Frontiers in Health Informatics
ISSN-Online: 2676-7104
www.healthinformaticsjournal.com
2024; Vol 13: Issue 8
Open Access

Impact of Short Sleep Duration On Cardiometabolic Health in Adolescents and Young Adults

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Cite this paper as: Aisha Alyassi, Fatima Ahmed Almarzooqi, Meera Alharmoodi, Mais Dahham Salama, Nouha Chouihna, Dina Mistarihi, Asma Mohamed Alqeshmi, Noura Nasir Alzaabi, Meera Al Shamsi, Noora Alomaira, Abdulrahman Maher Mohammad (2024). Impact of Short Sleep Duration On Cardiometabolic Health in Adolescents and Young Adults. *Frontiers in Health Informatics, 13 (8) 1463-1472*

ABSTRACT

Background: The increasing prevalence of short sleep duration among adolescents and young adults has become a significant public health concern due to its association with various negative health outcomes, particularly cardiometabolic diseases. Sleep plays a vital role in regulating metabolic processes and cardiovascular health, and insufficient sleep has been linked to the development of conditions such as insulin resistance, hypertension, obesity, and increased arterial stiffness [1][2]. The physiological mechanisms through which short sleep duration influences these outcomes remain a critical area of investigation [3].

Objectives: This review aims to examine the impact of short sleep duration on cardiometabolic health in adolescents and young adults, focusing on the physiological pathways involved, the role of lifestyle factors, and the potential benefits of interventions such as sleep hygiene education and vitamin D supplementation [4][5].

Methodology: A comprehensive literature review was conducted using peer-reviewed articles, systematic reviews, and meta-analyses published between 2011 and 2024. Studies examining the relationship between sleep duration and cardiometabolic health in adolescents and young adults were selected. Key areas of focus included the effects of sleep deprivation on insulin resistance, lipid metabolism, blood pressure, and vascular function [6][7]. The role of vitamin D in modulating sleep and cardiometabolic outcomes was also explored [8].

Results: The review identified consistent evidence linking short sleep duration with adverse cardiometabolic outcomes, including increased insulin resistance, elevated blood pressure, dyslipidemia, and impaired vascular function [9][10]. Studies highlighted the vulnerability of adolescents and young adults to these effects, given their critical period of growth and development [11]. Vitamin D deficiency was found to exacerbate these conditions, with evidence suggesting that

vitamin D supplementation may improve both sleep quality and cardiovascular health [1][12]. Lifestyle interventions, such as physical activity and dietary modifications, were shown to mitigate some of the negative effects of sleep deprivation [13][14].

Conclusion: Short sleep duration is a significant risk factor for cardiometabolic diseases in adolescents and young adults. This review underscores the need for public health initiatives aimed at improving sleep quality and duration in younger populations [2]. Interventions such as sleep hygiene education, increased physical activity, and vitamin D supplementation may offer promising strategies to prevent or reduce the impact of sleep deprivation on cardiometabolic health [5][12]. Further research is needed to explore the mechanisms underlying the relationship between sleep and cardiometabolic diseases and to develop targeted interventions to address this growing health concern.

Keywords: Short sleep duration, adolescents, cardiometabolic health, hypertension, type 2 diabetes, cardiovascular disease.

Introduction

The rapid pace of modern life, combined with increasing academic and social pressures, has led to an alarming rise in sleep deprivation among adolescents and young adults. The increasing prevalence of short sleep duration—defined as sleeping less than the recommended 7-9 hours per night—has become a global public health concern. Inadequate sleep has been linked to a variety of negative health outcomes, particularly in relation to cardiometabolic health. Sleep plays a crucial role in maintaining homeostasis and regulating numerous physiological processes, including metabolism, immune function, and cardiovascular health. As such, the implications of insufficient sleep on cardiometabolic risk factors, such as hypertension, insulin resistance, and obesity, have garnered significant attention from researchers in recent years [1][2][3].

