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Vitamin D Supplementation in Children Aged 2 to 12 in Countries with Cold Climates: A Systematic Review

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Abstract

Objectives: Low levels of blood vitamin D have been reported not only in children with otitis media and frequent respiratory tract infections, but also in PFAPA syndrome patients. Levels of vitamin D are influenced regional and racial differences.

The objective of this scientific literature review was to inspect whether people who live in countries with cold climates have a high demand for vitamin D supplementation; to know the population that requires vitamin D supplementation; to identify the countries that are most demanding for these vitamin D interventions; and to verify the appropriate duration of a successful intervention. For this, a systematic review was carried out under the PRISMA declaration, where 21 articles out of 207 were included, found in the PubMed, SciELO, and gray literature databases. In summary, the effective interventions were carried out mainly in homes, and with a duration equal to or less than 6 months, and it was possible to realize that the male population is the most likely to suffer from vitamin D deficiency.

Keywords: Vitamin D; Children; Cold Climate; Dietary Supplements

Introduction

Vitamin D is a fat-soluble hormone with two compounds: vitamin D3 and vitamin D2, which is essential for calcium homeostasis and bone metabolism. Vitamin D comes from exposure to sunlight and to a lesser extent from food (vegetable-animal source) or supplements [1-3]. Recommended levels of vitamin D are between 30 to 40 ng/ml (75-100nmol/L) [1,3,4].

In Western Europe, 50% of the population has vitamin D deficiency, at least in winter (<50nmol/L). This prevalence is lower in North America but increases considerably in South America, where a vitamin D deficiency of <50nmol/L predominates [5,6]. It should be noted that in countries with cold climate the use of vitamin D supplementation is recommended to counteract the effects of its deficiency [6]. There is vitamin D deficiency in countries with less exposure to the sun, so this deficiency occurs more frequently in places farthest from the Equator [5,7].

In the United States and Canada there have been intervention programs with vitamin D supplementation since 1904. In the United States, liquid milk and cereals that are usually served for breakfast are the foods most used for vitamin D fortification. Likewise, Canada fortifies liquid milk and margarine, with the purpose of increasing the intake of Vitamin D, reducing its deficiency in the population. On the other hand, in Finland, the fortification of foods with vitamin D began in 2003, with a program that incorporates

fortification of liquid dairy products, margarines and fat spreadables [8].

Several factors influence the levels of vitamin D in the body, including variation in sun exposure, clothing, skin pigmentation, age, obesity, latitude, the season of the year, and the hour of the day [9,10]. It is then understood that the variation in vitamin D levels is due to environmental, social, or physiological circumstances.

Vitamin D considerably increases the health of the muscles and the skeleton, therefore, it is essential for the mineralization of the bones, likewise, it reduces mortality directly related to bone problems - especially in older people [11-14]. Adequate intake of vitamin D provides less risk of suffering: osteoporosis [15,16], diabetes [17,18], cancer [19], multiple sclerosis [20], and rheumatoid arthritis [21,10].

Insufficiency of vitamin D in children produces a loss of bone density caused by diseases, moreover, it is estimated that 1,000 million people worldwide have vitamin D deficiency [22,23]. Due to a considerable deficiency of vitamin D, children can suffer from rickets [22]. Rickets causes softening and weakening in the bones [8].

In turn, malnutrition is understood as the insufficiency of nutrients due to a metabolism disorder, poor intake, or inadequate food supply [24,25]. However, some interventions seek to avoid or reduce malnutrition by promoting a healthy lifestyle in risk groups (children, adolescents, the elderly, and the chronically ill) [5,26,27].

For this reason, the purpose of this review is to inspect whether people who live in countries with cold climates have a high demand for vitamin D supplementation; to identify if vitamin D is efficient; and to verify the appropriate duration of a successful intervention.

Material and Methods

Study design

A systematic review following the PRISMA guidelines [28,29] was performed about nutritional intake of vitamin D in cold countries among children aged 2 to 12 years.

