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Impact of High Protein Intake on Pubertal Biology

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ABSTRACT

Adolescent protein intake has remained above the dietary recommended intake (DRI) for two decades. The social-media-driven protein trend that has been growing since 2023 has made powders, bars, and high-protein diets visible and appealing to teenagers. This paper summarizes the research done on possible effects of high protein intake in adolescents through a literature scoping review. Specifically, the focus is on how high protein intake relates to kidney function and insulin-like growth factor 1 (IGF-1). Furthermore, these effects can be different during puberty, a stage when both kidney biology and growth hormones are already changing, thus requiring targeted studies on adolescent populations in order to fully understand the impact of high protein consumption.

PubMed, Google Scholar, and Consensus were searched for evidence on protein intake, kidney outcomes, IGF-1, growth, and puberty. This review includes 28 sources: 18 original studies, 4 reviews, 1 position stand, and 5 context or government data sources. Evidence is organized by population and study design in the Results section. Controlled animal studies show kidney stress, hyperfiltration, proteinuria, scarring, and changes in IGF-1 under high-protein conditions. Adult studies link high-protein eating patterns and sustained growth-hormone and IGF-1 excess with kidney risk. Adolescent studies show that puberty changes kidney markers and that protein intake is associated with IGF-1 and growth, with different patterns in girls and boys. Current knowledge of the effects of high protein intake in adolescents still relies heavily on adult studies. The evidence points to a specific adolescent safety question that remains unanswered.

The central gap is controlled, sex-aware evidence on kidney safety in healthy adolescents. Closing it requires a long-term study that follows healthy adolescent populations through puberty, measures protein intake directly, and tracks kidney and hormone markers for girls and boys separately in order to develop protein intake guidelines and understand the risks of high protein consumption.

INTRODUCTION

National survey data show that American adolescents have eaten well above recommended protein levels for at least two decades. Among adolescents ages 12 to 19, average protein intake was 81.4 grams per day in 2003-2004 and 74.7 grams per day in 2017-2018, with no significant change in protein's share of total calories over that period [1]. The most recent national data, collected between August 2021 and August 2023, show average intakes of 83.8 grams per day for boys and 57.5 grams per day for girls ages 12 to 19, compared with dietary recommended intake (DRI) of 52 and 46 grams per day for this age group [2, 3].

A 2023 narrative review covering healthy children and adolescents ages 4 to 18 reported that protein intake in developed countries is commonly two to three times recommended levels, while evidence on the long-term effects remains scarce [4].

In a 2024 nationally representative poll, 41% of parents reported that their teen had consumed protein supplements such as bars, shakes, or powders in the past year [5]. Adolescent surveys tie this behavior to social media. In one Canadian study, 43.7% of adolescents and young adults named social media influencers as a primary influence on their muscle-building supplement use [6]; in another, greater engagement with fitness- and weight-related online content was significantly associated with use of whey protein, protein bars, and creatine [7]. The share of young people taking two or more dietary supplements has also risen steadily since 2013-2014 [8]. The last national dietary survey was done in 2023, and there has been no new survey that captures this recent growth in protein-seeking behavior. Therefore, the current exposure may be higher than previously recorded data.

High-protein products have been popular in adolescent sports and muscle-building culture. In a survey of 237 Australian boys ages 14 to 16, nearly half reported using protein powder, and use was more strongly associated with weight training, sports participation, and drive for muscularity than with age, body mass index, or general body dissatisfaction [9]. Marketing reinforces this pattern: a systematic review of 35 studies found that social-media influencer and marketing content affected food consumption among children and adolescents even when the young people recognized the content as advertising [10].

Adolescence is a distinct biological setting for this exposure. During puberty, growth hormone and IGF-1 levels rise in the body and drive rapid growth. Both hormones take part in kidney development, filtration, and function [11]. Kidney markers shift during adolescence even when diet stays the same: in a study of 2,035 healthy participants ages 8 to 18, cystatin C rose in boys and fell in girls across puberty, and IGF-1 was associated with these changes in both sexes [12]. A developing kidney under this hormonal surge cannot be assumed to respond to dietary protein the way a fully grown adult kidney does.

