Overall vitamin D status

The overall prevalence of Hypovitaminosis D in the population of the Albaha region was 72.2%; 45.9% (n=4,624) of the subjects were found to be vitamin D deficient (13.6 ± 4 ng/ml) and 26.3% (n=2,645) were found to be vitamin D insufficient (24 ± 3 ng/ml, Table 2). Only 27.8% (n=2,801) of the subjects had sufficiency of vitamin D (43 ± 12 ng/ml, Table 2 and Figure 1).

Table 2: Overall prevalence of vitamin D status among Albaha's population.

N		%	Age (years)							
			Vitamin D (ng/ml)		All		Child ≤ 18		Adult >18	
			Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
Sufficient	2,801	27.8	43 ± 12	40 (34-49)	41 ± 21	43 (27-58)	7 ± 5	5 (2-16)	49 ± 16	49 (36-60)
Insufficient	2,645	26.3	24 ± 3	24 (22-27)	39 ± 20	40 (25-54)	10 ± 5	10 (6-13)	46 ± 15	45 (34-57)
Deficient	4,624	45.9	13.6 ± 4	14 (11-17)	38 ± 17	36 (25-50)	12 ± 4	13 (10-11)	42 ± 16	39 (29-52)

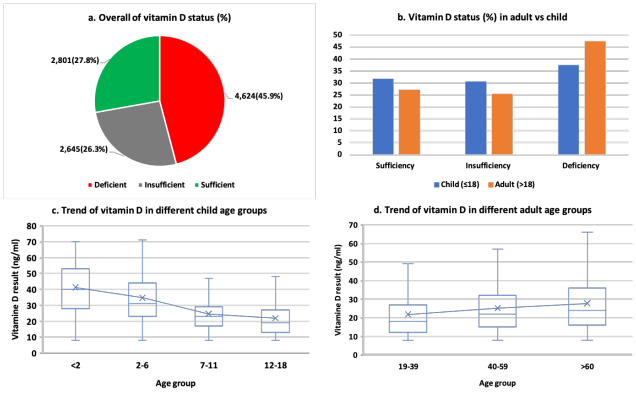

Figure 1: Vitamin D status of all subjects and in the child and adult categories. (A) Pie chart showing the overall prevalence of vitamin D deficiency, insufficiency and sufficiency in all subjects. (B) Bar chart showing the prevalence of each vitamin D status according to the two main age groups: child (18) and adult (18). Boxplots showing the trends in vitamin D concentration across the different age groups of children (C) and adults (D). Vitamin D results (concentration, ng/ml) are depicted on the y-axes, and age groups on the x-axes for the child category (<2, 2–6, 7–11, 12–18) and adult category (19–39, 40–59 and 60).

Vitamin D status by age

Comparative assessment of Hypovitaminosis D was accomplished between two age categories: child (≤ 18 years) and adult (>18 years).

Vitamin D deficiency was higher in the adult group and vitamin D sufficiency was higher in the child group (Figure 1b).

The mean vitamin D concentrations in different child and adult sub-categories are shown in Figures 1c and 1d, with opposite trends observed in these two groups. In the child group, vitamin D was found to decrease with age, while in the adult sub-categories, the vitamin D level was found to consistently increase with age.

In the child age subgroups, vitamin D deficiency was the most prevalent (54%) in the 12–18 group (Table 3) and then in the 7–11 group (37.6%).

The prevalence of vitamin D deficiency in the 2–6 and <2 groups was approximately 15% and 10%, respectively.

In contrast to the 12–18 group, the 7–11, 2–6 and <2 groups were 50%(OR=0.5, p=0.001), 92% (OR=0.08, p=0.001) and 96%(OR=0.04, p=0.001) less likely to be vitamin D deficient.

The child group with the greatest vitamin D insufficiency was the 7–11 group, and the <2 group had the lowest vitamin D insufficiency (17.3%).

Indeed, compared with the 12–18 group, the 2–6 and <2 groups showed lower probability of being vitamin D insufficient by a factor of 0.35 (p=0.001) and 0.15 (p=0.001), respectively.

In the adult category, the 19–39 groups exhibited the highest level of vitamin D deficiency (57.3%), followed by the 40–59 groups (42.9%) (Table 3). The adult group with the greatest vitamin D insufficiency was the 40–59 groups.

