

A scoping review of dietary interventions to treat obesity among Prader-Willi syndrome individuals

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SUMMARY: Prader-Willi syndrome (PWS) is a genetic disorder resulting from the absence of paternal 15q11-q13 alleles and is clinically characterised by pathological obesity, delayed satiety, hyperphagia, decreased muscle mass, and increased fat mass. Dietary management constitutes a key component in the prevention and treatment of obesity in individuals with PWS. This scoping study aimed to identify dietary interventions available for treating obesity among PWS individuals. A systematic search using the six stages of the scoping review methodology proposed by Arksey and O'Malley was conducted across four databases: PubMed, Scopus, EBSCOhost, and Cochrane Library. The inclusion criteria were full-text research articles published in English between 2017 and 2023, involving human participants with PWS, and reporting on dietary interventions for obesity management. Out of 100 articles retrieved, five studies were identified. Two studies described multidisciplinary programs integrating dietary and physical activity components, while three focused exclusively on dietary interventions. The outcomes varied by intervention and study design. Ketogenic diets and multidisciplinary programs with exercise often resulted in favourable weight and body fat reduction. However, strict diets like the modified Atkins faced adherence challenges and frequent weight regain. Multidisciplinary, supervised programs result in higher adherence and more effective weight management, with body mass index near normal. In conclusion, although research in this area remains limited, current evidence suggests that both dietary and multidisciplinary interventions have the potential to support obesity management in individuals with PWS.

Keywords: Prader-Willi syndrome, dietary intervention, obesity, weight management

1. Introduction

Prader-Willi syndrome (PWS) is a genetic disorder in which paternal alleles of the chromosome 15q11-q13 region are missing due to a genomic imprinting error or defect (1-3). PWS was first reported in 1956 by two Swiss endocrinologists, Andrea Prader and Heinrich Willi, with Alexis Labhart as an internist. The syndrome was estimated to occur once every 15,000 to 25,000 births (4). Two chromosomal abnormality tests can be used to validate the syndrome genetically. The first is fluorescent in-situ hybridisation (FISH), which only identifies PWS individuals with deletion and cannot distinguish between uniparental disomy (UPD) and an imprinting error. The second test is the DNA methylation analysis test (Methylation PCR), which identifies more than 95% of PWS genetic subtypes (5,6). There are three genetic subtypes: PWS deletion (60%), UPD (36%), and imprinting defect (4%) (6).

During pregnancy, the physical characteristics of PWS start appearing in the third trimester. Lethargy of foetus movement; abnormalities in the flexion of the hands, feet, and elbows; excessive accumulation of amniotic fluid; and breech presentation are noted (7). In early infancy, growth retardation and severe hypotonia occur in infants with PWS due to poor suckling ability. Weak crying, genital hypoplasia, and depigmentation are also observed (8). Additionally, in late childhood and adolescence, individuals with PWS are characterised by a short structure, a narrow nasal bridge, almond-shaped eyes with mild strabismus, thin upper lips, scoliosis, obesity, hypogonadism, mild hypoplasia, and small hands and feet (9). The PWS population experiences four nutritional phases of eating behaviours and weight gain difficulties. Feeding difficulties and a lack of appetite are noticed in the early period (0–9 months). The second phase is divided into two sub-phases. In the first phase (2a), individuals with PWS gain weight without increases

in appetite or calorie consumption. In the second phase (2b), increases in appetite and calorie consumption are reported although the PWS individuals still feel full. The third phase lasts from the age of eight until adulthood. Hyperphagia will be apparent, and the patient rarely feels full. It is considered impossible to control appetite during the final nutritional phase (10).

