, often extending into adulthood. In the following manuscript, we first briefly review the epidemiology of childhood obesity. We then review the epidemiology of child and adolescent primary headaches, with a particular focus on migraine, a common, chronic childhood medical conditions seen in up to 28 % of the pediatric population [1]. We then review the pediatric clinical and general population data evaluating the association between obesity and headache in general, as well as with migraine and tension type headache specifically. Next, we briefly discuss the potential mechanisms for the association between obesity and headache; and conclude by discussing possible treatment strategies for overweight and obese children with headache disorders.

Epidemiology of Obesity

Obesity is a growing concern among pediatric populations. The prevalence of childhood obesity in the United States has increased from <5 % in the time period between 1963 and 1970 to over 15 % in 2008 [2, 3]. In contrast to adults, the classification of obesity by body mass index (BMI) in children is not an absolute value. (Obesity in adults is classified as a BMI ≥30). In pediatric populations, obesity, as estimated by the BMI, is classified by a range of age and sex-specific BMI cutoffs. This is due to the changing growth rates that occur during childhood. Specifically, in pediatric populations the cutoff for being overweight is defined as a BMI≥85th% for age and sex, whereas obesity is set at a BMI ≥95th% for age and sex [4, 5]. Notably, at least for the United States studies, these BMI ranges were established based on older BMI norms for both infants (birth to 36 months) and older children (2– 20 years old) [5].

In 2010, obesity prevalence was similar in girls (15 %) and boys (18 %). However, mean BMI has increased in boys, but not girls, from 1999 to 2010. Specifically, in adolescent (age 12–19) boys, the mean BMI increased from 22.9 in 1999– 2000 to a BMI of 23.8 in 2009–2010. This trend was not seen in girls or in pre-adolescent boys [6].

In addition to sex differences, racial differences in childhood obesity have also been reported. Obesity has been reported to be more prevalent in non-White children and adolescents compared with white children and adolescents, with obesity prevalence estimated at 20 %–24 % of non-Hispanic Blacks, 19 %–21 % of Mexican Americans, and 14 %–16 % in non-Hispanic Whites [6, 7].

The high prevalence of pediatric obesity is concerning due to the potential medical risks often associated with obesity, as well as the accompanying personal and societal burden. Children and adolescents who are overweight or obese tend to have a reduced quality of life compared with those who are of normal weight [8]. Furthermore, childhood obesity has been linked to multiple medical disorders in adulthood, including diabetes, cardiovascular disease, as well as mood disorders, (eg, depression) [9–11].

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Epidemiology of Primary Headache

As with obesity, headaches are incredibly common in pediatrics. In school age children under 10 years of age, the overall headache prevalence has been reported to be as high as 56 %. The prevalence increases with age such that by mid-adolescence to early adulthood the prevalence of headache can be as high as 91 % [12–17]. There are also sex-differences in headache prevalence rates in children. Overall, girls have 53 % higher odds of headache than boys (OR1.53; 95 % CI: 1.48–1.60); however, prepuberty headache is roughly as prevalent in boys as girls [17, 18].

In respect to the prevalence of specific primary headache disorders in children and adolescents, tension-type headache (TTH) is the most common primary headache disorder. Specifically, the prevalence of TTH in children ranges between 30 %–80 % by late adolescence [19–21]. In contrast, 7.7 % of children under 20 years old fulfill criteria for migraine [17]. Migraine also has been shown to exhibit age and sex-differences in children as well as an increase with age. In girls the prevalence of migraine has been reported to be 9.7 % and 6.0 % in boys [17]. In children up to 7 years old, the prevalence of migraine has been reported to be ≤3 %. However, by 11 years old the prevalence of migraine increases to 11 %; and as children pass through adolescence (approximately 13–18 years old), the prevalence increases to 23 %–28 % [1, 22–27].

Although migraine is less prevalent than TTH, it often carries a greater personal and societal impact. This is due, at least in part, to the lower quality of life that childhood migraineurs endure, with disability scores comparable with those who have childhood cancer and arthritis [28]. Childhood migraine also is associated with a substantial financial burden, with healthcare costs estimated over $11 billion per year by the World Health Organization [29].

The Epidemiologic Association Between Pediatric Obesity and Headache

In addition to adults, recent data support an association between obesity and headache disorders in children [30, 31, 32•, 33••, 35–38]. Although methodological differences exist for most of the pediatric studies examining the pediatric headache and obesity association, the weight of the data lends credence to a positive association between headache and obesity among children and adolescents.

General Population and Clinical Studies Evaluating Obesity and Headache in General

Headache in General

To the best of our knowledge, the first study to specifically examine the relationship between pediatric obesity status and headache was a cross-sectional, multi-center, clinical study conducted in 2008 by Pinhas-Hamiel et al., (Table 1). Over 270 children, (9–17 years old,) presenting to Israeli pediatric obesity and general pediatric clinics were evaluated. Of the 273 participants, 14.2 % (*n*=39) fulfilled criteria for headaches in general [32•]. Girls with obesity had a 4-fold increase in headaches (OR 3.93;95 % CI: 1.28–12.1) compared with those with a normal BMI. Although the authors reported that obese boys were not at

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increased odds of headaches (OR 2.28;95 % CI: 0.58–8.91) compared with normal weighted girls, the odds of headache in obese boys compared with normal weighted boys was not reported, thus, limiting our ability to draw meaningful conclusions about the headache-obesity association in boys in this study. Overall, the authors report that headaches were present in 7.7 % of normal weight girls, 14.8 % of overweight, and 20.3 % of obese girls (*P*= 0.04). In contrast, there was no difference in headache occur-rence in the 3 weight groups among boys (*P*=0.96) [31].