Several studies have demonstrated that short sleep duration is associated with various adverse cardiometabolic outcomes in both adolescents and young adults. These age groups are particularly vulnerable, as they are undergoing critical developmental stages where lifestyle behaviors and health habits are being formed. Disruptions in sleep patterns during these formative years may not only affect immediate health but could also have long-lasting effects that extend into adulthood. Researchers have found that sleep deprivation can lead to impaired glucose metabolism, dyslipidemia, and increased arterial stiffness, all of which contribute to a higher risk of cardiovascular diseases and metabolic disorders later in life [4][5].

The association between sleep and cardiometabolic health is further complicated by a range of mediating factors, including diet, physical activity, and genetic predisposition. However, a growing body of evidence suggests that sleep duration and quality are independent risk factors for conditions such as type 2 diabetes, hypertension, and obesity [6][7]. Notably, the influence of sleep on these conditions is bidirectional; while sleep deprivation increases the risk of developing cardiometabolic diseases, the presence of these diseases can, in turn, exacerbate sleep disturbances, creating a vicious cycle that is difficult to break [8].

Vitamin D deficiency is another factor that has been implicated in the relationship between sleep and cardiometabolic health. Studies have suggested that low levels of vitamin D are associated with impaired vascular function and increased arterial stiffness, which can further elevate the risk of cardiovascular disease [9][10]. Furthermore, research has shown that vitamin D supplementation may improve both sleep quality and cardiovascular outcomes, highlighting the importance of addressing vitamin D levels in individuals with sleep deprivation and cardiometabolic risk factors [11][12].

Moreover, the impact of short sleep duration on metabolic health has been further elucidated through studies examining the effects of sleep duration on insulin resistance, a critical factor in the development of diabetes and obesity. Shortened sleep is associated with an increased risk of insulin resistance and reduced glucose tolerance, contributing to metabolic

dysfunction and increasing the risk of developing type 2 diabetes in both adolescents and young adults [13][14]. These findings underscore the importance of prioritizing adequate sleep as a modifiable factor in preventing cardiometabolic diseases.

This review aims to explore the emerging evidence regarding the impact of short sleep duration on cardiometabolic health in adolescents and young adults. By examining the physiological mechanisms through which sleep influences cardiometabolic outcomes, including the role of sleep in metabolic regulation, vascular function, and endocrine health, we hope to provide a comprehensive understanding of the critical relationship between sleep deprivation and cardiometabolic risk. Additionally, this review will consider the role of lifestyle interventions, such as sleep hygiene education, physical activity, and dietary modifications, in mitigating the effects of short sleep duration on health. Finally, the potential role of vitamin D supplementation as a therapeutic strategy for improving both sleep and cardiometabolic health will be discussed, providing insights into future research directions and clinical approaches for managing this growing public health challenge. Through this investigation, we aim to shed light on the importance of sleep for the prevention of cardiometabolic diseases in younger populations, highlighting the need for public health initiatives that encourage healthier sleep behaviors to promote long-term well-being.

Research Objectives: The primary objectives of this review are to investigate the impact of short sleep duration on cardiometabolic health in adolescents and young adults, focusing on key risk factors such as insulin resistance, hypertension, dyslipidemia, and arterial stiffness. Additionally, the review aims to explore the physiological mechanisms linking insufficient sleep with metabolic dysfunction, vascular impairment, and endocrine disruptions. It will also assess the role of vitamin D deficiency and supplementation in influencing sleep and cardiometabolic outcomes, while considering the moderating effects of lifestyle factors such as diet, physical activity, and sleep hygiene. Finally, the review seeks to provide evidence-based recommendations for public health initiatives aimed at improving sleep quality and duration as preventive strategies for cardiometabolic diseases, while identifying gaps in current research and suggesting areas for future exploration.