Search Strategy

A search was performed combining the terms ((((child) OR (infant)) AND (countries with cold climate)) AND (vitamin)) OR (vitamin d) AND (intervention) in the PubMed, SciELO and literature databases, and in the grey literature. This search returned a considerable number of results, some of which were of little use to the review. The systematic search was carried out in PubMed, SciELO and gray literature, limiting the results to investigations carried out from 2010 to 2021. Specifically, 207 results were obtained in PubMed. Before continuing with the selection of articles, inclusion criteria were defined.

Eligibility Criteria

Studies that met the following inclusion criteria were selected: a) Duration: up to 12 months; b) Sample: children between 2 and 12 years old; c) Study design: randomized controlled trial only; d) Country: interventions carried out in countries with extremely cold climates (Russia, Canada, United States, Iceland, Finland, Estonia, Norway, Sweden, Denmark, Latvia, France, New Zealand, Scotland, United Kingdom, Argentina, Chile, Faroe Islands and Poland); e) Period: between 2010 and 2021; f) Supplementation: vitamin D (Table 1).

Criteria	Description
(1) Type of intervention.	(c) Randomized Controlled Trial (RCT).
(2) Participants.	(b) Children between 2 and 12 years.
(3) Duration.	(a) Up to 12 months.
(4) Country of the participants.	(d) Countries with extremely cold climate.
(5) Period.	(e) Between 2010 and 2021.
(6) Supplementation.	(f) Vitamin D.

Table 1: Eligibility criteria of the studies.

Risk of Bias Assessment

To assess the methodological quality of the studies included in this review, we used the "Cochrane Handbook of Systematic Reviews of Interventions" [30], evaluating the risk of bias in each of the proposed items: (a) selection bias, (b) performance bias, (c) detection bias, (d) attrition bias, and (e) reporting bias.

Results

Search Outcome

The articles excluded in the systematic review were 185. The reasons for exclusion were: the duration exceeding 12 months (n=13); children outside the age range (n=47); the period was out of date according to the inclusion criteria (n=31); interventions that were not performed in countries with cold climates (n=80); interventions that did not use vitamin D supplementation (n=4); duplicates (n=1); not related to the subject to be investigated (n=10). Finally, 21 articles met the eligibility criteria and were considered for the qualitative synthesis (Figure 1).

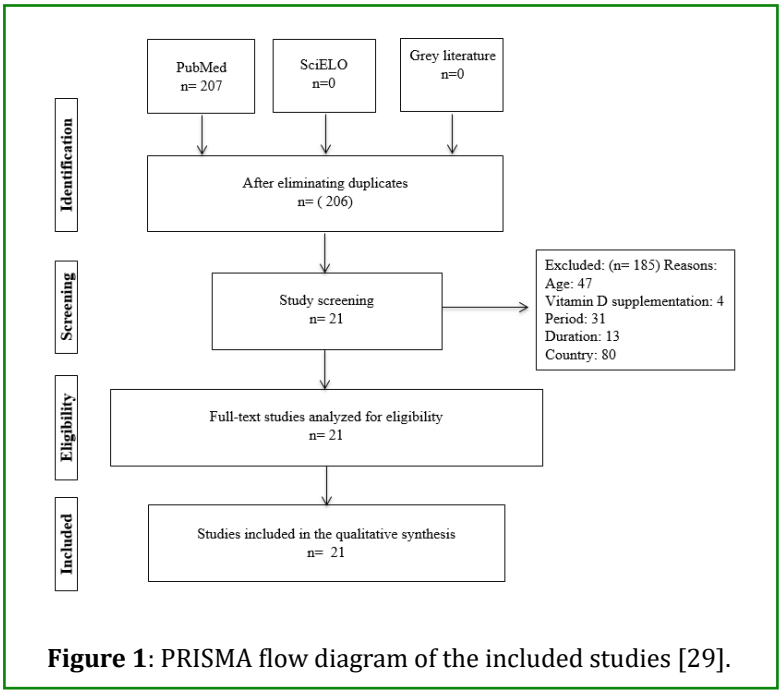

Figure 1: PRISMA flow diagram of the included studies [29].