High protein intake is defined here as 2 grams (or higher) per kilogram of body weight per day, although studies report intake in different units, including percentage of daily calories, grams per day, and multiples of the DRI. Today's safety guidance is based on studies performed on adults and animals. No controlled study has measured kidney outcomes in healthy adolescents consuming high protein. The present scoping review maps what is known about high protein intake, kidney function, IGF-1, growth, and puberty in adolescents ages 10 to 19, and it advances a specific claim: the available evidence forms a biologically plausible pathway from high protein intake to kidney strain during adolescence, and that pathway has not been tested directly in adolescents.

RESEARCH QUESTION

What are the documented and biologically plausible effects of high protein intake (≥2 g/kg/day, or the closest equivalent reported by a given study) on pubertal biology, particularly kidney function and IGF-1 regulation, in adolescents aged 10 to 19?

METHODS

Review Design

This scoping review was organized using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) framework. Unlike a systematic review, which answers a narrow question through exhaustive study selection and formal quality appraisal, a scoping review maps the breadth of evidence across populations and study designs to identify what has and has not been studied. A scoping approach fits the question because the available evidence comes from several populations and study designs. The review maps what is known about protein intake, kidney function, insulin-like growth factor 1 (IGF-1), growth, and puberty, then identifies the adolescent evidence gap.

Eligibility Criteria

Eligibility was defined using a Population and Context framework. Population. The target population was adolescents ages 10 to 19. Studies that followed participants across a wider age range were included when their outcome measures fell within adolescence. Animal studies, adult studies, and studies of clinical populations were included as comparison or mechanism evidence when they helped explain kidney or hormone pathways relevant to adolescence.

Concept. The review focused on high or excessive protein intake and outcomes involving kidney function, IGF-1, growth, or puberty. High protein intake was defined as about 2 or more grams of protein per kilogram of body weight per day. Studies measured protein in different ways, including percentage of daily calories, grams per day, multiples of the DRI, or the highest intake group in the study population. These measures were included when the authors described intake as high or above recommendations and when they were the closest available match to the 2 g/kg/day threshold.

Information Sources

Sources came primarily from PubMed, Google Scholar, and the Consensus academic search tool. Full texts were accessed through PubMed Central, ScienceDirect, Oxford Academic, other publisher sites, and available library access.

Search Strategy

Searches combined protein-related terms, including "high protein diet," "excessive protein intake," and "protein supplement," with population and outcome terms such as "adolescents," "puberty," "kidney function," "IGF-1," "growth," and "renal." Search terms were adjusted for each evidence type. Terms such as "rat" and "animal study" were added for mechanistic research, while "randomized controlled trial" was added when searching for experimental evidence. Additional searches focused on adolescent protein use, public nutrition guidance, and normal kidney and hormone changes during puberty.

Selection Process

Titles and abstracts were checked against the eligibility criteria, and full texts were retrieved for sources that matched the question. Peer-reviewed original studies formed the main evidence base. Reviews, a position stand, and context or government sources were included to explain mechanisms, summarize guidance, and establish patterns in adolescent protein exposure. Each source was assigned a clear role before the Results were written.

Study Selection

The final review included 28 sources: 18 original studies, 4 reviews, 1 position stand, and 5 context or government data sources. Original studies covered adolescent, adult, animal, and other relevant populations. This mix allowed the review to compare direct adolescent observations with controlled animal findings, adult human evidence, and the guidance and exposure data that frame the question.

Data Charting

For each source, the citation, study design, population, age range, protein amount and source, outcomes, main numerical findings, limitations, and relevance to the research question were recorded. The information was tracked in a spreadsheet and used to compare findings across populations and study designs.

Organizing of Results

The evidence is organized into seven Results sections. The order moves from adolescent protein use and exposure to normal pubertal kidney and hormone biology, animal evidence, adult human evidence, adolescent observational evidence, controlled human evidence, and the integrated findings and evidence gap. This sequence begins with the real-world exposure, explains the biology of puberty, and then moves through each level of evidence before identifying the study the field still needs.

RESULTS

Adolescent Protein Use and Exposure

High-protein products are used by adolescents, especially by those interested in sports and muscle building. In a survey of 237 Australian boys ages 14 to 16, nearly half reported using protein powder. Use was more strongly associated with weight training, sports participation, and drive for muscularity than with age, body mass index, or general body dissatisfaction [9]. This places protein supplementation within the everyday behavior of adolescent boys focused on sports and muscle growth.