According to de Lima *et al.* (2016), in comparison to those without the syndrome, individuals with PWS have specific dietary needs due to their reduced energy expenditure, constant food craving that leads to morbid obesity, complicated medical issues, and behavioural challenges. Children with PWS require an intake of 8-11 kcal/cm/day, whereas those who are typically developing require 11-14 kcal/cm/day (11). A balanced low-calorie diet consisting of approximately 30% fat, 45% carbohydrate (with at least 20 g of fibre per day), and 25% protein has been shown to bring significant improvements in body weight composition in individuals with PWS aged 2-10 years, compared with a standard energy-restricted diet (12). In individuals with PWS, weight gain starts before the onset of hyperphagia (13). As the prevalence of obesity rises, it elevates the intricacy and complexity of the issue (13). According to the report by de Lima *et al.* (2016), the main causes of early morbidity and mortality in people with PWS are obesity, as well as overweight-related illnesses (diabetes mellitus, cardiopathies, sleep disorders, and osteoarticular disorders) (1). Despite the lack of agreement on the most effective dietary strategies for preventing obesity among PWS individuals, the recommendation for a hypocaloric diet is widely acknowledged (1). Several publications have been produced on dietary interventions among PWS individuals in order to manage obesity (6,10,14), but no scoping reviews have been released. The current scoping review aims to identify the dietary interventions that have been utilised to treat obesity among PWS individuals.

2. Methodology

This scoping review was conducted to identify the dietary interventions that have been utilised to treat obesity among PWS individuals, following the six stages of the Arksey and O'Malley scoping review methodology (15): *i*) stating the research question, *ii*) identifying related literature, *iii*) selecting relevant studies *iv*), mapping out the data, *v*) outlining, arranging, and stating the results, and *vi*) proficient consultation.

2.1. Stage 1: Stating the research question

The most recent and relevant studies were employed to identify the research question. Consequently, the current scoping review aimed to answer the following research question: Which dietary interventions have been utilised to treat obesity among PWS individuals?

2.2. Stage 2: Identifying related literature

The present scoping review employed specific search terms and databases to identify the relevant literature. The following search terms were employed during the scoping review: (Dietary Treatment OR Dietary Intervention OR Dietary Approach OR Dietary Strategies OR Dietary Management OR Dietary Education OR Mediterranean Diet OR Low Caloric Diet OR Low Carb Diet) AND (Prader Willi Syndrome Children OR Prader Willi Syndrome Adolescent OR Prader Willi Syndrome Patients OR Labhart Willi Syndrome Children OR Labhart Willi Syndrome Adolescent OR Labhart Willi Syndrome Patients).

The inclusion criteria employed in this study were full-text research articles, human studies, English-language studies, and studies published between 2017-2023 that identified dietary interventions that have been utilized to treat obesity among PWS individuals. To identify relevant studies, a comprehensive search was conducted across four academic databases: Scopus, EBSCOhost, MEDLINE (PubMed), and CENTRAL. These databases were purposefully selected to provide broad coverage of research within the area of interest.

Studies that focused solely on hormonal treatments, pharmacological procedures, dietary supplement interventions, physical activity interventions, or surgical procedures without addressing dietary interventions were eliminated. Additionally, studies categorized as study protocols, conference abstracts, book chapters, case reports, reviews, and short communications were also excluded.

2.3. Stage 3: Selecting relevant studies

The study selection process was conducted autonomously by a single reviewer, who reviewed each article based on the inclusion criteria regarding the target population, study design, duration, intervention, outcomes of interest, and type of article. To minimize the risk of bias or omissions, the selected studies were then reviewed and verified by the two authors (Rajikan R and Abdul Hamid H). The PRISMA-ScR (Reporting Items for Systematic Review and Meta-Analysis Extension for Scoping Review) flowchart for the study selection process is shown in Figure 1 (16). After identifying the studies, the titles were evaluated to identify relevant studies to eliminate duplicate records. The abstracts were then assessed according to the eligibility criteria. Ultimately, the publications were selected after a full-text assessment.