The ≥ 60 group was found to have the greatest vitamin D sufficiency (37%). The 19–39 group was 3.3 times (OR=3.3, p<0.001) and 1.5 times (OR=1.5, p<0.001) more likely to be deficient and insufficient, respectively, with respect to the 60 group (Table 3).

The 40–59 group showed 70% (OR=1.7, p<0.001) and 30% (OR=1.3, p=0.001) higher probability of being vitamin D deficient and insufficient, respectively, compared to the ≥ 60 group.

Table 3: Associations between Vitamin D status and sex, nationality and age.

		Sufficiency			Insufficiency					Deficiency				
		N	%	Mean ± SD (ng/ml)	N	%	Mean ± SD (ng/ml)	OR (95%CI)	p value	N	%	Mean ± SD (ng/ml)	OR (95%CI)	p value
Overall		2,801	27.8	43 ± 12	2,645	26.3	24 ± 3			4,624	45.9	13.6 ± 4		
Sex														
Male		779	27	42.9 ± 11	803	27.8	24.2 ± 2	1		1,308	45.2	14.1 ± 3	1	0.6
Female		2,022	28.2	43 ± 11	1,842	25.6	24.5 ± 2	0.88 (0.7-0.9)	0.038*	3,316	46.2	13.4 ± 3	0.97 (0.8-1.1)	
Nationality														
Saudi		2,693	28.02	43 ± 11	2,518	26.2	24.4 ± 2	1		4,400	45.78	13.6 ± 3	1	0.04*
Non- Saudi		108	23.53	41 ± 12	127	27.67	24.4 ± 2	1.2 (0.9-1.6)	0.08	224	48.8	14.2 ± 3	1.26 (1-1.6)	
Age														
Child	<2	76	73.1	48.9 ± 13	18	17.3	24.6 ± 3	0.15 (0.08-0.2)	0.001*	10	9.6	13.6 ± 4	0.04 (0.02-0.08)	0.001*
	6-Feb	208	55.5	45.3 ± 12	112	29.9	24.6 ± 3	0.35 (0.4-0.6)	0.001*	55	14.7	15.5 ± 3	0.08 (0.06-0.1)	0.001*
	11-Jul	101	23.3	40.1 ± 11	170	39.2	24.4 ± 3	1.1 (0.7-1.5)	0.62	163	37.6	15.2 ± 3	0.5 (0.4-0.7)	0.002*
	18-Dec	127	18.2	42.0 ± 11	194	27.8	24.2 ± 3	1		377	54	13.8 ± 3	1	
Adult	19-39	714	20.3	43.5 ± 12	786	22.4	24.3 ± 3	1.5 (1.2-1.7)	0.001*	2,012	57.3	13.2 ± 3	3.3 (2.9-3.8)	0.001*
	40-59	968	29.3	42.4 ± 11	921	27.9	24.5 ± 3	1.3 (1.1-1.5)	0.001*	1,417	42.9	13.8 ± 3	1.7 (1.5-2)	0.001*
	>60	607	37	43.6 ± 12	444	27.1	24.3 ± 3	1		590	36	13.9 ± 3	1	0.001*
Male in different age groups														
Child	<2	37	72.5	46.6 ± 11	8	15.7	23.8 ± 2	0.1 (0.05-0.3)	0.001*	6	11.8	13.2 ± 4	0.07 (0.02-0.2)	0.001*
	6-Feb	120	56.9	45.3 ± 12	62	29.4	24.3 ± 3	0.3 (0.2-0.5)	0.001*	29	13.7	15.3 ± 3	0.1 (0.05-0.2)	0.001*
	11-Jul	58	29.6	38.9 ± 10	76	38.8	24.4 ± 3	0.8 (0.5-1.3)	0.4	62	31.6	15.3 ± 3	0.4 (0.2-0.7)	0.001*
	18-Dec	58	19.9	41.5 ± 11	92	31.6	24.3 ± 3	1		141	48.5	14.6 ± 3	1	
Adult	19-39	143	16.9	43.6 ± 12	190	22.5	24.0 ± 3	1.6 (1.2-2.1)	0.004*	513	60.6	13.8 ± 3	3.2 (2.4-4.1)	0.001*
	40-59	177	23.9	42.9 ± 11	217	29.3	24.1 ± 3	1.4 (1.1-1.9)	0.01*	346	46.8	14.1 ± 3	1.7 (1.3-2.2)	0.001*
	>60	186	33.5	41.7 ± 11	158	28.5	24.1 ± 3	1		211	38	13.9 ± 3	1	
Female in different age groups														
Child	<2	39	73.6	51.1 ± 14	10	18.9	25.1 ± 3	0.17 (0.8-0.3)	0.001*	4	7.5	14.1 ± 4	0.03 (0.01-0.08)	0.001*
	6-Feb	88	53.7	45.5 ± 12	50	30.5	25.0 ± 3	0.38 (0.2-0.6)	0.001*	26	15.9	15.6 ± 4	0.09 (0.05-0.1)	0.001*
	11-Jul	43	18.1	41.7 ± 13	94	39.5	24.3 ± 3	1.4 (0.9-2.3)	0.1	101	42.4	15.2 ± 3	0.6 (0.4-1.1)	0.09