Characteristics of the Included Studies According to Adherence and Gender

The intervention with the highest adherence (99%) was carried out by Agliplay et al. in Canada. Another relevant result showed an adherence of 97%, carried out by Hauger et al. in Denmark; and finally, Brett et al. showed an adherence of 96% in a study carried out in Canada. The study that obtained the lowest adherence (52%) was carried out by Lara et al. in Canada. Likewise, Gopal et al. showed adherence of 55% in a study carried out in the United Kingdom. The interventions with the highest percentage of adherence (between 96% and 99%) showed a significant participation of the boys (46% to 58%). On the other hand, concerning the articles with the least adherence, there was a low participation of the girls (46% to 48%) (Table 2).

N °	First author, Year, Country	Adherence (%)	Sex	
			♀ (%)	♂ (%)
1	Öhlund, I. (2012) Sweden	92	54	46
2	Gopal, J. (2016) United Kingdom	55	48	52
3	Mazahery, H. (2015) New Zealand	62	15	85
4	Ducharme, F. (2014) Canada	89	36	64
5	Mazahery. H. (2015) New Zealand	66	18	82
6	Lara, I. (2012) Canada	52	46	54
7	Lovell, A. (2015) New Zealand	85	47	53
8	Hauger, H. (2014) Denmark	97	54	46
9	Hauger, H. (2014) Denmark	92	54	46
10	Brett, N. (2014) Canada	96	47	53
11	Mortensen, C. (2014) Denmark	90	53	47
12	Agliplay, M. (2011) Canada	99	42	58
13	Öhlund, I. (2012) Sweden	92	54	46
14	Akkermans, M. (2012) Netherlands, United Kingdom, United States	71	43	57

15	Atkinson, M. (2012) United States	91	27	73
16	Pincikova, T. (2010) Sweden	81	-	-
17	Mortensen, C. (2014) Denmark	92	58	42
18	Jerzynska, J. (2014) France	82	-	-
19	Mazahery, H. (2015) New Zealand	-	-	-
20	Jerzynska, J. (2014) France	90	42	58
21	Karlsland, P. (2012) Sweden	87	54	46
Total, percentage		83	44	56

Table 2: Characteristics of the included studies according to adherence and gender.

Characteristics of the Studies Included Regarding Reasons for Exclusion and Recruitment

In this review, 21 articles were included, whose interventions were carried out in the following countries considered areas of extreme cold climate: Russia, Canada, United States, Iceland, Finland, Estonia, Norway, Sweden, Denmark, Latvia, France, New Zealand, Scotland, United Kingdom, Argentina, Chile, Faroe Islands, and Poland. Considering all the studies, the adherence of children was 83%. In these studies, the main reasons for sample loss were classified as follows: participants traveled abroad outside the intervention site; participants declined because they did not see benefits; concerned about side effects; lack of time; the participant did not like the supplement or study products; diseases were diagnosed during the intervention period; and several did not specify. The mean age of the participants was 6.3 years. The interventions were carried out in hospitals, universities, clinics, nurseries, preschools, and schools (Table 3).

N °	Author principal, Año, Country	Reasons for exclusion										Recruitment					Age	Adherence (%)
		V	EX	DEC	E/S	LIM	N/S	ENF	IT	N/E	H	U		C	G/P/E	N/E		
1	Öhlund, I. (2012) Sweden	1		1												1	-	92
2	Gopal, J. (2016) United Kingdom		1	1		1					1						5	55
3	Mazahery, H. (2015) New Zealand	1		1	1	1	1	1		1						1	5,3	62
4	Ducharme, F. (2014) Canada			1	1	1										1	2,9	89
5	Mazahery, H. (2015) New Zealand									1		1					5,35	66
6	Lara, I. (2012) Canada									1				1			7,9	52
7	Lovell, A. (2015) New Zealand		1													1	1	85
8	Hauger, H. (2014) Denmark	1										1					6,7	97
9	Hauger, H. (2014) Denmark	1	1	1								1					6,7	92
10	Brett, N. (2014) Canada			1			1								1		5,2	96
11	Mortensen, C. (2014) Denmark		1	1								1					6,6	90
12	Agliplay, M. (2011) Canada			1					1			1					2,7	99