2.4. Stage 4: Mapping out the data

Data extraction, the fourth stage of the Arksey and O'Malley process, refers to applying a descriptive-analytical method to chart the data. The data from the

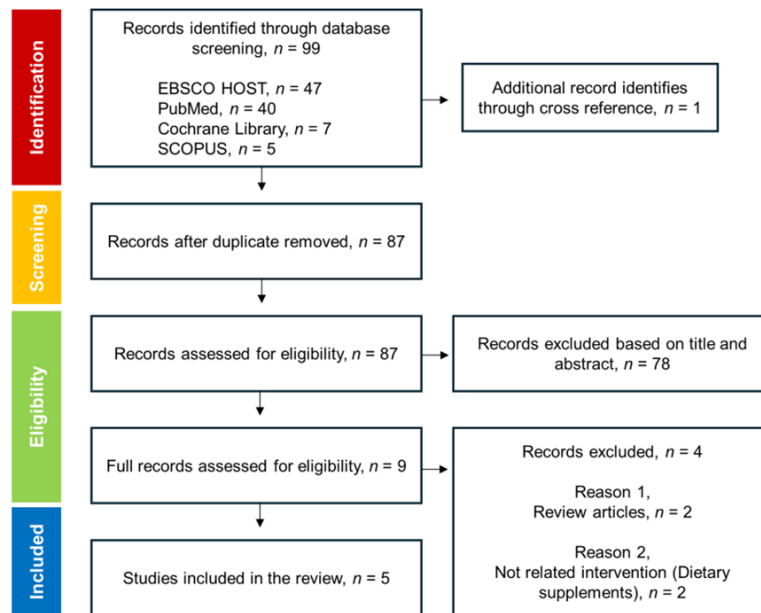


Figure 1. Reporting items for systematic review and meta-analysis extension for scoping review (PRISMA-ScR) flow chart diagram.

eligible studies were organized in a standardized table using Microsoft Excel. This highlighted fundamental components: English language, full-text articles, title, study objectives, participants, publication year, author(s), study duration, study design, intervention, and study outcomes and findings.

Although scoping reviews do not essentially require formal quality appraisal, we incorporated a basic quality appraisal to support clearer results interpretation. Studies evaluation focused on key domains such as authors (year) (ref), country, sample size and age (years), duration, study design, intervention, control group, adherence, and outcomes. Three reviewers independently performed the studies assessments, and differing opinions were discussed and resolved collaboratively. This approach provided a clearer vision of the evidence by reflecting detailed and nuanced information from the included studies. The appraisal highlighted notable strengths, including well-described interventions, duration and outcomes. However, a limitation is that, due to the heterogeneity in study designs and methodologies, the appraisal findings should be interpreted with caution and do not constitute a formal risk-of-bias evaluation. Nonetheless, these insights enriched our understanding and interpretation of the evidence without excluding any studies, ultimately strengthening the review's conclusions.

2.5. Stage 5: Outlining, arranging, and stating the results

The fifth stage of the Arksey and O'Malley framework (2005) is the creation of a result template by grouping comparable articles based on the inclusion criteria used in the review (review question and purpose), demonstrating

quantitative and thematic analysis, as well as applying the scoping review PRISMA guidelines shown in Figure 1 below.

2.6. Stage 6: Proficient consultation

The scoping review outcomes were assessed by three experts in nutrition and dietetics from the Faculty of Health Sciences at the Universiti Kebangsaan Malaysia. Each expert independently evaluated the review based on the established inclusion and exclusion criteria, methodological rigor, and relevance to the research objectives to ensure the accuracy and reliability of the assessment. Any disagreement was resolved by the reviewers through discussion.

3. Results

3.1. Study and participants characteristics

The literature search was conducted across four electronic databases, and 100 publications were retrieved using the framework and inclusion criteria mentioned above. After duplications were removed, 87 records remained for screening. At this stage, 87 records were identified and evaluated for eligibility by reading each study's abstract, and nine articles were selected for full-text evaluation to determine their eligibility. A total of four records were excluded, with justifications. Two reviews and two non-relevant interventions (dietary supplement only) studies were excluded. Only five articles fulfilled the review's inclusion criteria, as shown in Figure 1. Participants' characteristics and studies' geographical contexts are highlighted in Table 1. Across the five studies, a total of