	18-Dec	69	17	42.5 ± 12	102	25	24.0 ± 3	1		236	58	13.4 ± 3	1	
Adult	19-39	571	21.4	43.4 ± 12	596	22.4	24.3 ± 3	1.5 (1.2-1.8)	0.001*	1,499	56.2	12.9 ± 3	2.9 (2.4-3.4)	0.001*
	40-59	791	30.8	42.3 ± 11	704	27.4	24.6 ± 3	1.3 (1.1-1.5)	0.003*	1,071	41.7	13.7 ± 3	1.5 (1.2-1.7)	0.001*
	>60	421	38.8	44.4 ± 12	286	26.3	24.4 ± 3	1		379	34.9	13.8 ± 3	1	
	Saudi in different age groups													
Child	<2	75	72.8	49.2 ± 13	18	17.5	24.6 ± 3	0.15 (0.08-0.2)	0.001*	10	9.7	13.6 ± 4	0.04 (0.02-0.09)	0.001*
	6-Feb	203	55.2	45.5 ± 13	110	29.9	24.6 ± 3	0.3 (0.2-0.4)	0.001*	55	14.9	15.5 ± 3	0.1 (0.06-0.1)	0.001*
	11-Jul	99	23.4	40.1 ± 11	165	39	24.4 ± 3	1.1 (0.8-1.5)	0.6	159	37.6	15.2 ± 3	0.5 (0.3-0.7)	0.002*
	18-Dec	125	18.2	41.9 ± 11	194	28.3	24.2 ± 3	1		367	53.5	13.8 ± 3	1	
Adult	19-39	677	20.6	43.6 ± 12	732	22.3	24.2 ± 3	1.5 (1.3-1.8)	0.001*	1,879	57.1	13.1 ± 3	2.8 (2.4-3.2)	0.001*
	40-59	922	29.4	42.5 ± 11	869	27.7	24.5 ± 3	1.3 (1.1-1.5)	0.001*	1,348	42.9	13.7 ± 3	1.5 (1.3-1.7)	0.001*
	>60	592	36.9	43.7 ± 11	430	26.8	24.3 ± 3	1		582	36.3	14.9 ± 3	1	
	Non-Saudi in different age groups													
Child	<2	1	100	30	0	0	-	-	-	0	0	-	-	-
	6-Feb	5	71.4	39.8 ± 14	2	28.6	23.0 ± 4	-	-	0	0	-	-	-
	11-Jul	2	18.2	39.5 ± 7	5	45.5	24.0 ± 1	-	-	4	36.4	15.3 ± 3	-	-
	18-Dec	2	16.7	47.5 ± 19	0	0	-	-		10	83.3	14.1 ± 3	-	
Adult	19-39	37	16.5	41.2 ± 11	54	24.1	24.3 ± 3	1.6 (0.6-3.6)	0.3*	133	59.4	13.7 ± 3	6.7 (2.6-17.1)	0.001*
	40-59	46	27.5	41.4 ± 12	52	31.1	24.5 ± 3	1.2 (0.5-2.7)	0.6	69	41.3	14.9 ± 3	2.8 (1.1-7.1)	0.3
	>60	15	40.5	41.3 ± 13	14	37.8	24.2 ± 2	1		8	21.6	14.5 ± 4	1	