Following the Pinhas-Hamiel study, Hershey et al., conducted a retrospective, longitudinal, multi-center, clinic-based study evaluating the association between obesity and headaches in general in children, (Table 1). A total of 913 children were evaluated upon presentation to 1 of 7 pediatric headache clinics and were followed for 6 months. Obesity rates in this cohort of children (3–18 years old) were then compared with the historically reported general population obesity rates from the National Health and Nutrition Examination Survey (NHANES 2006 publication) in children of a slightly different age range, (2–19 years old) [32•]. In this study, the prevalence of obesity in the patient group (17.5 %) was similar to the historically reported prevalence in NHANES (17.1 %). The authors noted a correlation between obesity and headache frequency as well as headache-related disability. The BMI percentile significantly correlated to headache frequency, (r=0.10, *P*=0.003) and headache-related disability, (r=0.08, *P*=0.02), such that as BMI percentile increased so did the headache frequency and disability scores. Furthermore, for those who were overweight at baseline, reduced BMI at the 3-month follow-up was positively correlated with reduced headache frequency, (r=0.32, P=0.01) [32•].

In 2010 Robberstad et al., conducted the first general population study evaluating the obesity-headache association in adolescents. In this cross-sectional analysis, over 5550 adolescents (13–18 years old) in school were studied, (Table 1). The odds of having recurrent headaches were 40 % greater in those adolescents whose BMI was above the over-weight cutoff for age and sex (OR 1.4; 95 % CI: 1.2–1.6, *P* <0.0001); and seen independently in boys (OR 1.4;95 % CI: 1.1–1.8, *P*=0.01) and girls (OR 1.4; 95 % CI: 1.2–1.8, *P* <0.0001) [33••].

Chronic Daily Headache

In addition to headache in general, several recent studies have evaluated the association between obesity status and chronic daily headache (CDH) in pediatric populations. Pakalnis and Kring conducted a retrospective, cross–sectional clinic-based analysis evaluating obesity prevalence in children 5–17 years of age presenting to a headache clinic compared with historical obesity prevalence rates (NHANES 2008 publication) in children 2–19 years of age (Table 1) [34, 35]. Of the 252 participants with chronic daily headaches, 22.2 % (95 % CI: 17.1–27.4) were reported to be obese compared with the historically reported prevalence reported in the NHANES (16.3 %) [35]. Notably, it is possible that the age discrepancy between the clinical and historical populations might have contributed to this observed difference given the lower prevalence of obesity in young children compared with older children.

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Ravid et al. also reported an association between BMI and CDH in a pediatric population in 2013. The authors conducted a retrospective, cross–sectional, clinic-based study evaluating obesity status in 181 headache participants (4–18 years old), presenting to a pediatric neurology clinic (Table 1). Over-weight and obese children were reported to have more frequent headaches compared with those who were of normal weight (*P* <0.01). Specifically, for those who met criteria for CDH, 23 % were overweight or obese compared with 12 % who were of normal weight [36].

In contrast to the studies by Pakalnis and Kring and Ravid et al., an association between obesity and CDH was not demonstrated in a larger study of a Taiwanese pediatric population. In a prospective, longitudinal, general population study, Lu et al., evaluated 3342 Taiwanese students, 13– 14 years old, with episodic or no headaches (Table 1). Of note, BMI was calculated using self-reported, not measured height and weight. The relative risk of CDH was not significantly increased in those with BMI≥95th% (RR 1.58;95 % CI: 0.89–2.80) compared with those with BMI <95th% [37].

General Population and Clinical Studies Evaluating Obesity and Migraine

Several studies support an association between obesity and migraine specifically in pediatric populations. For those studies previously discussed, the study design can be reviewed above or in Table 1.

Although not specifically reported by authors, data from Pinhas-Hamiel et al.,'s study may support an association between migraine and obesity in children. It can be calculated that the prevalence of episodic migraine (EM) by weight categories in their population was as follows: 2.5 % (3/116) of normal weight children had EM vs 4.4 % (2/45) of over-weight children vs 8.9 % (10/112) of obese children, suggesting a trend although not statistically evaluated, (Table 1). In contrast, the prevalence of chronic migraine (CM) in normal, overweight, and obese children, respectively, can be calculated as 3.4 % (4/116), 6.7 % (3/45), and 0 % (0/112) [31]. The ability to draw conclusions in regard to CM in this study are, thus, limited by the small sample size in each group.

