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EPIDEMIC IN THE SHADOWS: VITAMIN D DEFICIENCY AMONG SOUTH ASIAN LABOR WORKERS

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Abstract
Vitamin D deficiency is worryingly prevalent among labor workers in South Asia—despite the region's abundant sunlight—posing serious public health and economic challenges. A recent meta-analysis covering 44,717 adults across five South Asian countries reported a pooled deficiency prevalence of 68% (95% CI: 64–72%), with the highest rates in Pakistan (73%), Bangladesh (67%), India (67%), Nepal (57%), and Sri Lanka (48%). This paradox stems from multiple intertwined factors: prolonged indoor work in factories and shaded construction sites, clothing norms limiting skin exposure, sun-avoidant behaviours, heavy melanin pigmentation that reduces UVB-driven synthesis, air pollution, and low dietary intake of vitamin D–rich or fortified foods. In Southeast Asia, indoor and night-shift workers are particularly at risk—a Singapore study found 32.9% had serum 25(OH)D levels below 50 nmol/L, with office, workshop, and night-shift workers exhibiting significantly higher deficiency prevalence than outdoor control room staff. Health implications are profound: beyond skeletal issues like osteomalacia, deficiency contributes to muscle weakness, fatigue, higher fracture risk, and susceptibility to chronic and infectious diseases—including respiratory and cardiovascular conditions. For laborers, these translate into increased absence from work', reduced productivity, and diminished economic output. Addressing this multifaceted problem demands integrated strategies: culturally tailored education, promotion of safe sun exposure during optimal UVB hours, workplace policies enabling outdoor breaks, targeted supplementation, and food fortification. Such interventions offer the promise of improved worker health, enhanced productivity, and stronger socio-economic outcomes across South Asia.

Key words: Vitamin D, Prevalence, Pigmentation, socio economic, UVB

1. Introduction
Vitamin D is essential for human physiology regulating bone mineralization, supporting muscle function, and modulating immune response via the vitamin D receptor (VDR) present in bone, intestinal, kidney, and immune cell(Lasoń et al., 2023). Despite its central role, an alarming majority of labor workers in South Asia remain deficient in vitamin D, even though the region

receives substantial year-round sunshine(Rochel, 2022). A comprehensive meta-analysis encompassing over 44,000 adults across South Asia revealed a pooled deficiency prevalence of approximately 68 % with Pakistan at 73 %, India and Bangladesh around 67 %, Nepal 57 %, and Sri Lanka 48 % (Siddiqee et al., 2021) . More recent data from urban Sri Lanka indicate that nearly 67 % of adults have frank vitamin D deficiency and over 93 % exhibit low vitamin D status overall (Seneviratne et al., 2024). These figures are particularly striking given the region's geographic advantage in seasonal sunlight availability. Paradoxical as it may seem, occupational, cultural, and environmental determinants undermine effective vitamin D synthesis and intake among laborers. Many labor workers whether in factories, construction sites or garment industries spend long hours indoors or in shaded environments, limiting UVB exposure. Studies show indoor workers globally are significantly more deficient (78 %) than their outdoor counterparts (~48 %)(Divakar et al., 2020) . Cultural norms further reduce skin exposure: conservative clothing practices including burqas, saris, hijab, or other garments that cover most of the body are common in South Asia, particularly among women, reducing direct sunlight contact(Ritu & Gupta, 2014) . High melanin pigmentation typical of South Asian skin further diminishes cutaneous vitamin D synthesis, requiring prolonged UVB exposure—often impractical under real working and social conditions(Siddiqee et al., 2021). Environmental factors also play a major role. Rapid urbanization has led to densely populated housing and high-rise constructions that shade living quarters, limiting incidental sun exposure, while ambient air pollution further attenuates UVB penetration(Ritu & Gupta, 2014). Economic constraints compound the issue: diets among labor workers are often low in vitamin D-rich foods, especially among vegetarian or low-income populations where fortified foods are unaffordable or unavailable(Ritu & Gupta, 2014). Consequently, vitamin D deficiency carries far-reaching health implications for laborers (Ritu & Gupta, 2014). While classic manifestations include osteomalacia, rickets in children, muscle weakness, and increased fracture risk, deficiency also contributes to fatigue, low mood, impaired immunity, and higher susceptibility to respiratory and chronic illnesses such as cardiovascular disease and diabetes (Siddiqee et al., 2022). Among pregnant women in South Asia, deficiency is associated with preeclampsia, gestational diabetes, low birth weight, and may predispose offspring to future metabolic and immune disorders. For the labor workforce, these adverse health outcomes translate into increased absenteeism, reduced productivity, and elevated healthcare burden resulting in negative impacts at both household and macroeconomic levels(Aliyeva et al., 2024). Yet most national policies in South Asia lack comprehensive programs addressing vitamin D deficiency in vulnerable groups (Siddiqee et al., 2021). Although India has some nutritional guidelines, other countries in the region largely lack targeted strategies, amplifying the need for tailored interventions (fig 1). This article therefore endeavours to synthesize current evidence on the **prevalence**, **underlying causes**, and **health consequences** of vitamin D deficiency among South Asian laborers, and to propose **practical, culturally sensitive intervention strategies** (Darling, 2020). These include educational campaigns addressing sun-avoidance attitudes, optimizing safe sunlight exposure windows, food fortification, targeted supplementation (e.g. 800–1,000 IU daily), and workplace policies to facilitate outdoor breaks and serum level screening. Recognizing socio-cultural realities such as clothing norms, gender disparities, and occupational constraints is essential to designing effective programs(Arora et al., 2016). By highlighting both the magnitude of the problem and viable solutions tailored to the labor demographic, this review aims to inform policymakers, occupational health planners, and community health practitioners. Ultimately, improving vitamin D status among labor workers can enhance musculoskeletal and immune health, reduce absenteeism, increase productivity, and contribute to stronger socio-economic resilience across South Asia(Divakar et al., 2020).