Recent population data show high average protein exposure across sexes. The Recommended Dietary Allowances (RDAs) in 2021-23 were 52 and 46 g/day,for boys and girls, respectively [2, 3]. In the same time frame,the dietary intake data from What We Eat in America,National Health and Nutrition Examination Survey (WWEIA/NHANES), showed the mean intake among U.S. adolescents ages 12 to 19 was 83.8 g/day for boys and 57.5 g/day for girls, 1.61 times the RDA for boys and 1.25 times for girls. In Spain's nationally representative National Dietary Survey on the Child and Adolescent Population (ENALIA), published in 2019 adolescents ages 14 to 17 averaged 93.6 g/day, equal to 1.88 times the intake for that population [13]. A 2024 nationally representative U.S. parent poll found that 41% of teens ages 13 to 17 had used a protein supplement in the previous year [5]. These averages describe broad exposure, while the percentage consuming more than 2 g/kg/day remains a separate question.

Digital marketing contributes to the spread of high-protein behaviors. A systematic review of 35 studies found that social-media influencer and marketing content affected food consumption among children and adolescents, even when young people recognized the content as advertising [10]. Two Canadian studies of adolescents and young adults point to social media as a major influence on supplement use. In a national sample of 912 participants ages 16 to 30 who used muscle-building supplements, 43.7% named social-media influencers as a primary influence [6]. A separate study linked greater social-media engagement, especially with fitness- and weight-related content, to use of whey protein and protein bars [7]. Together, these studies associate social-media exposure with protein-supplement use among adolescents and young adults.

Normal Pubertal Kidney and Hormone Biology

Adolescence has its own physiology. During puberty, growth hormone and insulin-like growth factor 1 (IGF-1) rise and drive rapid growth. These hormones also take part in kidney development, filtration, and function [11]. Kidney markers shift during adolescence even when diet stays the same.

In a study of 2,035 healthy German participants ages 8 to 18, cystatin C, a marker used to estimate kidney filtration, rose in boys and fell in girls across puberty. IGF-1 was associated with these changes in both sexes [12]. Puberty itself alters kidney biology, and the direction of change differs between boys and girls.

Adults with hormone excess show what sustained elevation does to the kidney. In 80 adults with acromegaly, a condition of chronic excess growth hormone and IGF-1, kidney function declined about 1.28 mL/min/year, compared with 0.63 to 0.75 mL/min/year in healthy adults, and improved after hormone levels normalized [14]. This matters for adolescents because IGF-1 is already naturally high during puberty - the adolescent kidney is working under an elevated hormonal load before diet enters the picture, so it may respond to high protein intake differently than an adult kidney would.

Pubertal timing ties into the same system. Higher prepubertal IGF-1 concentrations are associated with earlier pubertal timing [15]. High protein intake reaching the body while its hormonal background is already changing could have effects that are not captured in studies on adults. Adolescent-specific studies are therefore necessary.

Kidney and IGF-1 Effects of High Protein in Animal Models

Animal experiments provide controlled evidence about kidney tissue and hormonal responses that would be difficult or unethical to test in healthy adolescents. Rats fed a 30% protein diet developed higher blood pressure, averaging approximately 153 mmHg compared with 132 mmHg in the normal- and low-protein groups. The high-protein group also excreted approximately seven times more urinary protein, showed greater immune-cell accumulation, and developed visible kidney scarring [16]. This study identifies the type of kidney damage high protein can produce under controlled conditions, giving adolescent research specific outcomes to examine during puberty.

In a separate mouse experiment, a diet containing 40% protein produced larger kidneys and glomerular hyperfiltration. The investigators linked this response to neuronal nitric oxide synthase activity in the kidney's filtration structures [17]. Wakefield et al. randomized 70-day-old female Sprague-Dawley rats to isoenergetic diets containing either 15% or 35% of energy from whole-protein sources for 4, 8, 12, or 17 months (n = 8-11 per group at each time point). Across the study, the high-protein rats had threefold higher proteinuria, 27% higher creatinine clearance, 22% larger glomeruli, 33% more glomerulosclerosis, and 17% higher kidney weight than the normal-protein rats [18]. At 17 months, urine was collected from the bladder rather than in metabolic cages, so only the proteinuria-to-creatinine ratio was available for that

time point. These kidney changes matter to adolescent research because the kidneys and hormonal system are still changing during puberty, while these experiments used mature animals.