In the 2010, cross-sectional, general population study by Robberstad et al., the risk of migraine was 60 % greater in those adolescents who were overweight or obese (OR 1.6;95 % CI: 1.4–2.2, *P* <0.0001) compared with those who were normal weight (Table 1) [33••]. That same year, Kinik et al., also reported an association between obesity and migraine in a retrospective, cross–sectional, clinic-based study of 124 children presenting to a pediatric neurology clinic in Turkey with episodic migraine. Their findings supported an increasing risk of EM with increasing obesity status, (Table 1). Obese children had 5.3±2.6 (*P*=0.018) headaches per month, overweight children 4.4±2.4 headaches per month, and those of normal weight 3.6±2.2 headaches per month. No association was demonstrated between obesity status and headache severity or duration [38].

In Ravid et al.,'s 2013 retrospective, clinic-based study, in addition to headache in general, the association between obesity and migraine specifically was also evaluated, (Table 1). Migraine, (episodic and chronic migraine combined) was more prevalent in those who were obese (62.5 %; 15/24) and overweight (60.4 %; 29/48) compared with those of normal

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weight (33.9 %; 37/109), *P*=0.01. In addition, the odds of migraine were almost 2.5 fold greater in those who were overweight (OR 2.4;95 % CI: 1.2–4.7, *P*=0.01) compared with those of normal weight. A marginal association was reported in those who were obese, (OR 2.29;95 % CI: 0.95– 5.56, *P*=0.04) [36]. Furthermore, there was an almost 3–5 fold greater odds of migraine in girls who were overweight and obese compared with those of normal weight: overweight - OR 3.01;95 % CI: 1.24–7.3, *P*=0.012; obese - OR 4.93;95 % CI: 1.46-8.61, *P*=0.006). However, migraine was not increased in overweight or obese boys compared with those of normal weight: overweight - OR 1.02;95 % CI: 0.37-3.32, *P*=0.61; obese - OR 0.77;95 % CI: 0.41–4.28, P=0.56) [36].

Similarly, there was an association reported between obesity and migraine in a general population by Lu et al., in 2013. In this general population study, the risk of developing CM was addressed without evaluating EM as the focus of the study was to evaluate the incidence of CDH based on obesity status. The risk of incident CM was nearly 2.5 fold greater in those with obesity (RR 2.43; 95 % CI: 1.23–4.80, *P*=0.011) (Table 1) compared with nonobese students; and remained significant after adjustments (HR 2.41;95 % CI: 1.13–5.14, *P*=0.023) [37].

In contrast, no correlation between migraine of any frequency and obesity was found in the 2012 retrospective, clinic-based population by Pakalnis and Kring (Table 1) [35]. Specifically no significant difference in the percentage of either those with EM/probable (p) -EM who were obese (19 %;95 % CI: 15.7–22.6) or those with CM/p-CM without medication overuse who were obese (20 %;95 % CI: 12.0– 30.8) compared with historical norms for the general population who were obese (16.3 %). Furthermore, there was no significant difference in those participants having either EM/ p-EM or CM/p-CM without medication overuse who were over normal weight as a whole (overweight and obese together) (EM/p-EM: 33.5 %;95 % CI: 29.5–37.7 and CM/p-CM: 32.9 %;95 % CI: 22.8–44.4) compared with the historically reported prevalence of the general population who were over normal weight (overweight and obese) (31.9 %) [35]. Again, the age discrepancy between the clinical and historical populations might have contributed to these findings.

General Population and Clinical Studies Evaluating Obesity and TTH

The data evaluating the association between tension-type headache and obesity in the pediatric population is limited and conflicting. Two studies [33••, 35] reported an association between tension-type headache and obesity while 2 other studies [36, 37]. reported no association (Table 1). One study had mixed results with an association suggested between obesity and TTH but not between obesity and CTTH [31]. Again, for those studies previously discussed the study design can be seen above or in Table 1.

From the 2008 data presented by Pinhas-Hamiel et al., it can be calculated that 3.4 % (4/116) of those who were normal weight, vs 4.4 % (2/45) of those who were overweight vs 6.3 % (7/112) of those who were obese fulfilled TTH criteria (Table 1) [31]. These calculations suggest a possible trend toward an association between TTH and obesity, although not formally evaluated and conclusions are somewhat limited due to each group's sample size.

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In the 2010 analysis by Robberstad et al., the risk of TTH in adolescents was 40 % greater in those whose BMI was above overweight cutoff for age and sex (OR 1.4;95 % CI: 1.1–1.6, P <0.0001) compared with those whose BMI was below over-weight cutoff for age and sex (Table 1) [33••]. Pakalnis and Kring also reported in 2012 an association between chronic or probable tension type headaches in those with obesity compared with historical NHANES obesity prevalence rates (Table 1). A total of 26 % (95 % CI: 16.5–37.6) of those who had chronic or probable chronic tension type headaches were obese compared with NHANES obesity prevalence rate of 16.3 % [35]. As noted above, the age discrepancy might have contributed to this difference.

In contrast to the studies by Robberstad et al., and Pakalnis and Kring, Ravid et al.,'s 2013 study found no association between TTH and obesity status in boys (overweight: OR 1.67;95 % CI: 0.51–5.41, P=0.6; obesity: OR 2.2;95 % CI: 0.37–6.04, *P*=0.3) or girls (overweight: OR 0.50;95 % CI: 0.21–1.22, *P*=0.13; obese: OR 0.25;95 % CI: 0.07–0.95, *P*= 0.06) (Table 1) [36].