13	Öhlund, I. (2012) Sweden				1								1			6,3	92
14	Akkermans, M. (2012) Netherlands, United Kingdom, United States									1	1		1			-	71
15	Atkinson, M. (2012) United States		1										1			10,9	91
16	Pincikova, T. (2010) Sweden									1					1	-	81
17	Mortensen, C. (2014) Denmark	1							1			1				6,7	92
18	Jerzynska, J. (2014) France									1			1			-	82
19	Mazahery, H. (2015) New Zealand									1		1				-	-
20	Jerzynska. J. (2014) France									1			1			-	90
21	Karlsland, P. (2012) Sweden					1	1						1	1		7,8	87
Total, percentage		5	5	8	3	4	3	1	2	8	2	7	7					

Table 3: Characteristics of the studies with interventions consiting of vitamin D supplementation in extreme cold climates.
Abbreviations of Reasons for Exclusion: (-): No data; V: Travel abroad; EX: Excluded; DEC: Declined, did'nt see benefits; E/S: Worried about side effects; LIM: Lack of time; N/S: Did not like the supplement or the products of the study; ENF: Illness diagnosed during the study; IT: Interruption of the treatment; N/E: No specified.

Duration, Place and Responsible of the Intervention

Concerning the duration, 33% of the interventions carried out had duration between six and 12 months; and 67% had duration of one day to six months. Interventions took place more frequently in homes and to a lesser extent in family health centers, university health centers, and school/preschool nurseries. Those responsible for carrying out these interventions were mostly fathers and mothers, and to a lesser extent nurses, doctors, pediatricians, and health professionals (Table 4).

N °	First author, Year, Country	Place of the intervention								Duration	Responsible for the intervention						
		H	U	CESFAM	HOG	C	CSU	G/P/E	N/E		ENF	MED	PD	OTRO	PS	PM	N/E
1	Öhlund, I. (2012) Sweden				1			1		3 months	1			1		1	
2	Gopal, J. (2016) United Kingdom				1					8 days						1	
3	Mazahery, H. (2015) New Zealand				1					12 months						1	
4	Ducharme, F. (2014) Canada				1		1			7 months	1						
5	Mazahery, H. (2015) New Zealand	1			1					12 months						1	1
6	Lara, I. (2012) Canada					1				3 months				1			
7	Lovell, A. (2015) New Zealand				1					12 months						1	

8	Hauger, H. (2014) Denmark				1					20 weeks						1	
9	Hauger, H. (2014) Denmark		1		1					20 weeks						1	
10	Brett, N. (2014) Canada				1					6 months						1	
11	Mortensen, C. (2014) Denmark		1		1					20 weeks				1		1	
12	Agliplay, M. (2011) Canada				1					4-9 months		1					
13	Öhlund, I. (2012) Sweden	1								3 months	1					1	
14	Akkermans, M. (2012) Netherlands, United Kingdom, United States	1			1	1				4 months			1				
15	Atkinson, M. (2012) United States	1								3 months		1					
16	Pincikova, T. (2010) Sweden								1	5 months							1
17	Mortensen, C. (2014) Denmark				1					4 months					1	1	
18	Jerzynska, J. (2014) France								1	5 months		1					
19	Mazahery, H. (2015) New Zealand	1								12 months					1	1	
20	Jerzynska, J. (2014) France			1	1	1				5 months		1				1	
21	Karlsland, P. (2012) Sweden				1	1				3 months					1	1	
Total		5	2	1	15	4	1	1	2		2	4	1	3	3	14	2

Table 4: Characteristics of the studies according to duration, place of the intervention and responsibles.
1: Data specified; H: Hospital; U: University; CESFAM: Family health center; HOG: Home; C: Clinic; CSU: University health center; G/P/E: Preeschool of School; N/E: No specified; ENF: Nurse; MED: Medical doctor; PD: Pediatrician; PS: Health professional; P/M: Father or mother.