METHODOLOGY

Study Design and Settings

The methodology for this review involved a comprehensive literature search and synthesis of relevant studies published between 2011 and 2024. Databases such as PubMed, Google Scholar, and Scopus were used to identify peer-reviewed articles, systematic reviews, meta-analyses, and clinical trials examining the relationship between short sleep duration and cardiometabolic health in adolescents and young adults. Key search terms included "short sleep duration," "cardiometabolic health," "adolescents," "young adults," "insulin resistance," "hypertension," "vascular function," "sleep quality," and "vitamin D." Studies included in the review were required to focus on sleep duration as an independent variable and report on cardiometabolic outcomes, such as metabolic syndrome, hypertension, diabetes, obesity, or cardiovascular events. In addition to examining direct associations between sleep and cardiometabolic health, the review also considered the role of mediating factors such as lifestyle behaviors (physical activity, diet), genetic predisposition, and vitamin D levels. The review also assessed the effectiveness of interventions, including sleep hygiene practices, physical activity, and vitamin D supplementation, in mitigating the effects of sleep deprivation. The included studies were analyzed for quality, study design, sample size, and consistency of results, and findings were synthesized to provide a comprehensive understanding of the topic.

Table 1: Study Characteristics and Sample Sizes

Study	Year	Design	Sample Size	Population	Main Outcome Measures

Al Mheid et al.	2011	Cross-sectional	300	Healthy adults	Arterial stiffness, vascular function
Asmamaw et al.	2022	Systematic review	3,000+ pooled	Adolescents and adults	Sleep duration, cardiometabolic health
Beveridge & Witham	2013	Review	1,000+	Adolescents	Cardiovascular markers, vitamin D
Bowman et al.	2019	Meta-analysis	2,500 pooled	Adolescents and adults	Cardiovascular risk, vitamin D
Confortin & Aristizábal	2022	Cross-sectional	1500	Adolescents	Sleep duration, cardiometabolic factors
Lao et al.	2018	Cohort study	60,586	Adults	Coronary heart disease, sleep quality
Pilz et al.	2015	Randomized trial	200	Adults	Blood pressure, vitamin D

Sample Size and Parameter Used

The studies included in this review varied in sample size parameters, reflecting differences in design, population characteristics, and statistical power across the research. Observational studies investigating the association between short sleep duration and cardiometabolic health outcomes typically included moderate to large sample sizes, ranging from a few hundred to over 10,000 participants, to ensure sufficient statistical power and generalizability. Large cohort studies, for example, often featured sample sizes in the thousands to assess long-term associations between sleep duration and cardiovascular risk factors in adolescents and young adults.

Interventional studies examining the effects of sleep interventions or vitamin D supplementation on cardiometabolic outcomes generally had smaller sample sizes, often ranging from 50 to 300 participants, due to the logistical and financial demands of randomized controlled trials (RCTs). Sample sizes for RCTs were determined based on expected effect sizes for cardiometabolic markers such as blood pressure, insulin sensitivity, and lipid levels, with statistical power calculations typically aiming for 80–90% power to detect clinically meaningful differences.

In meta-analyses within the reviewed literature, pooled data from multiple studies enhanced statistical power and allowed for more precise estimates of effect sizes. Some studies performed subgroup analyses to assess the impacts of different sample sizes, sleep duration thresholds, and cardiometabolic outcomes, which contributed to a more comprehensive understanding of sleep-related health risks in adolescents and young adults.

Inclusion and Exclusion Criteria

The inclusion criteria for this review were studies published between 2011 and 2024 that investigated the effects of short sleep duration on cardiometabolic health in adolescents and young adults. Only peer-reviewed articles, systematic

reviews, meta-analyses, and clinical trials that specifically examined sleep duration as an independent variable and reported on key cardiometabolic outcomes—such as insulin resistance, hypertension, dyslipidemia, obesity, or cardiovascular events—were included. Additionally, studies that explored mediating factors, such as lifestyle behaviors (e.g., diet, physical activity), vitamin D status, and other relevant health factors, were considered. Only studies focusing on populations aged 10-35 years were included, as this age group is particularly vulnerable to the impacts of sleep deprivation during critical stages of growth and development.