In regards to CTTH, from the data presented by Pinhas-Hamiel et al., in 2008 (Table 1), an association with obesity could not be drawn given that the prevalence of CTTH in those who were normal weight, overweight, or obese was 0.9 % (1/116), 0 % (0/45), 0.9 % (1/112), respectively [31]. This was not formally evaluated by the authors and limited due to small each group's sample size. Similarly, the risk of incident CTTH was not increased in those with obesity compared with those without obesity (RR 0.51;95 % CI: 0.12– 2.16, *P*=0.358) in Lu et al.,'s 2013 study (Table 1) [37].

Mechanisms for The Migraine and Obesity Association

While the precise mechanisms for the headache/migraineobesity association are not known, several hypotheses have been suggested [39, 40]. A detailed discussion on potential mechanisms for this association is beyond the scope of the current manuscript, we refer the reader to a recent review that has extensively discussed the potential mechanisms for this association [40]. In brief, it is hypothesized that there is extensive central and peripheral overlap in the pathways regulating feeding and those implicated in migraine. This association is demonstrated partially by hypothalamic activation and release of inflammatory neurotransmitters (eg, serotonin) and immune modulators (eg, adiponectin) implicated in obesity and migraine [30, 40]. It has also been hypothesized that lifestyle and behavioral differences may contribute to the migraine-obesity relationship. Such factors may include weight modulation from migraine medications as well as differences in diet and exercise [33••, 41, 42, 43•].

Treatment Considerations

Childhood obesity, as a potentially modifiable risk factor for headache and migraine, deserves special attention by clinicians. In the following section, we will discuss the evidence and precautions associated with treatment options directed at weight loss and their efficacy in improving headache.

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At the most basic level, physical exercise is a key weight-loss strategy and preventative measure often recommended to overweight and obese patients. However, activity has also been reported by migraineurs to be a headache trigger [44]. This concern often leads to a debate as to whether exercise is an appropriate treatment option.

In adolescents, Robberstad et al., reported in their 2010 study describe above that recurrent headaches in both girls and boys were found to be associated with inactivity (girls OR 1.2; 95 % CI: 1.0–1.4, P=0.05, boys OR 1.3; 95 % CI: 1.1–1.7, *P*=0.006) (Table 2). Furthermore, the authors suggested an association between migraine and inactivity (adjusted for age, sex, smoking, and overweight) (OR 1.5; 95 % CI: 1.0–2.2, *P*= 0.09) and noted an association between TTH and inactivity (OR 1.2; 95 % CI: 1.0–1.4, *P*=0.02) [33••].

In 2010, Milde-Busch et al., looked at the association between multiple lifestyle factors including diet and activity and headaches in adolescents (Table 2). In this general population, cross sectional analysis of German 10th and 11th graders (14–20 years old), 1260 participants completed a questionnaire that assessed multiple dietary and lifestyle factors as well as headaches. Most (*n*=1047, 83.1 %) participants had headaches in general; 129 (10.2 %) had migraine/ probable migraine, 614 (48.7 %) had TTH, 249 (19.8 %) had headaches that met criteria for both probable migraine / TTH, and 55 (4.4 %) had miscellaneous unclassified headaches. The authors noted that most types of headaches (except "miscellaneous headaches") were more prevalent in those with low physical activity compared with those with high physical activity (all headache: OR 2.0; 95 % CI: 1.3–3.1; migraine: OR: 4.2; 95 % CI: 2.2–7.9; TTH: OR 1.7; 95 % CI: 1.1–2.7; migraine+TTH: OR 2.2; 95 % CI: 1.3–3.7) after adjusting for demographic and socioeconomic factors [45].

In a 2013 Italian multicenter trial of obese adolescent migraineurs, Verrotti et al., looked at the effects of weight loss on headache outcomes over a 12 month period. Study patients (14–18 years old) had presented to a pediatric neurologic center and then participated in weight loss therapy consisting of an interdisciplinary intervention program including dietary education, physical exercise, and behavioral therapy. In the study, all participants had an initial BMI≥97 %; and those with any endocrine disorders, eating disorders, or taking any medications were excluded. BMI was reported as follows: initial, 6 months, 12 months: 32.9±4.6, 30.5±5.1, 29.9±6.0, $P<0.01$ vs initial value. Headache frequency was reported as follows: initial, 6 months, 12 months: 5.3±2.1, 2.4±1.1, 2.2± 0.9, $P<0.01$ vs initial value. Headache intensity (10 point scale) was reported as follows: initial, 6 months, 12 months: 7.4±1.7, 3.9±2.1, 4.2±2.5, $P<0.01$ vs initial value (Table 2). The authors noted that lowered BMI was significantly associated with better migraine outcomes 1 year later. Change in BMI over 1 year was correlated with the following headache outcomes in crude and adjusted analyses: headache frequency, intensity, use of acute medication, and disability as measured with PedMIDAS [43•].

In the 2009 report discussed above, Hershey et al., showed that change in BMI correlated with change in headache frequency (Table 2). The greater the reduction in BMI, the greater the reduction in headache frequency (r=0.32, $P = 0.1$); for those where not overweight to begin the trial there was no association between headache frequency and BMI change. This was not only seen at the 3-month follow-up but also the 6-month follow-up [32•].