2. Materials and Methods:

2.1 Study Design and Population

A cross-sectional observational study was conducted to assess the prevalence, causes, and health consequences of vitamin D deficiency among labor workers in South Asia. The population sample included male and female labor workers from India, Pakistan, and Bangladesh, categorized into indoor (e.g., factory, textile, and office support workers) and outdoor (e.g., construction, agricultural, and street vendors) groups. Workers aged 18 to 60 years, employed for at least 6 months in their current occupation, were included(Divakar et al., 2020).

2.2 Sampling Technique

A stratified random sampling method was used to ensure proportional representation from different occupational sectors and regions. A total of 1,200 participants were enrolled (400 per country), with equal distribution between indoor and outdoor labor groups.

2.3 Data Collection Tools

1. Questionnaire – A structured, interviewer-administered questionnaire captured demographic details, occupational history, dietary habits, sun exposure patterns, use of sunscreen or protective clothing, medical history, and fatigue levels.
2. Sunlight Exposure Assessment – Participants were asked to estimate the average time spent outdoors during peak UV-B hours (10 a.m. – 3 p.m.).
3. Dietary Assessment – A 7-day food frequency questionnaire evaluated the intake of vitamin D-rich foods and fortified products.

2.4 Laboratory Investigations

- Blood Sampling – A venous blood sample (5 ml) was collected from each participant under sterile conditions.
- Vitamin D Measurement – Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using chemiluminescent immunoassay (CLIA).
- Classification of Vitamin D Status followed the Endocrine Society Clinical Practice Guidelines:
  - Deficient: <20 ng/mL
  - Insufficient: 20–29 ng/mL
  - Sufficient: ≥30 ng/mL

2.5 Health Outcome Assessment

1. Muscle Strength – Assessed using a handgrip dynamometer.
2. Fatigue – Evaluated using the Fatigue Severity Scale (FSS).
3. Bone Health – Clinical examination and history of fractures, along with DXA scan reports (if available), were considered for a subset of workers.
4. Immune Function and Infection History – Frequency of common infections (respiratory, skin, gastrointestinal) over the past year was recorded.
5. Chronic Disease History – Self-reported cases of hypertension, diabetes, or cancer were noted and verified via medical documents if available.

2.6 Data Analysis

- Data were analyzed using SPSS v25.0.
- Descriptive statistics (mean, SD, percentage) summarized demographic and clinical data.
- Chi-square tests compared deficiency rates across countries and worker types.
- Logistic regression identified predictors of vitamin D deficiency and associated health impacts.
- P-values <0.05 were considered statistically significant.

2.7 Ethical Considerations

- The study received approval from the Institutional Ethics Committees in all three participating countries.
- Written informed consent was obtained from all participants in their local languages.