Table 1. The characteristics of PWS individual's dietary interventions that have been utilized to treat obesity included studies

Authors (Year) (Ref)	Country	Sample Size (n) & Age (Years)	Duration	Study Design	Intervention	Control Group	Adherence	Outcomes
Koizumi M, <i>et al.</i> (2020) (3)	Japan	n = 17 / (2–7 years)	Between November 1981 and March 2018	Retrospective Study	Energy-restricted diet (< 10 kcal/cm height/day) with macronutrient distribution of 13–20% protein, 50–60% carbohydrates, and 20–30% fat, supplemented with vitamins/minerals. Parents received education on PWS behavior, diet, and physical activity.	Comparison held among PWS subgroups (GH-up; not explicitly reported. 4 of 7 subjects completed the diet; others dropped due to compliance challenges.		No significant weight reduction was shown among participants.
Felix G, <i>et al.</i> , (2020) (4)	USA	n = 7 / (6–12 years)	4 months	Feasibility Study	Modified Atkins diet with limited carbohydrates (10–15 g/day), customized protein and fat intake, vitamin and mineral supplementation, and hydration emphasis.	None	All included subjects	Weight loss was limited: one participant lost weight, while others maintained their weight. After the participants stopped following the intervention, weight regain was observed.
Teke Kisa P, <i>et al.</i> (2023) (17)	Turkey	n = 10 (median age 52.5 (47–77) months)	16.5 (11–52) months	Retrospective, cross-sectional descriptive study	A ketogenic diet consists of a macronutrient distribution of daily calories (75–85% from fat and 15–25% from protein + carbohydrates).	None	who completed ≥6 months with high adherence.	A favorable weight loss was observed among participants.
Bedogni G, <i>et al.</i> (2020) (18)	Italy	n = 45 / (22–30 years)	Between June 2001 and February 2013	Retrospective cohort study	A Mediterranean diet subtracting at most 500 kcal from TEE, one hour of aerobic exercise, and 3–4 km of walking.	None	Regular follow-up every 6 months, attendance to in/out-patient programs documented	A significant reduction in body weight after a follow-up period of 6 years. This weight loss is associated with a decrease in body fat mass (FM), total cholesterol, and low-density lipoprotein (LDL).
Hirsch HJ, <i>et al.</i> (2021) (19)	Israel	n = 34 / (4–19 years)	From 2008 to 2019.	Cross-sectional study	Caloric requirements are determined by height and BMI, with macronutrient ratios of 40–45% carbohydrates, 25–30% protein, 30% fat, and 30 minutes of daily treadmill activity.	PWS adults living at home with families, matched by age to PWS adults hostel residents	High adherence due to structured and supervised hostile environment	Participants demonstrated effective weight management with body mass index (BMI) values within or approaching the normal range.

113 participants with PWS were included, comprising both adult and paediatric populations. Of these, 55.7% of the participants were female, and 44.2% were male. The studies exhibited varied age ranges, with the first (2–7 years) and third (4–6.5 years) focusing on early childhood, whereas the second (6–12 years) encompassed middle childhood to early adolescence. The fourth study exclusively focused on young adulthood (22–30 years), whereas the fifth study encompassed the widest age range (4–19 years), spanning early childhood to early adulthood. Additionally, studies were conducted across various geographical locations, which were Japan, the USA, Italy, Turkey, and Israel. Moreover, the studies adopted a range of research approaches, comprising three retrospective studies, one clinical feasibility study, and one cross-sectional study, spanning multiple settings such as research institutions and hospitals. A notable variability in the intervention duration was observed, ranging from short-term interventions of four months to long-term follow-up assessments spanning up to 36 years.

3.2. Dietary interventions for obesity treatment

This comprehensive review identified two distinct dietary intervention approaches. Three articles focused exclusively on dietary interventions (3,4,17), while two examined multidisciplinary programs that combined dietary intervention and physical activity (18,19), as summarized in Table 1.