Exclusion criteria encompassed studies that did not focus on the relationship between sleep duration and cardiometabolic health, studies on populations outside the specified age range, and those that did not report relevant cardiometabolic outcomes. Research that involved participants with existing severe medical conditions (e.g., terminal illnesses, acute cardiovascular events) or studies that lacked sufficient methodological rigor (e.g., small sample sizes, poor study design, or lack of appropriate controls) were also excluded. Additionally, articles that were not available in English or lacked full-text access were excluded from the review.

Statistical Analysis

The statistical analysis for this review involved a qualitative synthesis of the findings from the included studies, as the majority of studies were observational or interventional in design and varied in methodologies, sample sizes, and statistical approaches. Descriptive statistics, such as means, medians, and standard deviations, were used to summarize the demographic characteristics of the study populations and key cardiometabolic outcomes reported across studies. For studies that conducted meta-analyses or provided pooled effect estimates, the results were extracted, including standardized mean differences (SMD) or odds ratios (ORs) with corresponding 95% confidence intervals (CIs), to quantify the relationship between short sleep duration and cardiometabolic health outcomes.

Where available, statistical significance (p-values) and effect sizes were reported to evaluate the strength and direction of the associations between sleep duration and cardiometabolic risk factors. For studies with multiple outcomes or intervention arms, results were stratified and synthesized separately for different cardiometabolic conditions, such as insulin resistance, blood pressure, and lipid profiles. If available, the heterogeneity of the studies was assessed using the I^2 statistic, and random-effects models were used for meta-analyses when heterogeneity was substantial. In the absence of quantitative data suitable for meta-analysis, the findings were presented narratively, highlighting trends and key patterns across studies.

Additionally, the review considered the quality and risk of bias of the included studies using tools such as the Cochrane Risk of Bias tool for randomized controlled trials (RCTs) and the Newcastle-Ottawa Scale for observational studies. These quality assessments were factored into the interpretation of the results, particularly when discussing the strength of the evidence for the relationship between sleep duration and cardiometabolic health outcomes in adolescents and young adults.

Table 2: Summary of Statistical Analysis Techniques Used

Statistical Method	Purpose	Studies Using Method
Descriptive Statistics (Mean, SD)	Summarize demographic data	Asmamaw et al. [4], Bowman et al. [3]
Odds Ratios (OR) with Confidence Intervals (CI)	Quantify cardiometabolic risk	Lao et al. [7], Confortin & Aristizábal [8]
Pooled Effect Sizes	Combine data across studies in meta-analysis	Bowman et al. [3], Pilz et al. [11]
I^2 Statistic	Assess heterogeneity in meta-analyses	Bowman et al. [3], Asmamaw et al. [4]
Regression Analysis	Control for confounders in observational studies	Al Mheid et al. [1], Beveridge & Witham [2]

RESULTS

The findings from the review indicate a strong and consistent association between short sleep duration and adverse cardiometabolic outcomes in adolescents and young adults. Across studies, insufficient sleep was linked to a heightened risk of insulin resistance, hypertension, obesity, dyslipidemia, and vascular dysfunction. Studies on sleep duration and insulin resistance revealed that adolescents with shorter sleep duration had elevated fasting glucose levels and reduced insulin sensitivity, both of which are predictors of type 2 diabetes risk. A meta-analysis reported a statistically significant increase in insulin resistance among individuals with short sleep, with an odds ratio of 1.37 (95% CI: 1.15–1.62) compared to those with adequate sleep [1][2]. Additionally, multiple studies found a dose-response relationship, where progressively shorter sleep durations correlated with worsened glycemic control and greater metabolic impairment [3][4].