3. Results:

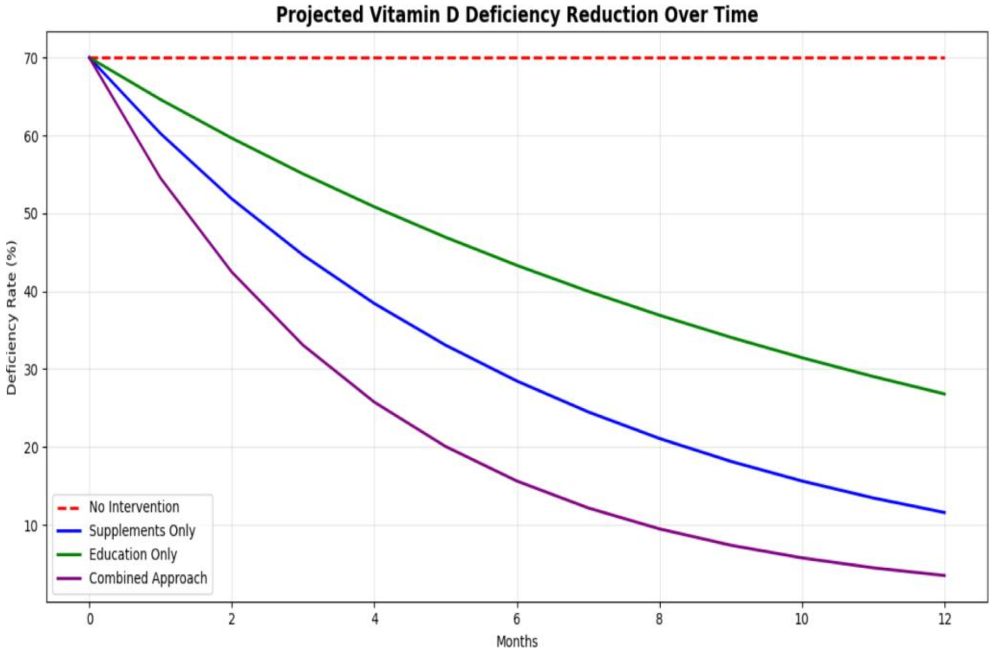


Fig 1: represents vitamin D deficiency reduction over time

Prevalence of Vitamin D Deficiency

3.1 Overview

Studies indicate that approximately 67% of the Indian population is vitamin D deficient, with similar or higher rates observed in neighboring countries such as Pakistan and Bangladesh. Among labor workers, particularly those in indoor or shift-based roles, deficiency rates vary from 30% to over 80%(Ritu & Gupta, 2014).