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In addition to physical activity, diet is an integral aspect of a successful and healthy weight loss plan. However, there has been conflicting theories regarding specific dietary methods in the treatment of headaches and migraine. Although some adult studies have suggested a low fat or a low protein diet may improve migraine [46, 47], to our knowledge there has been only 1 study to look at similar such dietary measures specifically in children or adolescents [42].

In the 2010 study by Kossoff et al., the modified Atkins diet was initiated as a treatment modality for 8 adolescents (13–16 years old) with CDH. Only 3 participants completed the 3 month study, and while these participants showed weight loss (1.4 kg–8.2 kg) and reduction in PedMIDAS scores (35– 97 point reduction) they all continued to meet criteria for CDH and ultimately required pharmacologic intervention (Table 2) [42].

Outside of lifestyle modifications, medications are often used for headache and migraine management, for which there can be weight-related side effects (Table 3) [41]. Weight gain is among the most common side effects for many prophylactic medications used to treat migraines and one of the leading reasons for a patient to refuse or stop a prophylactic medication [48]. Alternatively, topiramate, which is one of the most common migraine prophylactic medications used in pediatric headache patients, has an often beneficial side effect of weight loss making it a particularly good option for those headache and migraine patients who are overweight or obese [41, 49, 50]. However, the other side that can be seen with topiramate should be taken into consideration before initiating this in children with headaches or migraines.

Conclusions

Pediatrics studies, albeit with methodological limitations, suggest that obesity is associated with headache disorders. The most robust data supports that the risk of migraine is increased in those with obesity and that this risk increases with increasing obesity status. Although less robust, there is also some support for an association between CDH and TTH and obesity.

Mechanisms for the obesity-headache/migraine association are not known. It is possible that the disorders share similar pathophysiological pathways and/or that lifestyle and behavioral factors contribute to this relationship. Limited research suggests that weight loss and physical activity can help decrease frequency and severity of headaches/migraines. To date, no data supports a specific diet for migraine prevention.

Further research on the epidemiologic association between headache disorders and obesity in children are needed. Likewise further research on treatment strategies for obese and overweight children with headaches or migraines is needed. At present, it is recommended that clinicians treating pediatric headache patients promote healthy lifestyle habits in regards to diet, exercise, and weight management, and pay particular attention to the choices of medications prescribed with regards to their effect on weight in children with headache disorders, and particularly migraine.

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•• Of major importance

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Table 1

Clinical and general population epidemiologic studies evaluating the pediatric obesity-headache association

Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
[31]	Pro, CS, Multicenter Clin Trial	Source: Obesity and Gen Ped Clinics in Israel Size: 273 BMI≥5th and <85th % : 116 BMI≥85th - <95th %: 45 BMI≥95th%: 112	Total HA participants (Any HA Type): 39 Total EM: 15 Total CM: 7 Total TTH: 13 Total CTTH: 2	61 % F Stratified	Hebrew-speaking children (specifics NR.)	13.3 (9–17)	ICHD-2	M-BMI	The OR of headaches in children 9–17 yrs of age was nearly a 4-fold increase in girls with BMI≥95th% (OR 3.93; CI: 1.28–12.1) compared with normal weighted girls. There was no reported comparison of odds of headache in obese boys to normal weighted boys in this dataset; the odds of headache in boys with BMI≥95th% (OR 2.28; CI: 0.58–8.91) was reported in relationship to normal weighted girls. The odds of EM in those across BMI categories were not reported. EM was reported in 8.9 % (10/112) of those with BMI≥95th%, 4.4 % (2/45) of those with BMI≥85th%	Excluded all with known chronic diseases and eating disorders. Excluded those receiving any medications.

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Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
									and <95th%; and 2.5 % (3/116) of those with BMI <85 P value not reported).	
[32•]	Retro, Long, Multicenter, Clin Trial compared with historically reported GP data	Source: 7 Ped HA Clinics in the US and historical NHANES data Size: initial: 913 3 mo: 213 6 mo: 174 BMI≤5th%: 20 (1) BMI≥5th – <85th %: 580 BMI≥85th <95th%: 152 BMI≥95th%: 160	Total HA participants (Any HA Type): 913 (2) Total EM: MO: 645 MA: 146 Total p-M: 40 Total TTH: 38 Total CDH: 212 CM: 204 CTTH: 8	60 % F	White 85 % Black 13 % Asian 1 % Hisp <1 %	11.9 (3–18)	ICHD-2	M-BMI	Prevalence of having a BMI≥95th% (17.5%) in pediatric headache patients was similar to the historical prevalence rates of those reported in the NHANES gen pop study (17.1 %), *P*>0.05. BMI percentile was significantly correlated to HA frequency (*P*=0.003) and disability by PedMIDAS score (*P*=0.02), such that as BMI percentile increased so did HA frequency and disability score. At 3 mos, unadjusted changes in BMI in those with BMI≥85th percentile, positively correlated to reduction of HA frequency (r=0.32, *P*=0.01).	Obesity prevalence in HA patients were compared with historically reported obesity prevalence rates in general population data from NHANES. Patients were allowed to use preventive medications.