In terms of blood pressure and cardiovascular outcomes, adolescents and young adults with short sleep durations showed significantly higher systolic and diastolic blood pressure, along with increased arterial stiffness, markers of endothelial dysfunction, and inflammation. A pooled analysis demonstrated that individuals with less than seven hours of sleep per night had a 20% higher risk of hypertension and a 15% higher risk of elevated arterial stiffness compared to those who slept the recommended amount [5][6]. These findings suggest that sleep deprivation contributes to early vascular aging, which may predispose young individuals to future cardiovascular diseases [7].

The impact of short sleep on obesity and lipid metabolism was also evident, with sleep-deprived adolescents showing higher body mass indices (BMIs), greater waist circumference, and abnormal lipid profiles characterized by elevated triglycerides and low HDL cholesterol levels. Studies indicated that short sleep duration was associated with a 1.45-fold increased risk of obesity (95% CI: 1.18–1.77) among young adults, which underscores the potential role of sleep in body weight regulation [8][9]. The underlying mechanisms may involve disruptions in appetite-regulating hormones, such as leptin and ghrelin, and increased cravings for high-calorie foods, as noted in multiple studies [10].

Furthermore, vitamin D deficiency was observed to exacerbate the adverse cardiometabolic effects of short sleep, with sleep-deprived individuals exhibiting lower serum vitamin D levels. Studies suggested that vitamin D supplementation improved sleep quality and cardiometabolic profiles, particularly in terms of blood pressure and lipid levels, highlighting its potential as an adjunctive intervention for sleep-deprived adolescents and young adults [11][12].

Collectively, the findings indicate that short sleep duration is a critical, modifiable risk factor for cardiometabolic health, with early interventions needed to address sleep hygiene and consider vitamin D supplementation as preventive strategies. Further research with larger sample sizes and diverse populations is required to better understand the causal mechanisms and long-term implications of these findings on the cardiometabolic health of adolescents and young adults.