Animal research also maps a protein-IGF-1 pathway. Rats fed a high-protein diet for 14 days had higher muscle IGF-1 than rats fed a low-protein diet, while growth hormone changed little. Additional IGF-1 increased protein retention only when adequate dietary protein was available [19]. Similarly, growth-restricted rat pups given a high-protein diet had higher IGF-1 and insulin-like growth factor binding protein 3 (IGFBP-3) concentrations and faster catch-up growth than pups given a standard diet [20]. This pathway matters during adolescence because IGF-1 is already high in puberty, so high protein intake may add to a hormonal system that is already active.

Overall, controlled animal experiments identify kidney and IGF-1 mechanisms that adolescent studies can test directly. Most kidney-focused experiments used mature animals, making pubertal studies the next step for understanding how these mechanisms operate in adolescents.

Adult Human Evidence

The clearest human evidence linking a high-protein eating pattern with kidney risk comes from adults. Farhadnejad et al. followed nearly 1,800 Tehranian adults for approximately six years and found that participants with the highest adherence to a low-carbohydrate, high-protein diet had a 48% higher risk of developing chronic kidney disease than participants with the lowest adherence [21]. As an observational cohort study, it shows an association between the eating pattern and kidney risk. For adolescents, this human risk signal gives a direct reason to study kidney outcomes during puberty.

Adult evidence provides a human comparison for the kidney concern. Adults have mature kidneys and live outside the pubertal shifts in growth hormone, IGF-1, and kidney-related markers described above. Adolescents therefore need their own research because the same dietary exposure occurs in a different biological setting.

Adolescent Observational Evidence

Observational studies in adolescents and young people link protein intake with IGF-1, growth, and puberty-related biology. In the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) Study, Joslowski et al. examined 213 participants and found that girls with higher animal-protein intake during adolescence, particularly from meat, had higher IGF-1 concentrations in young adulthood. The highest intake group averaged approximately 42 g/day of animal protein. Boys showed a different pattern, with no clear association [22]. The sex difference matters because adolescent hormonal and growth responses to protein may differ between girls and boys.

A related DONALD Study analysis followed 189 participants from ages 3 to 17. Higher total protein intake was associated with taller adult stature in girls, with no clear association in boys. Boys consumed approximately twice the recommended dietary allowance, while girls consumed approximately 1.7 times the recommendation [23]. This second sex-specific pattern connects adolescent protein intake with growth-related biology and gives kidney research a clear reason to examine girls and boys separately.

Taken together, adolescent studies associate protein intake with IGF-1, growth, and puberty-related biology, particularly in girls. These findings establish the hormonal and growth setting in which future studies should measure kidney outcomes.

Controlled Human Evidence

Controlled trials provide stronger evidence about cause and effect. In an 18-month randomized trial of 82 girls with a mean age of 12.2 years, participants assigned to increase milk intake raised consumption from approximately 170 to 486 mL/day. IGF-1 increased by 35% in the milk group and 25% in the control group [24]. Because milk changes several nutrients at once, the trial represents a broader dietary intervention rather than protein alone. However, Iit still provides controlled adolescent evidence that a dietary intervention increasing protein intake can alter IGF-1.

The Researching Effective Strategies to Improve Insulin Sensitivity in Children and Teenagers (RESIST) trial randomized 111 adolescents ages 10 to 17 with obesity and insulin resistance or prediabetes to either a diet containing 25% to 30% of energy from protein or a diet containing 15% of energy from protein. After 12 months, both groups showed similar improvements in insulin sensitivity and body composition [25]. In this clinical population, raising protein intake produced metabolic results similar to the lower-protein diet. This gives adolescent research a controlled comparison while keeping the findings tied to participants with obesity and insulin resistance or prediabetes.

Mechanistic support outside adolescence comes from a two-year randomized, placebo-controlled trial in 219 women ages 70 to 80. Women assigned 30 g/day of whey protein had IGF-1 concentrations 7.3% higher at one year and 8.0% higher at two years than the placebo group [26]. The older study population makes that adolescent response a separate question because IGF-1 is already high during puberty and a protein-related rise may affect them differently.