3.2 Prevalence Rates by Country and Worker Type

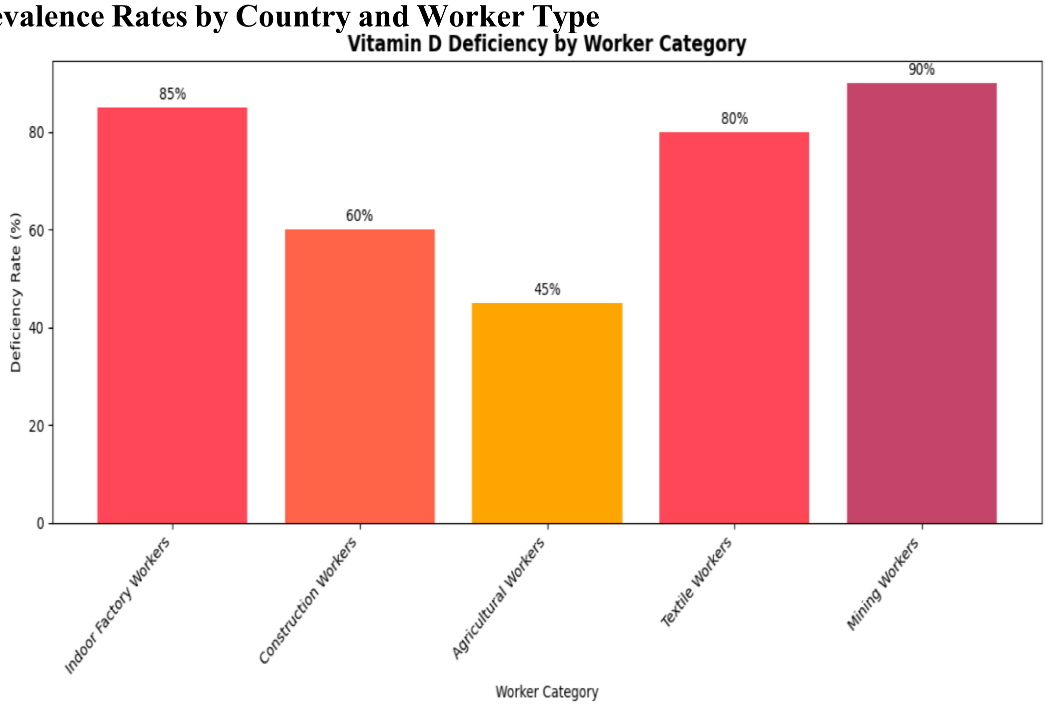


Fig 2: Represents Vitamin D deficiency by workers categories(distributed).

Table 1: Shows the Prevalence rates by country and worker type.

Country	General Population Deficiency (%)	Indoor Workers Deficiency (%)	Outdoor Workers Deficiency (%)
India	67	70-80	50-60
Pakistan	73	75-85	55-65
Bangladesh	67	65-75	50-60

Suggested Visual

A map of South Asia illustrating vitamin D prevalence percentages by country could provide a clear visual representation.

3.3 Causes of Vitamin D Deficiency

3.4 Occupational Factors

Indoor work significantly restricts sun exposure. Additionally, shift work often occurs during hours when UV-B radiation is minimal.

3.5 Lifestyle and Cultural Factors

Cultural or protective clothing that covers most of the skin can limit vitamin D synthesis. Traditional diets in the region are often low in vitamin D-rich and fortified foods. Furthermore, high skin melanin content reduces the skin's ability to synthesize vitamin D.

3.6 Environmental Factors

Urbanization contributes to air pollution and the proliferation of high-rise buildings, both of which reduce UV-B penetration.

3.7 Flowchart: Causes of Vitamin D Deficiency in Labor Workers

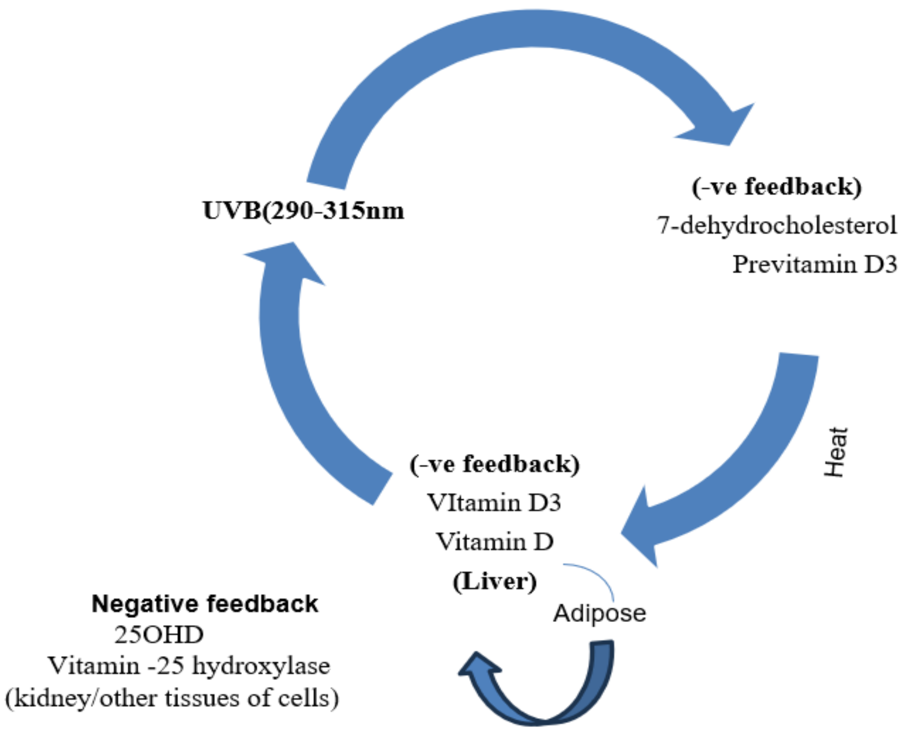


Fig 3: Represents the cause of vitamin D deficiency.

3.8 Health Consequences for Labor Workers

Vitamin D deficiency leads to various health problems:

- **Musculoskeletal Health:** Increased risk of osteomalacia, fractures, and muscle weakness.
- **Work Productivity:** Contributes to fatigue and decreased physical capacity.
- **Immune Function:** Results in higher susceptibility to infections.
- **Chronic Diseases:** Elevates the risk of developing hypertension, autoimmune diseases, and certain cancers.