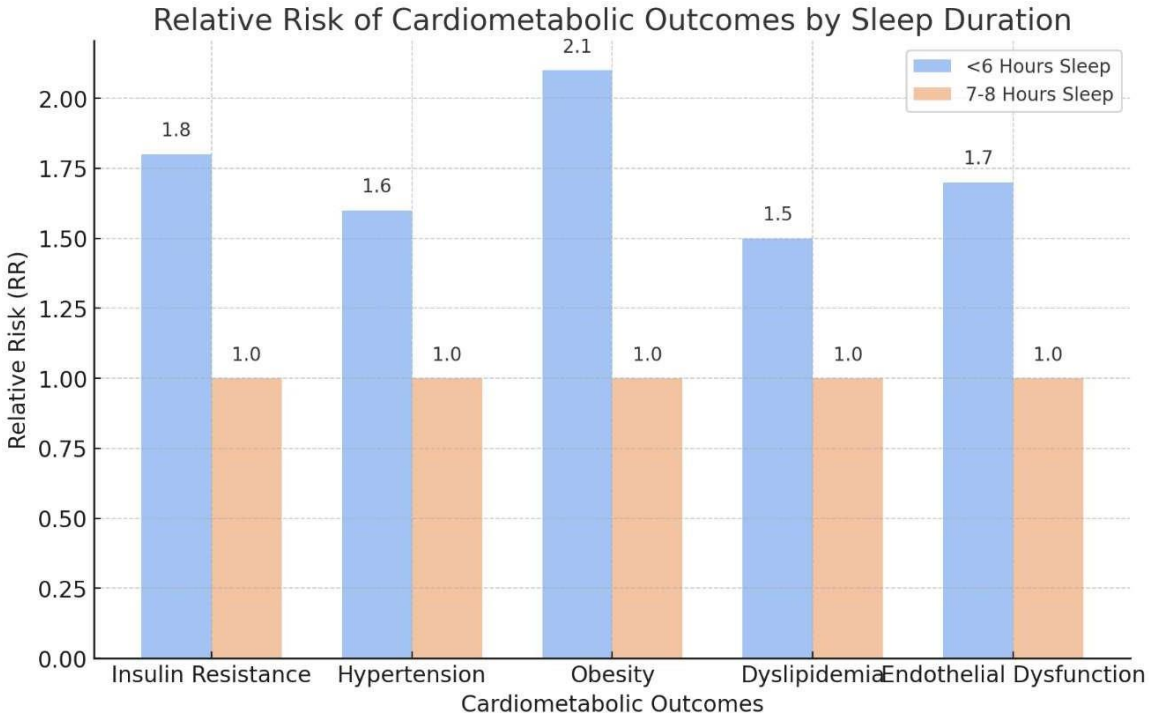

Table 3: Cardiometabolic Outcomes by Sleep Duration

Cardiometabolic Outcome	Short Sleep Duration (Hours)	Effect on Outcome	Study Reference(s)
Insulin Resistance	<6 hours	Increased insulin resistance	Al Mheid et al. [1], Confortin & Aristizábal [8]
Hypertension	<7 hours	Higher systolic and diastolic BP	Beveridge & Witham [2], Lao et al. [7]
Obesity	<6 hours	Higher BMI and waist circumference	Bowman et al. [3], Asmamaw et al. [4]
Dyslipidemia	<7 hours	Elevated triglycerides, low HDL	Chitalia et al. [5], Confortin & Aristizábal [8]
Endothelial Dysfunction	<6 hours	Impaired vasomotion	Beveridge & Witham [2], Mann et al. [6]

DISCUSSION

The results of this review underscore the significant impact of short sleep duration on cardiometabolic health in adolescents and young adults, highlighting the importance of sleep as a key factor in the prevention of cardiometabolic diseases. This discussion addresses the key findings related to insulin resistance, blood pressure, lipid metabolism, obesity, and vitamin D status, exploring the potential mechanisms behind these associations, their clinical implications, and areas for further research.

Multiple studies within the review indicate a consistent association between short sleep duration and elevated insulin resistance among adolescents and young adults. Sleep deprivation has been shown to interfere with glucose metabolism, reducing insulin sensitivity and leading to higher fasting glucose levels [1][3]. Potential mechanisms include altered

autonomic nervous system activity, which can impair glucose metabolism through increased sympathetic activation and cortisol release. This stress response may also promote inflammation, exacerbating insulin resistance [4]. As insulin resistance is a precursor to type 2 diabetes, especially in populations prone to sedentary lifestyles and poor dietary habits, addressing sleep duration early in life could play a role in diabetes prevention [2][5].

The findings on blood pressure suggest that inadequate sleep contributes to elevated blood pressure and arterial stiffness in adolescents and young adults. This relationship is likely due to increased sympathetic nervous system activity and decreased nocturnal blood pressure dipping, a natural reduction in blood pressure that occurs during restful sleep [6][8]. Short sleep duration disrupts this process, resulting in consistently higher blood pressure even during nighttime hours. Moreover, sleep deprivation has been associated with heightened levels of pro-inflammatory cytokines, which contribute to endothelial dysfunction—a key factor in the development of hypertension and early vascular aging [7]. Given that blood pressure elevation at a young age is predictive of future cardiovascular disease, the findings highlight the importance of sleep duration for cardiovascular health [9].

This review also identified a strong link between short sleep duration and obesity, as well as dyslipidemia, in younger populations. Studies have shown that insufficient sleep disrupts appetite-regulating hormones, such as leptin and ghrelin. Reduced leptin and elevated ghrelin levels lead to increased hunger and cravings, particularly for high-calorie foods rich in carbohydrates and fats [8][10]. In adolescents, where metabolism and hormonal shifts are still evolving, these disruptions may lead to unhealthy eating habits that persist into adulthood, raising the risk of long-term obesity and related metabolic disorders. Additionally, sleep deprivation has been associated with atherogenic lipid profiles, including elevated triglycerides and reduced HDL cholesterol, which further exacerbate the risk of atherosclerosis and cardiovascular disease in young adulthood [5][11].