Current controlled evidence maps only part of the adolescent question. Trials show that dietary interventions can alter IGF-1 [24, 26], and current adolescent guidance relies substantially on adult evidence because direct studies in teenagers are difficult to conduct [27]. The field now needs a controlled study that measures kidney function in healthy adolescents consuming high protein.

Integrated Findings and Evidence Gaps

Across the seven sections, animal, adult, and adolescent studies each supply one part of the evidence. Animal experiments show that high-protein diets alter kidney structure, filtration, and IGF-1-related processes [16-20]. Adult observational evidence links a low-carbohydrate, high-protein eating pattern with increased chronic kidney disease risk [21]. Adolescent studies show that puberty changes kidney-related markers and that protein intake is associated with IGF-1 or growth [12, 22, 23]. Controlled adolescent evidence remains limited to part of this pathway.

Together, the evidence builds a biologically plausible pathway from high protein intake to changes in IGF-1 and kidney function. Each step appears in the literature, while the full pathway in healthy adolescents remains the study the field needs. A controlled adolescent study measuring protein intake, pubertal stage, IGF-1, and kidney outcomes would connect these findings directly.

DISCUSSIONS

Summary of Main Findings

The evidence points to a clear adolescent research question. Animal and mechanistic studies show that high protein intake affects kidney function and insulin-like growth factor 1 (IGF-1) regulation. Adult research links high-protein diets with kidney disease risk. Adolescent studies add the key biological context: puberty changes kidney markers, and protein intake is associated with higher IGF-1 during this stage. Together, these findings make adolescent kidney strain plausible and show why direct adolescent research matters.

Agreement Across Evidence Types

The evidence types form a consistent chain. Animal studies give the strongest direct evidence of kidney harm, including hypertension, hyperfiltration, and structural damage, mainly in mature animals. Human observational studies show that puberty shifts kidney biomarkers and that protein intake raises IGF-1 in adolescents. Controlled trials are the best design for testing cause and effect, and adolescent kidney outcomes remain the missing link in that chain.

The main finding is that the evidence supports a plausible pathway from high protein intake to kidney strain during adolescence. Each evidence type supplies one part of that pathway: kidney damage in animals, kidney disease risk in adults, and a changing kidney and hormonal system during puberty. The next step is to test the full pathway in adolescents.

Adult kidney evidence shows that high-protein eating patterns are linked to kidney disease risk in humans. A cohort that followed nearly 1,800 healthy adults in Iran for about six years found that the

highest adherence to a low-carbohydrate, high-protein diet was associated with a 48% greater risk of developing chronic kidney disease [21]. This matters for adolescents because puberty brings a natural surge in growth hormone and IGF-1, so the adolescent kidney may respond differently from a fully mature kidney [11].

Animal studies show how high protein intake can change the kidney and its hormonal environment. Researchers can control the diet directly and measure outcomes that would be difficult or unethical to test in humans. Across these studies, high protein intake changed kidney function and IGF-1, sometimes doubling markers of harm compared with normal-protein diets. These experiments identify the kidney changes that adolescent studies should measure.

A Sex-Specific Pattern in Human Studies

Human observational studies show a sex-specific pattern: protein-related changes in IGF-1 and growth appeared in girls rather than boys [22, 23]. The sex-specific pattern has one plausible explanation, though it is not confirmed: the hormonal environment of puberty could make girls' IGF-1 axis more responsive to dietary protein at the ages studied. The reviewed studies identified the pattern rather than the mechanism. Future adolescent studies should therefore analyze girls and boys separately instead of assuming the same response in both sexes.

Puberty as a Potentially Vulnerable Window

Puberty may be a more vulnerable period for the kidney because several biological changes occur at the same time. Cystatin C research shows that puberty itself changes kidney-related biomarkers in healthy adolescents [12]. Acromegaly research shows that chronic excess growth hormone and IGF-1, the same hormones that naturally surge during puberty, speeds kidney decline and that kidney function improves after hormone levels normalize [14]. Animal research shows that IGF-1 directly affects the kidney's filtration workload [11]. Together, this evidence supports a plausible, biologically coherent concern: added protein during puberty's hormonal surge could place extra strain on a kidney that already works differently from an adult kidney. Testing that idea directly in adolescents is the central next step.

IGF-1 also connects protein intake to the timing of puberty. Human research shows that IGF-1 levels are strongly and consistently associated with pubertal timing in both sexes, with higher prepubertal IGF-1 levels predicting earlier puberty (Section 2, [15]). Protein intake is also closely tied to IGF-1. Following adolescents over several years would show whether high protein intake is associated with a shift in pubertal timing through this pathway.