3.3. Exclusive dietary interventions

Three studies investigated dietary interventions for obesity management in PWS individuals with obesity. Koizumi *et al.* (3) conducted a retrospective analysis of the effect of nutritional intervention on patients aged 2 to 27 years with PWS who were treated at Osaka Women's and Children's Hospital from 1981 until 2018 (3). In the study, a caloric restriction program was implemented in growth hormone (GH) treated and untreated PWS individuals. Participants received less than 10 kcal/cm height per day, age-specific macronutrient ratios (13–20% protein, 50–60% carbohydrates, and 20–30% fat), as well as vitamin and mineral supplementation. Moreover, regular exercise and parents' continuing education on PWS-specific eating habits were recommended for all subjects. The results showed that the GH-treated group had higher muscle mass (73.1%) and lean body mass (76.8%), whereas the GH-untreated group had increased fat mass (35.8%) (3). These findings suggested that GH therapy in line with dietary control and regular physical exercise stimulates muscle anabolism and inhibits body fat accumulation in PWS individuals.

In a US-based pilot study (4), the modified Atkins diet (MAD) was trialled in seven individuals with PWS over four months. The diet involved 10–15 grams of

net carbs per day, while protein and fat intake were adjusted to induce ketosis, alongside the prescription of multivitamins and minerals. Participants were also provided counselling on diet, measuring urine ketones, recipes, and meal samples. Among the four participants who completed the four-month diet trial, one achieved a weight loss of 2.9 kg, while the others maintained their weight. The body mass index z-scores of three of the four individuals improved. However, after the regimen was terminated, all subjects gained weight, including the patients who had lost weight (4). This highlights the limited sustainability of MAD without long-term adherence strategies.

A Turkish descriptive cross-sectional study (17) investigated the impact of a structured dietary intervention in a sample of 10 PWS participants aged 47–77 months old. Families attended a four-hour education session, and personalized eating plans were generated based on medical history, level of physical activity, and nutritional requirements. The intervention was conducted for 16.5 months and involved restricting the caloric intake to 600–1,800 kilocalories per day, of which 70–85% were obtained from fats, while 15–30% were obtained from proteins and carbohydrates, with carbohydrate consumption restricted to 20–60 g/d. Body weight according to the Standard Definition (SD) significantly reduced from 2.10 to 0.05 ($p = 0.007$) with a decrease in median BMI SD from 3.05 to 0.41 ($p = 0.002$). These results suggest that the structured dietary education program and individualized dietary intervention would be useful for weight control in PWS individuals.

3.4. Multidisciplinary interventions (diet and physical activity)

Two studies evaluated the impact of multidisciplinary interventions incorporating both diet and physical activity components in individuals with PWS. In a retrospective cohort study conducted in Italy (18), the effects of a long-term metabolic rehabilitation program on 45 obese PWS individuals aged ≥ 17 years were assessed. The intervention comprised a Mediterranean diet with an energy intake of 500 kcal less than total energy expenditure and a structured physical activity program involving five days of supervised physical activity. This included one hour of moderate aerobic activity and three to four kilometres of outdoor walking. Patients and caregivers were regularly counselled about diet and fitness. BMI reduced by 1.7 kg/m² and 2.1 kg/m² over three and six years, respectively, and weight decreased by 3.6 kg and 4.6 kg, respectively. Body fat percentage dropped by 2%, and total and low-density lipoprotein cholesterol decreased (18). The results indicate that following a Mediterranean diet in conjunction with a well-structured exercise program can considerably improve BMI, weight, body composition,

and lipid profile in obese subjects with PWS.