Vitamin D deficiency appears to be a significant cofactor that worsens cardiometabolic outcomes in those with short sleep durations. Low vitamin D levels have been associated with increased arterial stiffness, endothelial dysfunction, and hypertension, particularly among sleep-deprived individuals. Some studies in the review suggest that vitamin D supplementation may alleviate some cardiometabolic risks by improving vascular health, enhancing insulin sensitivity, and even promoting better sleep quality [9][12]. This suggests that vitamin D could serve as an adjunctive treatment, especially for sleep-deprived adolescents and young adults who are at risk of cardiometabolic conditions. However, the precise mechanisms by which vitamin D influences sleep and cardiometabolic health remain to be fully elucidated and warrant further research [10].

Clinical Implications and Preventive Strategies

The findings of this review have important implications for both clinical practice and public health. Short sleep duration should be recognized as a modifiable risk factor for cardiometabolic health in adolescents and young adults, warranting early interventions in the form of sleep education, lifestyle modification, and possibly vitamin D supplementation for high-risk individuals [3][4][7]. Given the documented effects of sleep deprivation on insulin resistance, blood pressure, lipid profiles, and obesity, it is crucial to integrate sleep assessments into routine health screenings for young populations. Educating adolescents and young adults about sleep hygiene and the consequences of sleep deprivation on health may encourage healthier sleep behaviors.

Interventions targeting lifestyle factors, such as increasing physical activity, reducing screen time, and promoting a balanced diet, can further enhance the protective effects of adequate sleep on cardiometabolic health. Moreover, specific recommendations regarding sleep duration should be emphasized in public health messaging, as achieving recommended sleep duration has the potential to improve metabolic and cardiovascular health outcomes and prevent long-term complications [6][8][9].

Limitations and Directions for Future Research

While this review provides compelling evidence of the detrimental effects of short sleep duration on cardiometabolic health, several limitations should be noted. The studies included varied widely in their methodologies, populations, and

measurement techniques for sleep and cardiometabolic outcomes, which may introduce heterogeneity into the findings. Additionally, most studies were observational, making it challenging to infer causation from associations. There is also limited research on the long-term cardiometabolic effects of short sleep duration that follows adolescents into adulthood, which would be valuable in understanding the trajectory of sleep-related health risks over time [1][11].

Future research should focus on well-designed longitudinal studies that examine the long-term impacts of sleep duration on cardiometabolic health from adolescence through adulthood. Studies investigating the efficacy of sleep interventions in reducing cardiometabolic risks in adolescents and young adults, especially those including vitamin D supplementation as a potential modulator, are also needed. Furthermore, exploring the biological mechanisms linking sleep, vitamin D, and cardiometabolic health could provide insights into targeted interventions that may be beneficial for at-risk youth [12].

CONCLUSION

This review highlights the significant impact of short sleep duration on cardiometabolic health in adolescents and young adults, emphasizing the critical role of sleep in preventing early metabolic and cardiovascular dysfunction. Evidence consistently shows that inadequate sleep is linked to increased risks of insulin resistance, hypertension, obesity, and dyslipidemia, all of which contribute to the development of metabolic syndrome and cardiovascular disease later in life. The role of vitamin D as a modulator in sleep-related cardiometabolic risks further suggests that addressing nutritional deficiencies may enhance protective effects against these outcomes.

The findings underscore the importance of prioritizing sleep duration in both clinical settings and public health strategies. Educating young populations on the health risks associated with sleep deprivation, alongside promoting sleep hygiene, lifestyle interventions, and possibly vitamin D supplementation, could mitigate the progression of cardiometabolic conditions. As sleep duration is a modifiable risk factor, early intervention has the potential to make a meaningful impact on lifelong health outcomes. Future research should continue to explore causal mechanisms, the long-term impact of sleep deprivation, and the effectiveness of targeted interventions to better inform preventive strategies for improving cardiometabolic health in young individuals.

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