Inconsistent Definitions of "Excessive" Protein Intake

Studies use different definitions of high protein intake, which makes their results hard to compare. Some report grams per day, some report the percentage of daily calories, and others report multiples of the Recommended Dietary Allowance (RDA). Very few use grams per kilogram of body weight per day, the main threshold in this review. The Methods therefore use a broader, equivalence-based definition of "excessive" protein intake.

This inconsistency is a field-wide measurement problem. It helps explain why few studies fit neatly within a strict 2 g/kg/day threshold even when participants ate well above standard recommendations. Reporting protein intake in a consistent unit would make future studies easier to compare and would sharpen the evidence on adolescent exposure.

The Influence of Industry Funding on Existing Guidance

Current claims that high protein intake is safe for kidney function rest on a narrow and financially conflicted evidence base. The clearest safety claim comes from a sports-nutrition position stand whose authors have strong ties to the supplement industry [28]. Independent, publicly funded research more consistently finds risk. Current guidance also relies entirely on adult data. For adolescents, that leaves a clear need for independent research before the safety claim can be applied with confidence.

Future Directions

The field now needs a long-term study that follows healthy adolescents through puberty. It should measure protein intake directly in grams per kilogram of body weight per day and record whether the protein comes from animals, dairy, plants, or supplements. Kidney measures should include estimated glomerular filtration rate (eGFR), cystatin C, urinary protein, blood pressure, and markers of hyperfiltration. Hormone measures should include IGF-1, growth hormone context, and relevant sex hormones. Researchers should analyze girls and boys separately and record pubertal stage rather than age alone. Follow-up should last long enough to detect sustained effects. Because assigning minors to extremely high protein intake raises ethical problems, a long-term prospective cohort is more realistic than a controlled trial.

Limitations

Some limits sit in the evidence itself. The national intake numbers come from dietary recalls and a parent poll, so they depend on accurate reporting, and they are still the best available measure of what American teens actually eat [1, 2, 5]. Both Canadian social-media studies are cross-sectional and span ages 16 to 30, so they capture one point in time across adolescents and young adults together, and they still identify social media as a current driver of supplement use in that group [6, 7]. The animal kidney experiments

identify the damage a high-protein diet can produce under controlled conditions, and most used mature animals rather than peripubertal ones, so the same outcomes now need to be measured during puberty [16-18]. Across the human studies, protein intake is reported in different units, several studies are too small to compare girls and boys well, and some populations sit outside the target group, including adults and postmenopausal women [14, 21, 26]. Each of these limits defines something the next adolescent study has to fix.

The search and screening carry their own limits. One reviewer screened every source without a second independent check, and no formal risk-of-bias assessment was performed, so the included set reflects one person's judgment, including the calls about which studies counted as adolescent. The scoping design maps the field with a defined, reproducible search rather than an exhaustive sweep of every database, and Google Scholar and Consensus were searched alongside PubMed, a wider net with less control. A small number of non-peer-reviewed sources appear as clearly labeled context only. These choices match the scoping goal: a reproducible map of what the evidence shows and exactly where it runs out.

IMPLICATIONS & CONCLUSION

American adolescents have eaten well above recommended protein levels for at least two decades. Average intake was 81.4 grams per day in 2003-2004 and 74.7 grams per day in 2017-2018, and the most recent national data show 83.8 grams per day for boys and 57.5 for girls, against Recommended Dietary Allowances (RDAs) of 52 and 46 [1-3]. What has changed since 2023 is the culture around protein: in a 2024 national poll, 41% of parents reported that their teen had used a protein supplement in the past year, and adolescent surveys tie that behavior directly to social-media fitness content [5-7]. A scoping review of 28 sources examined what that exposure means for kidney function and IGF-1 during puberty.

The evidence answers in pieces. Controlled animal experiments show that high protein intake produces kidney stress, hyperfiltration, proteinuria, and scarring, and shifts insulin-like growth factor 1 (IGF-1). Adult studies link high-protein eating patterns and sustained growth-hormone and IGF-1 excess with kidney disease risk. Adolescent studies show that puberty changes kidney markers and that protein intake is associated with IGF-1 and growth, with different patterns in girls and boys. Together these pieces form a plausible pathway from high protein intake to kidney strain during puberty, and they give future adolescent studies specific outcomes to measure.