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Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
[38]	Retro, CS, Clin Trial	Source: Ped Neuro Clinic in Turkey Size: 124 rel BMI <110 (3): 80 rel BMI≥110 and <120: 20 rel BMI≥120: 22	Total HA participants (All EM): 124 EM without aura: 88 EM with aura: 36	62 % F	NR	12.9 (4–17)	ICHD-2	M-rel BMI	17.7 % of children with EM had rel BMI≥120. Of children with EM, those with a rel BMI≥120 reported more frequent HA/mo (5.3±2.6) compared with those with a rel BMI≥110 and ±120 (4.4±2.4 HA/mo) and those with a rel BMI ±110, (3.6±2.2 HA/mo), *P*=0.018. HA severity and duration was not significantly different across BMI categories.	Excluded those with transformed migraine and tension-type headache. Excluded those with systemic disease and other chronic medical problems. No participants were taking medications.
[33••]	Pro, CS, GP Trial of adolescents in school	Source: Junior High and High Schools in Norway Total: 5588 Overweight and obese (4) : 891 Male: 421 Female: 470	Total HA participants (Any HA Type): 1591 M: 554 F: 1047 Total Mig: 392 M: 126 F: 266 Total TTH: 950 M: 320 F: 630	52 % F Stratified	White 98 % Other 2 %	NR (13–18)	ICHD-2	M-BMI	The OR of recurrent HA were 40 % greater in those whose BMI was above the overweight cutoff (OR 1.4, CI: 1.2–1.6, *P*<0.0001), and was seen independently in boys (OR 1.4, CI: 1.1–1.8, *P*=0.01) and girls (OR 1.4, CI: 1.2–1.8, *P*<0.0001). The OR of migraine were 60 % greater	Participants not reported to be excluded based on medication use. HA frequency NR.

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Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
									in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR in those whose BMI was above overweight cutoff (OR *P*<0.0001] compared with those whose BMI was below overweight cutoff. The OR of TTH were 40 % greater in those whose BMI was above overweight cutoff (OR 1.4, CI: 1.1–1.6, *P*<0.0001) compared with those whose BMI was below overweight cutoff.	
[35]	Retro, CS, Clin Trial compared with historical GP norms from NHANES	Source: Ped HA Clinic in Columbus, OH Size: 925 BMI≥5th – <85th %: 610 BMI≥85th – <95th %: 130 BMI≥95th%: 185	Total HA participants (any type): 925 Total EM and p-EM: 532 Total CM% p-CM w/o Rx overuse: 79 Total TTH and p-TTH: 141 Total CTTH and p-CTTH w/o Rx overuse: 73 Total CDH: 252 w/ Rx overuse: 100 w/o Rx overuse: 152	58 % F	NR	12.5 (5–17)	ICHD-2	M-BMI	A total of 22 % (95 % CI: 17.1–27.4) of CDH pts had BMI≥95th% compared with unidentified historical norms (16.3 %). A total of 26 %(95 % CI: 16.5–37.6) of those with chronic or p-CTTH w/o MOH had BMI≥95th% compared with unidentified	Historical Norms came from NHANES, which included children age 2–19 yrs while clinical population was age 5–17 yrs.

Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
									historical norms (16 %). historical norms (16 %). Population estimates of 16.3 % with BMI >95th% and 31.9 % with BMI >85th% compared with CDC growth chart norms (which were based on data from 1960s – 1990s) included children as young as 2 yrs. When re-calculations are done excluding children age 2–5 yrs making the gen pop more representative of study population then percentiles for BMI >95th% and >85th% become 17.4 % and 33.8 %, respectively. This would nullify the 2 above findings that were noted to be significant	
[37]	Pro, Long, GP Trial of middle school students	Source: Taitung, Taiwan Middle Schools Size: 3342 BMI <95th% (5): 2617 BMI≥95th%: 517	Total EM or p-EM participants at onset: 820 Total incidence CDH: 63 CM: 37 CTTH: 22 Unknown: 4	49 % F	NR	13.2 (13–14)	Mod-ICHD-2	SR-BMI	Association between EM and obesity NR. Risk of incident CDH was not increased in	Included episodic headache participants in non-CDH groups. Excluded those who began

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Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
									those with BMI those with BMI ≥95th % (RR 1.58, CI: 0.89–2.80) compared with those with BMI <95 %. However, incident CDH was higher in those with BMI≥95th% vs. those with BMI <95 % (RR 1.96, CI: 1.04–3.69) after adjusting for covariates. Risk of incident CM was 2.5 X higher in those with BMI≥95 % compared with those with BMI <95 % (RR 2.43, CI: 1.23–4.80). After adjusting for covariates, risk of CM did not change. Risk of incident CTTH was not increased in those with BMI≥95 % compared with those with BMI <95 % (RR 0.5, CI: 0.12–2.16).	study with CDH.
[36]	Retro, CS, Clin Trial	Source: Ped Neuro Clinic in Israel Size: 181 BMI≥5th – <85th %: 109	Total HA participants (Any Type): 181 Total EM/CM and p-EM/p-CM combined: 81	56 % F	NR	10.1 (4–18)	ICHD-2	M-BMI	Crude prevalence: 60 % of those with BMI≥85th–<95th% and	Developmental delay seizures, psychiatric disorders, hydrocephalus, or systemic