Similarly, a study from Israel by Hirsch *et al.* (19) examined the impact of multidisciplinary interventions on weight management among obesity in 34 children and adolescents aged 4–19 years old living in residential care homes with an average follow-up of 6.9 years. Participants were compared to age-matched controls living in family environments. Both cohorts participated in annual multidisciplinary clinics with similar dietary, exercise, and behavioural interventions. Individualized meal plans were developed by dietitians, and the calorie intake was between 800 and 1,500 kcal in subjects with a BMI below 23 kg/m². The macronutrient distribution was 40–45% carbohydrates, 25–30% protein, and 30% lipids. Treadmill exercise was tailored by weight into regular 30-minute bouts (19). The results indicated that of the 23 participants, four subjects who lived at the family home had a BMI exceeding 30 kg/m², compared to 17 of the 23 participants living at a care home. Moreover, most participants with a high BMI upon entering a care home lost weight and kept their normal weight status (19). The results suggest that multidisciplinary care home-structured intervention settings may offer more effective support for long-term weight control in PWS individuals compared to less structured home environments.

4. Discussion

A comprehensive strategy is essential for monitoring health and improving the quality of life of individuals with PWS. This includes dietary therapy, physical activity, hormonal treatments, and pharmacotherapy. PWS individuals' demands are subjective. Although recent advancements have enhanced our understanding of the genetic factors contributing to obesity in PWS, optimal weight management protocols remain a subject of ongoing debate. Ensuring that individuals with PWS adhere to a balanced diet from an early age is critical because this fosters physical well-being and helps them manage hyperphagia and obesity throughout their lives (20,21).

The primary purpose of this scoping review was to identify dietary interventions that have been applied to treat obesity among PWS individuals. The five studies included in the review explored dietary interventions and measures of effectiveness related to PWS (3,4,17–19). These included three exclusive dietary interventions and two multidisciplinary programmes combining diet, physical activity, and caregiver support. The study by Koizumi *et al.* involved age-appropriate dietary intervention of less than 10 kilocalories per centimetre, in addition to dietary supplements such as vitamins and minerals, which were applied for PWS children (3). The second study examined the effects of a MAD on PWS children (4), while the third study used ketogenic diets as an intervention for PWS children (17). The fourth study examined a multidisciplinary metabolic rehabilitation

program composed of a Mediterranean diet and physical activity in terms of its potential effectiveness in assessing weight and body composition (18). Lastly, the fifth study involved long-term weight management in PWS individuals residing in care homes using a multidisciplinary metabolic rehabilitation program (19). Although the included studies provided valuable insights, the rarity of PWS resulted in only a small number of eligible studies, each with limited sample sizes and varied methodologies. This restricts the generalizability of the findings and hampers robust conclusions about long-term effectiveness and safety of dietary interventions. Future research with larger cohorts and standardized protocols is essential to strengthen the evidence base and improve applicability across diverse PWS populations.

Furthermore, considerable heterogeneity exists among the included studies, reflected in their diverse designs — retrospective, cross-sectional, and feasibility studies and intervention durations ranging from 4 months up to 36 years. Additionally, the studies employed differing outcome measures and varied dietary intervention protocols, complicating direct comparisons and synthesis. This variability highlights the pressing need for future investigations to adopt standardized study designs, consistent intervention frameworks, and uniform outcome assessments to enable clearer interpretation of intervention efficacy and safety in individuals with PWS.

Evidence for exclusive dietary strategies was mixed. In the study by Koizumi *et al.*, a hypocaloric diet implemented for weight control intervention alone did not yield statistically significant findings (3). Furthermore, PWS individuals in the treated group saw linear growth due to GH administration (3). The administration of GH may have played a role in the observed height rise, irrespective of the hypocaloric diet, as it directly affects bone growth and height development. Moreover, the hypocaloric diet supplied the necessary nutrients to support the action of GH. On the other hand, the results from other studies have proven the diet's effectiveness when paired with structured protocols (1,11). Notably, the investigations mentioned the exact amounts and types of dietary elements, educating PWS individuals and caregivers about the hypocaloric diet, provision of personalized dietary plans, and regular follow-up to confirm an appropriate and effective dietary approach (1,11). This underscores the critical need for a structured and comprehensive approach to maintain growth and weight control among PWS population. Future interventions should prioritize multidisciplinary collaboration of structured dietary protocols, GH therapy, caregiver education, and long-term studies of personalized weight and growth management among PWS individuals to ensure dietary strategies are both clinically effective and sustainable in real-world settings.