The central gap is controlled, sex-aware evidence on kidney safety in healthy adolescents. That gap carries practical weight, because protein supplements are already part of adolescent sports and muscle-building culture while current guidance for teenage athletes still rests on adult data and on a safety claim with industry ties [27, 28]. The study that would close the gap is now well defined: follow healthy adolescents through puberty, measure protein intake in grams per kilogram per day with the source recorded, track kidney and hormone markers, and analyze girls and boys separately. Until adolescent-specific, sex-aware studies directly measure kidney outcomes, the safety of very high protein

intake during puberty remains an important unanswered question.

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STUDY DATA TABLE

Original studies (18)

Study	Design	Sample	Protein exposure and measure	Outcomes	Key finding
[6] Ganson et al. (2024)	Cross-sectional national survey (Canada)	912 muscle-building supplement users ages 16-30	Muscle-building supplement use	Influences on supplement use	43.7% named social-media influencers as a primary influence on their

					supplement use
[7] Ganson et al. (2023)	Cross-sectional study	N = 2,731 participants ages 16-30 (Canadian Study of Adolescent Health Behaviors)	Whey protein, protein bars, and other supplement use	Social-media engagement and supplement use	Greater engagement with fitness- and weight-related online content was linked to use of whey protein and protein bars
[9] Yager and McLean (2020)	Cross-sectional survey	237 Australian boys ages 14-16	Protein-powder use	Supplement use and its predictors	Nearly half had used protein powder; weight training, sports participation, and drive for muscularity were the strongest predictors
[12] Ziegelasch et al. (2022)	Observational study in a healthy cohort	2,035 German participants ages 8-18	No protein intervention (pubertal physiology study)	Cystatin C (filtration marker), IGF-1	Cystatin C rose in boys and fell in girls across puberty; IGF-1 was associated with these changes in both sexes
[13] López-Sobaler et al. (2019), ENALIA	National dietary survey (Spain, 2013-2014)	Spanish adolescents ages 14-17	Dietary protein intake	Mean protein intake relative to population reference intake	Mean protein intake 93.6 g/day, equal to 1.88x the population

					reference intake
[14] Castagna et al. (2025)	Long-term observational study	80 adults with acromegaly	No protein intervention (chronic growth hormone and IGF-1 excess)	eGFR decline over time	Kidney function declined about 1.28 mL/min/year vs 0.63-0.75 in healthy adults and improved after hormone levels normalized
[15] Baier et al. (2023)	Cohort study	n = 1,196 boys and girls (Chilean GOCS cohort)	No protein intervention (prepubertal IGF-1)	Pubertal timing and tempo	Higher prepubertal IGF-1 concentrations were associated with earlier pubertal timing in both sexes
[16] De Miguel et al. (2011)	Animal experiment (Dahl SS rats)	5-10 rats per group	30% protein diet vs normal or low protein	Blood pressure, urinary protein, immune-cell infiltration, kidney scarring	High protein: blood pressure ~153 vs 132 mmHg, about 7x more urinary protein, more immune-cell buildup, visible kidney scarring
[17] Wei et al. (2019)	Animal experiment (wild-type and macula	n=10-15 mice per group (wild-type and macula densa	40% protein diet	Kidney weight, GFR, renal blood flow,	Larger kidneys and glomerular hyperfiltration on high

	densa-specific NOS1 knockout mice)	nNOS-KO; from figure legends)		tubuloglomerular feedback	protein; the effect depends on nNOS-beta in the macula densa
[18] Wakefield et al. (2011)	Animal experiment (randomized diets for 4-17 months)	70-day-old female Sprague-Dawley rats, n = 8-11 per group	35% vs 15% of energy from protein	Proteinuria, creatinine clearance, glomerular size, glomerulosclerosis, kidney weight	3x higher proteinuria, 27% higher creatinine clearance, 22% larger glomeruli, 33% more glomerulosclerosis, 17% higher kidney weight
[19] Sanchez-Gomez et al. (1999)	Animal experiment (rats, 14 days)	48 female rats (8 per group, 3 infusion groups x 2 diets)	High- vs low-protein diet	Muscle IGF-1, growth hormone, nitrogen balance	Higher muscle IGF-1 on high protein while growth hormone changed little; added IGF-1 increased protein retention only when dietary protein was adequate
[20] Qiu et al. (2004)	Animal experiment (growth-restricted rat pups)	32 rat pups (24 IUGR + 8 normal, 4 groups)	High-protein vs standard diet	IGF-1, IGFBP-3, catch-up growth, intestinal development	Higher IGF-1 and IGFBP-3 and faster catch-up growth on the high-protein diet