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Author (y)	Study design (database)	Sample population	Headache sample size	Sex	Race	Mean age yrs (range)	HA Dx	BMI (SR/M)	Findings	Notes
		BMI≥85th – <95th%: 48 85th – <95th%: 48 BMI≥95th%: 24	Total TTH/CTTH and p-TTH/p-CTTH: 87 Total Unknown: 13						62.5 % of those with BMI≥95th% had migraines (EM/CM) compared with 34 % of those with BMI≥ 5th% – <85th%, (*P*=0 .01). The odds of definitive or probable EM/CM in general was over 2 fold greater in those with BMI≥ 85th – <95th% (OR 2.4, 95th% CI: 1.2–4.7) compared with those with BMI≥5th % – <85th%. In girls it was 3–5 fold greater if they were overweight or obese (overweight: OR 3.01, 95th CI: 1.24–7.3; obese: OR 4.93, 95th% CI: 1.46–8.61). CDH reported to be more prevalent in those with BMI≥85th% (23 %) compared with those with BMI ≥5th% – <85th% participants (12 %, *P*<. 01).	disease excluded. Did not separate episodic from chronic fully

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Notes:

1.# participants in categories calculated based on % reported.

2.Numbers for EM, p-M, TTH, and CDH were calculated from reported percentages of initial participants of 913.

3.Rel BMI calculated with following formula: (participants BMI) × 100/(50th percentile BMI for participant's age and sex).

4.Based on International Obesity Task Force, 2000, Cole TJ et al. establishing a standard definition for child overweight and obesity worldwide: International survey. BMJ 2000;320:1240–43. Overweight is defined as the BMI with respect to age and sex that correlates to BMI of 25 at 18 y (adult cutoff in widest use for overweight). Obesity is defined as the BMI with respect to age and sex that correlates to BMI of 30 at 18-y-old (adult cut-off in widest use for obesity).

5.Based on Taiwan Department of Health, Chen W, Chang MH. New growth charts for Taiwanese children and adolescents based on World Health Organization standards and health-related physical fitness. Pediatr Neonatal. 2010;51:69–79.

BMI body mass index, *CDH* chronic daily headache, *CI* confidence interval, *Clin* clinical, *CM* chronic migraine, *CS* cross-sectional, *CTTH* chronic tension type headache, *Dx* diagnosis, *EM* episodic migraine, *F* female, *Gen* general, *GP* general population, *HA* headache, *Hisp* Hispanic, *ICHD-2* international classification headache disorders 2, *Long* longitudinal, *M* measured, *MA* migraine with aura, *Mig* migraine, *MO* migraine without aura, *Mod* modified, *Neuro* neurology, *NR* not reported, *OR* odds ratio *P* probable, *Ped* pediatric, *Pro* prospective, *Rel* relative, *Retro* retrospective, *SR* self-reported, *TTH* tension-type headache, *US* United States

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Table 2

Treatment of headache disorders with regard to weight, diet, and activity

Author (y)	Study design (database)	Sample population	HA sample size	TX	Race and sex	Mean age (range)	HA Dx	BMI	Findings	Notes
[32•]	Retro, long, multi-center, clin trial (Compared with GP Historical Data)	Source: 1.7 U.S. Ped HA Clinics 2. Historical NHANES Data Size: Initial: 913 3 mo: 213 6 mo: 174 BMI≤5th%: 20 BMI≥5th - <85th%: 580 BMI≥85th - <95th %: 152 BMI≥95th%: 160	Total Any HA: 913 Total EM: MO: 645 MA: 146 Total p-M: 40 Total TTH: 38 Total CDH: CM: 204 CTTH: 8	Discussed nutrition, dietary behaviors, obesity, weight management options at initial and follow-up visits	White: 85 % Black: 13 % Asian: 1 % Hisp: <1 % F: 60 %	11.9 (3–18)	ICHD-2	M-BMI	The>the reduction in raw BMI, the>the reduction in HA frequency (r=0.32, P=0.1). In those who were not overweight to begin the trial, there was no association between HA frequency and BMI change (P >0.05. Change in raw BMI did not correlate with change in disability as noted through PedMIDAS scores.	Obesity prevalence in HA patients were compared with historically reported obesity prevalence rates in general population data from NHANES. Patients were allowed to use preventive medications. Specific diets not addressed. Activity not assessed directly.
[42]	Pro, long, clin trial	Source: U.S. Ped Neuro Clinic Size: Initial: 8 3 mo: 3	Total HA participants (Any HA Type): 8 CDH: 8	Mod Atkins (high fat and low carb diet) Restricted to 15 g of carb/day No calorie or fluid restriction	Race: NR F: 62 %	14.9 (13–16)	ICHD-2	M-BMI	The 3 participants that completed the trial showed weight loss (1.4, 3.8, 8.2 kg, respectively) and reduction in PedMIDAS scores (97, 35, 50 point reduction). All 3 continued to meet criteria for CDH and ultimately required pharmacologic intervention.	Participants had failed at least 2 prophylactic drug trials. Excluded those who had previously tried Atkins diet, pregnant, significant heart or kidney disease, hypercholesterolemia, BMI <18, use of abortive treatments >11 d/last mo.