Next, the MAD has been implemented as a dietary intervention in weight management for PWS individuals (4). The first prospective clinical study that involved

a comprehensive support system for PWS individuals noted varying levels of low-carbohydrate diet adherence (4). Overall, weight loss was barely noticeable (4). Conversely, the supporting literature on a keto diet in other populations suggests that Cervenka *et al.* employed a more rigid dietary limit — 20 grams of net carbohydrates daily — without comparable emphasis on caregiver training or tailored dietary planning. The limited strategy used led to weight gain in some participants with an elevation of some biomarkers, such as cholesterol and LDL (22). This highlights that the approach used in the intervention demands further assessments and adjustments to enhance its efficacy in weight management outcomes among similar populations. Furthermore, it is essential to evaluate the risks associated with MAD to determine cardiovascular safety and therapeutic value.

As for the ketogenic diet, several studies revealed its effectiveness in reducing body weight among the normal population (23-26). Moreover, the results of the included study imply that a reduced-calorie, carbohydrate-restricted, well-balanced diet that incorporates strict observation can favourably influence weight reduction in individuals with PWS (17). Furthermore, the investigation of a reduced energy intake and a well-balanced diet for weight control in children with PWS indicated that dietary education, regular feedback, relying on caregiver-reported dietary recalls collected biannually, and altering the macronutrient allocation culminated in a remarkable mass reduction compared to conventional caloric restriction alone (12). Additionally, the study outcomes stated that a high-fibre diet was superior to a standard reduced-calorie diet (12). Hence, despite the promising outcomes shown in PWS populations when using the ketogenic diet, the effectiveness and safety of this dietary approach cannot be definitively determined due to the limited number of participants and the short length of the trials. Therefore, long-term clinical trials with large sample sizes are urgently needed before such restrictive dietary interventions are recommended to focus on future studies.

Restrictive dietary approaches such as Ketogenic and MAD showed efficacy in addressing obesity management among PWS individuals. Despite their potential, they introduce remarkable risks such as safety, long-term feasibility, and adherence. Evidence noted that ketogenic diet commonly reported side effects such as gastrointestinal upset, elevated cholesterol or triglycerides, liver enzyme abnormalities, and, although infrequent, complications like cardiomyopathy or pancreatitis (27,28). Restrictive diets must be cautiously assessed among the PWS population, where metabolic and hormonal imbalances and instability exist. Furthermore, adhering to low-carbohydrate dietary regimens poses significant challenges to maintain, due to compulsive food-seeking behavioural characteristic of PWS and hyperphagia. Regarding the MAD, clinical

findings indicated notable adherence challenges, where participants commonly faced adherence issues and post-intervention weight regain (20). Caregiver burden is substantial as they must manage both behavioural supervision and medical follow-up, including blood tests for lipid profiles, and hepatic and renal function. In addition, nutritional markers are essential to minimize risks and ensure safety (10). This emphasizes that while restrictive dietary interventions may present therapeutic value, their practical implementation demands cautious long-term evaluation, personalized consideration, and comprehensive care team involvement. Future investigations are needed to emphasize not only therapeutic impact, but also the development of sustainable, and realistic diet protocols that are designed to accommodate PWS individual's physiological characteristic and eating behaviours.

From the perspective of long-term multidisciplinary dietary rehabilitation programs for people with PWS, an investigation by Bedogni *et al.* revealed a significant average weight reduction and a corresponding decrease in BMI after a follow-up period of six years (18). These results are consistent with those of a previous study on obesity in PWS individuals, and they highlight the important role of multidisciplinary dietary rehabilitation programs in weight control among people with PWS (29). In addition, based on their investigation, Bedogni *et al.* emphasized a logical decrease in the percentage of adipose tissue and an increase in muscle development, both of which are consistent with the expected results of an average weight reduction. We can perceive that people with PWS can achieve similar results with a continuous and appropriate dietary rehabilitation intervention. However, it is difficult to derive a cause-and-effect relationship from an observational study. Results obtained in a tertiary care centre may restrict broader applicability in other contexts. In addition, full body composition measurements were not available due to technical limitations, which could have affected the accuracy of the results. Future investigations are recommended to verify these findings using more robust designs and comprehensive assessment tools across diverse healthcare contexts.