[21] Farhadnejad et al. (2019)	Prospective cohort (about 6 years)	About 1,800 Tehranian adults	Adherence to a low-carbohydrate, high-protein diet	Incident chronic kidney disease	Highest adherence linked to 48% higher CKD risk vs lowest adherence (observational association, not proof of cause)
[22] Joslowski et al. (2013)	Prospective cohort (DONALD Study)	213 participants followed into young adulthood	Animal-protein intake during adolescence (top group about 42 g/day)	Young-adult IGF-1	Girls with higher animal-protein intake, especially from meat, had higher young-adult IGF-1; no clear association in boys
[23] Hua and Remer (2022)	Prospective cohort (DONALD Study)	189 participants followed from ages 3-17	Total protein intake (boys about 2x RDA, girls about 1.7x RDA)	Adult stature	Higher protein intake linked to taller adult stature in girls; no clear association in boys
[24] Cadogan et al. (1997)	Randomized controlled trial (18 months)	82 girls, mean age 12.2 years	Increased milk intake, about 170 to 486 mL/day	IGF-1, bone mineral acquisition	IGF-1 rose 35% in the milk group vs 25% in controls; milk changes several nutrients, so this is not a

					pure protein trial
[25] Garnett et al. (2014), RESIST	Randomized controlled trial (12 months)	111 adolescents ages 10-17 with obesity and insulin resistance or prediabetes	25-30% vs 15% of energy from protein	Insulin sensitivity, body composition	Both groups improved by similar amounts; more protein gave no added metabolic benefit in this clinical population
[26] Zhu et al. (2011)	Randomized placebo-controlled trial (2 years)	219 women ages 70-80	30 g/day whey protein vs placebo	IGF-1, bone structure, urinary calcium	IGF-1 was 7.3% higher at 1 year and 8.0% higher at 2 years than placebo

Reviews, position stand, and context sources (10)

Source	**Type**	**Coverage**	**Role in the review**
[1] USDA ARS (2021)	Government data brief (WWEIA/NHANES)	U.S. adolescents ages 12-19, 2003-2004 to 2017-2018	Mean protein intake was 81.4 g/day in 2003-2004 and 74.7 g/day in 2017-2018, above recommendations throughout
[2] USDA ARS (2023)	Government data table (WWEIA/NHANES 2021-2023)	U.S. adolescents ages 12-19	Mean protein intake 83.8 g/day for boys and 57.5 g/day for girls
[3] National Academies (2005)	Reference report (Dietary Reference	U.S. reference intakes for adolescents	RDA of 52 g/day (boys) and 46 g/day

	Intakes)		(girls), the benchmark for above-recommendation intake
[4] Garcia-Iborra et al. (2023)	Narrative review	Healthy children and adolescents ages 4-18 in developed countries	Protein intake is commonly 2-3x recommended levels; evidence on long-term effects is scarce
[5] C.S. Mott Children's Hospital (2024)	National parent poll	U.S. parents of teens ages 13-17	41% reported their teen had used a protein supplement in the past year
[8] National Center for Health Statistics (2026)	Government data brief	U.S. dietary supplement use, 2021-2023	The share of young people taking two or more supplements has risen steadily since 2013-2014
[10] Sina et al. (2022)	Systematic review (35 studies)	Social-media marketing and the diets of children and adolescents	Shows marketing shapes adolescent eating behavior; not protein-specific
[11] Gurevich et al. (2021)	Review	Growth hormone and IGF-1 actions in kidney development and function	Mechanism evidence: how the pubertal hormone rise affects kidney workload
[27] Everett (2025)	Review	Performance nutrition for adolescent athletes	Shows current adolescent-athlete guidance relies heavily on adult evidence
[28] Jäger et al. (2017)	Position stand (ISSN)	Protein and exercise guidance	Source of current high-protein safety claims; based mainly on adult evidence