Discussion

This research aimed to recognize the adherence to vitamin D supplementation in children aged 2 to 12 years in countries with cold climates; identify which gender has lower levels of vitamin D; determine which countries with extremely cold climates are most successful in vitamin D supplementation interventions; and know the convenient time to carry out effective interventions.

Vitamin D comes mostly from exposure to sunlight and to a lesser extent from food or supplements. During winter, the ozone layer absorbs a considerable amount of UVB radiation, therefore less sunlight reaches the skin [31]. That is to say, people who live in cold climates that have a higher absorption of UVB radiation in their ozone layer will have less absorption of vitamin D. The alteration of the metabolism of vitamin D is favored by bad weather conditions (cold climate and humid). Likewise, clothing in countries with cold weather conditions less exposure to sunlight [32]. While vitamin D differs by latitude and skin pigmentation around the world, there is evidence that living in areas with excessive sunlight does not help achieve adequate amounts of vitamin D [33].

The adherence to the interventions was high, which suggests that the countries present in the review of the scientific literature are areas that require vitamin D programs or interventions. One of the countries to carry out vitamin D interventions would be Canada because it has high participation in the interventions and presents enough emphasis on the matter since they constantly fortify their population with products that contain vitamin D.

Natural sources of vitamin D are mainly oily fish and eggs, but children are not used to eating these natural sources due to taste rejection. Therefore, vitamin D supplementation in food is important if there is little sun exposure. Vitamin D supplementation is found mainly in dairy products such as milk, cheese, and yogurt. However, many studies state that this supplementation is not as effective since the recommended intake of vitamin D is not achieved, Vitamin D supplementation does not reduce the incidence of invasive cancer or cardiovascular events [34]. However, Dr. Vásquez mentions the efficacy of this supplementation as an accompanying therapy in the treatment of serious diseases (osteoporosis, cancer, diabetes, hypertension, and multiple sclerosis, among others) [35]. Likewise, vitamin D supplementation protects against acute respiratory tract infection in general [36]. On the other hand, nutritional interventions help to have better effects on serum levels of vitamin D [37]. There is a need to carry out vitamin D supplementation interventions in preschool children since its importance is only mentioned in vital processes such as adolescence, pregnancy, menopause, and aging [35].

The most effective interventions had a duration equal to or less than six months, with the active participation of the parents in the home. These results indicate that, being a dependent population, children will spend a longer period of time with their parents, who will provide them an efficient intervention. Also, based on the qualitative analysis, it can be concluded that the male population is the most likely to suffer from vitamin D deficiency. One of the limitations existing is that to know the status of vitamin D in the body, people must undergo a blood test, which has a high cost; therefore it is hard to test massively.

Conclusions

To carry out effective vitamin D supplementation interventions, they must have a duration equal to or less than six months, and must have the active participation of parents at home. Special emphasis should be placed on the male population, since it is the most likely to suffer from vitamin D deficiency. Adherence to interventions was high, which suggests that the countries present in the review of the scientific literature are areas that require programs or vitamin D interventions.

Author Contributions

J.A.-G. Design, conceptualization of the study, and approval of the final draft. J.A.-G., B.G., C.S. and G.G.P.d.S. Design of the search strategy, articles extraction, data analysis, preparation of the figures and/or tables, writing and review of the drafts of the manuscript, and approval of the final draft, Cross-check of extracted data, review, writing and editing of the manuscript. J.A.-G., B.G., C.S. and G.G.P.d.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

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