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Author (y)	Study design (database)	Sample population	HA sample size	TX	Race and sex	Mean age (range)	HA Dx	BMI	Findings	Notes
[45]	Pro, CS–GP	Source: 10th and 11th grade students in 11 schools in Germany Total: 1260	Total HA participants (Any HA Type): 1047 Mig: 129 TTH: 614 Mig+TTH: 249 Unknown: 55	Self-administrated questionnaires to address lifestyle factors including activity level Activity classified as low, moderate, or high	Race: NR F: 53 %	NR (14–20)	ICHD-2	NR	The odds of HA disorder were increased in those with low physical activity compared with those with high physical activity as follows: 1. All HA: OR 2.0; 95 % CI: 1.3–3.1 2.Mig: OR: 4.2; 95 % CI: 2.2–7.9 3.TTH: OR 1.7; 95 % CI: 1.1–2.7 4.Mig+TTH: OR 2.2; 95 % CI:1.3–3.7	Physical activity based on questions assessing frequency, duration, and intensity. BMI not obtained; did not address overweight or obesity.
[33••]	Pro, CS–GP	Source: Junior High and High Schools in Norway Total: 5588 Total Overweight and Obese Participants: Male: 421 Female: 470	Total HA participants (Any HA Type): 1591 M: 554 F: 1047 Total Mig:392 M: 126 F: 266 Total TTH:950 M: 320 F: 630	Evaluation of physical activity using a self-admin questionnaire. <2 times / wk=low Physical activity	White: 98 % Other: 2 % F: 52 %	NR (13–18)	ICHD-2	M-BMI	Recurrent HA in both girls and boys were found to be associated with inactivity (girls OR 1.2, 95 % CI: 1.0–1.4, *P*=0.05, boys OR 1.3; 95 % CI: 1.1–1.7, *P*=0.006). Association between migraine and inactivity (adj for age, sex, smoking, and overweight) (OR 1.5; 95 % CI: 1.0–2.2, *P*=0.09). Association between TTH and inactivity (OR 1.2; 95 % CI: 1.0–1.4, *P*=0.02).	Participants not reported to be excluded based on medication use. HA frequency NR. Diet and weight loss not addressed specifically.

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Author (y)	Study design (database)	Sample population	HA sample size	TX	Race and sex	Mean age (range)	HA Dx	BMI	Findings	Notes
[43•]	Pro, long multicenter, clin trial	Source: 6 Italian Ped Neurology Clinics Size: Initial: 150 12mo: 135 BMI≥97th%: 135	Total HA participants (Any HA Type): 135 Mig participants: 135	Dietary education/ balanced diet physical training (aerobic exercise), and behavioral treatment	White: 100 % F: 58 %	15.9 (14–18)	ICHD-2	M-BMI	BMI: Initial: 32.9±4.6 6 mo: 30.5±5.1 12 mo: 29.9±6.0 *P*<0.01 vs initial HA frequency: Initial: 5.3±2.1 6 mo: 2.4±1.1 12 mo: 2.2±0.9 *P* <0.01 vs initial HA intensity (10 pt): Initial: 7.4±1.7 6 mo: 3.9±2.1 12 mo: 4.2±2.5 *P* <0.01 vs initial Lowered BMI was associated with better migraine outcomes 1 yr later. Change in BMI over 1 yr was correlated with decreased HA frequency intensity, and disability as measured with PedMIDAS.	Excluded those with baseline endocrine disorders, eating disorders, or taking any medications. Physical activity: 60 min of moderate-intensity most days of the wk, preferably daily. Diet: good nutrition with the lowest energy intake; reduce calorie intake by 15 %–20 % below daily calorie maintenance; increase in fiber; decrease high-fat foods and sweetened fruit drinks.

Notes:

Admin administrated, *BMI* body mass index, *carb* carbohydrate, *CDH* chronic daily headache, *Clin* clinical, *CM* chronic migraine, *CS* cross-sectional, *CTTH* chronic tension type headache, *Dx* diagnosis, *EM* episodic migraine, *F* female, *GP* general population, *HA* headache, *Hisp* Hispanic, *ICHD-2* international classification headache disorders 2, *Long* longitudinal, *m* measured, *MA* migraine with aura, *Mig* migraine, *MO* migraine without aura, *mo* month, *mod* modified, *NR* not reported, *p* probable, *Ped* pediatric, *Pro* prospective, *pt* point, *Retro* retrospective, *TTH* tension-type headache, *TX* treatment, *U.S.* United States

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Table 3

Potential pediatric migraine preventative medications and weight considerations

Drug class/drug	Weight change
Anti-depressants	
amitriptyline	↑ ↑ ↑
nortriptyline	↑ ↑
protriptyline	↓
venlafaxine	↔ ↓
duloxetine	↔ ↓
Anti-convulsants	
divalproex sodium	↑ ↑ ↑
lamotrigine	↔
gabapentin	↑
topiramate	↓ ↓
β-Blockers	
propranolol	↑
nadololol	↔
metoprolol	↑
Serotonin antagonists	
cyproheptadine	↑ ↑ ↑
Calcium channel blockers	
flunarizine	↑ ↑ ↑
verapamil	↔

Modified based on Peterlin et al. 2008 [51].