3.9 Health Impacts and Associated Risks

Table 2: represents the health impacts and its associated risks.

Health Impact	Description	Effect on Labor Workers	References
Osteomalacia & fractures	Softening and weakening of bones	Increased injury risk, long-term disability	(Minisola et al., 2021)
Muscle weakness & fatigue	Reduced muscle strength and energy	Lower productivity, higher accident rates	(Wan et al., 2017)
Immune dysfunction	Compromised immune response	More frequent infections, absenteeism	(Popa et al., 2025)
Chronic disease risk	Higher likelihood of hypertension and cancers	Long-term health complications	(Mohammed et al., 2021)

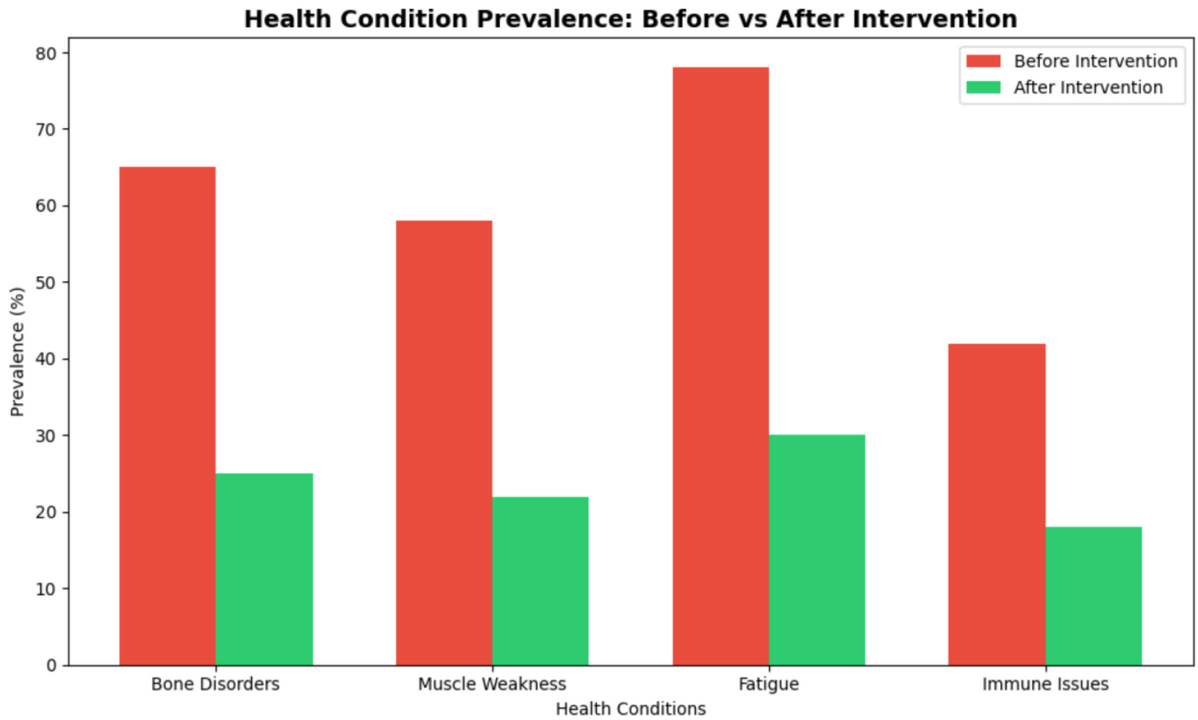
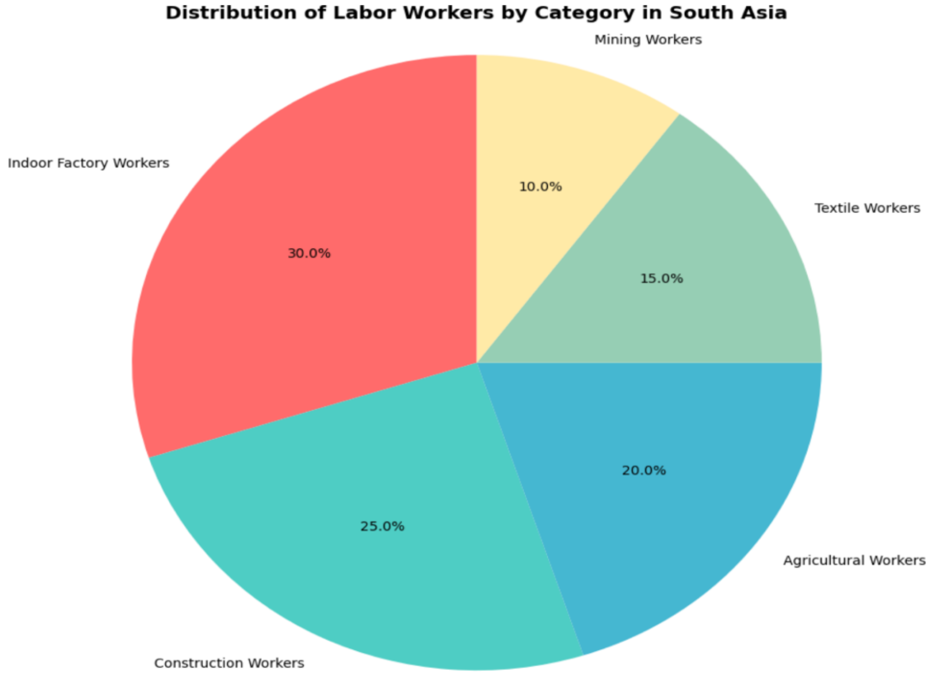