The accomplishment of the dietary intervention among PWS individuals living in care homes can be attributed to the regulated environment, unfailing backing from a multidisciplinary group, and limited availability of energy-dense foods in comparison to the subjects who lived in the family home (19). Similarly, Kaufman *et al.* conducted a study of a PWS group living with their families, implementing diet restrictions, supervised exercise, and a structured environment, which led to significant weight reduction among PWS participants (30). The findings from both investigations highlight the significance of a controlled environment and multidisciplinary assistance in helping PWS individuals successfully manage their weight. This type

of investigation requires a larger sample size and a more thorough analysis of the social, environmental, or health factors that contribute to the observed findings. Further research is needed with larger populations and across different living conditions to disentangle the impact of related factors such as caregiver capacity, socioeconomic status, and access to health services. Moreover, the controlled conditions and multidisciplinary guidance provided in these PWS studies raise issues regarding validity, as such settings may not reflect exact real-life conditions. The effectiveness of dietary interventions cannot be generalized to different living conditions. Therefore, further research is necessary. In addition, a more holistic research framework that extends beyond obesity, such as behavioural, psychological, and metabolic health, could provide a more comprehensive understanding of the overall health of PWS individuals living in residential hostels and family care settings.

5. Strengths and limitations of the study

The strengths of the present review included the use of a systematic search strategy to locate publications demonstrating the dietary intervention strategies used to treat obesity in PWS patients. The risk of bias was reduced by screening duplicates and applying prior inclusion criteria. As PWS is a rare genetic disorder, this review is the first scoping study to comprehensively identify the dietary intervention strategies used to treat obesity among PWS individuals. To establish this, we conducted a systematic and extensive literature search across multiple databases — PubMed, Scopus, EBSCOhost, and the Cochrane Library — using relevant keywords related to PWS and dietary intervention, as detailed in the methodology section. This thorough search found no previous scoping reviews specifically addressing dietary approaches for obesity in this population, hereby underscoring the originality and significant contribution of the present study. Consequently, only a small fraction of the studies would likely have been missed. Nonetheless, certain limitations must be acknowledged. The small number of recent publications on PWS dietary intervention studies is due to the rarity of the syndrome, which occurs once every 15,000 to 25,000 births (4), and its complexity, as well as the challenges linked to recruitment, ethical considerations, resource constraints, and lack of awareness. While these challenges exist, ongoing efforts are being made by researchers, healthcare professionals, and advocacy organisations to better understand and manage PWS.

6. Conclusion

In summary, the current scoping review highlighted the dietary interventions, such as the ketogenic diet, as well as other approaches like multidisciplinary metabolic

rehabilitation programs and living in a restricted environment, that have been used to treat obesity among individuals with PWS. However, it is important to note that the small number of eligible studies, along with small sample sizes and methodological differences due to the rarity of the syndrome, pose a challenge to the generalizability of findings and to establish more conclusive evidence on the long-term impact of dietary interventions in individuals with PWS. Although adherence to restricted diets can be challenging for people with PWS and their caregivers, significant results have been observed with a long-term multidisciplinary dietary program and a ketogenic diet (17-19). Further research in the field of dietary intervention, involving larger, more standardized samples, and methodologies are essential for developing systematic dietary approaches that can effectively contribute to the prevention and treatment of obesity in people with PWS. Specifically, there is a need for well-designed randomized controlled trials, standardized dietary protocols, and longitudinal studies to fill existing evidence gaps and better evaluate long-term outcomes and adherence challenges. This scoping review has laid the foundation for future research and underlined the importance of constant efforts to understand and implement effective dietary approaches for people with PWS.

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