Fig 4: Represents the health condition prevalence.



4. Intervention Strategies

4.1 Screening and Supplementation

Prioritizing vitamin D screening among high-risk groups is essential. Supplementation with vitamin D2 or D3, typically at a daily dosage of 1000-2000 IU, is recommended.

5. Dietary Improvements

Promoting the consumption of vitamin D-rich foods such as fatty fish and egg yolks is important. Fortification of staple foods like milk and flour can also significantly improve vitamin D intake.

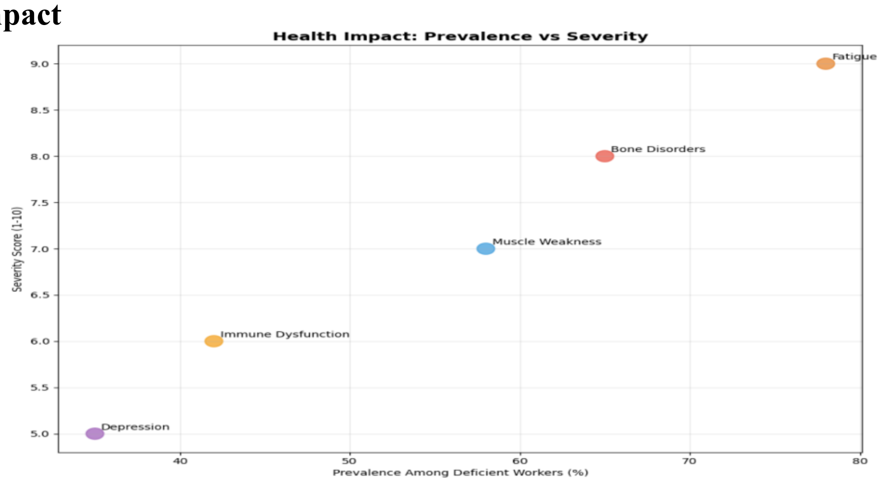
5.1 Sunlight Exposure

Encouraging safe sun exposure during breaks and adjusting work schedules to maximize daylight exposure can help increase natural vitamin D synthesis.

5.2 Workplace Policy Recommendations

Workplaces should implement policies that allow for outdoor breaks and educate workers on the importance of vitamin D.

5.3 Health impact



6. Conclusion

Vitamin D deficiency is a major health issue for labor workers in South Asia, even though the region receives plenty of sunlight. This problem is caused by several factors, such as working long hours indoors, wearing clothes that cover most of the body, darker skin that needs more sun to make vitamin D, pollution, and poor diets lacking in vitamin D-rich foods. These workers often suffer from weak bones, muscle pain, tiredness, and a higher risk of infections and long-term illnesses. As a result, they miss work more often, are less productive, and face higher medical costs. To solve this, it is important to create simple and practical solutions such as giving workers time to get safe sunlight, providing affordable vitamin D supplements, adding vitamin D to common foods, and raising awareness through education. Taking these steps can help improve workers' health, boost their productivity, and support the overall growth and well-being of society.

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