Vitamin D status by sex

The prevalence of vitamin D deficiency was slightly higher in females (46.2%, n=3,316) compared to males (45.2%, n=1,308). However, male subjects were 1.12 times (OR=0.88, 95%CI=0.7–0.9, p=0.083) and 1.031 times (OR=0.97, 95%CI=0.8–1.1, p=0.6) more likely to be vitamin D insufficient and deficient compared to female subjects (Table 3).

Vitamin D status by nationality

The prevalence of vitamin D deficiency was slightly higher in non-Saudi subjects (48.8%, n=224) compared to Saudi subjects (45.78%, n=4,400) (Table 3). In total, 27.67% (n=127) and 26.2% (n=2,518) of non-Saudi and Saudi subjects, respectively, were found to be vitamin D insufficient. The probability of Hypovitaminosis D (deficiency and insufficiency) was assessed to compare the two ethnic groups. Non-Saudi subjects exhibited a 26% (OR=1.26, p=0.04) and 20% (OR=1.2, p=0.08) higher chance of being vitamin D deficient and insufficient, respectively, in comparison to Saudi subjects.

Vitamin D status and interaction between variables

When sex and age were analysed, for both the male and female child categories, the eldest age group [12–18] was found to have the highest vitamin D deficiency, with 48.5% and 58% prevalence, respectively (Table 3). Prevalence of vitamin D insufficiency was found to be approximately 39% in the 7–11 group of both male and female children. The most impacted age group in both nationality categories (Saudi child and non-Saudi child) was the 12–18 group, and the deficiency prevalence was 83.3% in non-Saudi children and 53.5% in Saudi children. In adults, the 19–39 group showed the greatest

level of vitamin D deficiency for both males (60.6% deficient) and females (56.2% deficient). Males and female adults showed equal levels of vitamin D insufficiency (28%) in the 40–59 groups. Saudi (57.1%) and non-Saudi (59.4%) adults showed almost equal levels of vitamin D deficiency in the most affected age group (19–39). The same mean ± SD (25 ± 14 ng/ml) vitamin D level was recorded for Saudi males, Saudi females and non-Saudi males, while that of non-Saudi females was slightly lower (23 ± 13 ng/ml). All males, all females and all Saudis were found to have almost the same mean ± SD vitamin D level (24.7 ± 14 ng/ml), whereas that of all non-Saudis was slightly lower (23.4 ± 13 ng/ml). The probability of a male adult, male child, female adult and female child being vitamin D deficient or insufficient was almost similar to that of all adults and children (Table 3). When compared to the >60 years age group, the 19–39 group of non-Saudi adults exhibited a greater likelihood of being deficient and insufficient by a factor of 6.7 (p=0.001) and 1.6 (p=0.001), respectively (Table 3). However, when compared to the >60 years age group, the 19–39 and 40–59 groups of Saudi adults were deficient by a factor of 2.8 (p=0.001) and 1.5 (p=0.001), respectively (Table 3). Lastly, in comparison to the 12–18 years age group, all other groups of Saudi children were less likely to have Hypovitaminosis D (deficiency and insufficiency) to a greater extent.

DISCUSSION

Addressing health disparities has been the principal focus of recent public health endeavours [45]. To that end, many essential micronutrients and their deficiency-related health issues have become a major point of discussion in the community of biochemical research; vitamin D and its deficiency in the global population have attracted the attention of the scientific community in recent years [46]. This retrospective observational study examined the prevalence of Hypovitaminosis D, specifically 25(OH)D levels, in the Albaha population in the KSA. Even though vitamin D status has been investigated in other regions of the KSA, this is the first time a study has been conducted on Hypovitaminosis D in Albaha. Previous studies revealed that demographic factors (age, sex and ethnicity) are major determinants of 25(OH)D concentration level [4,47]. Association of vitamin D status with major demographic determinants of vitamin D concentration levels in the Albaha population has been identified in the present study. The prevalence of vitamin D deficiency, insufficiency and sufficiency was determined by analysing 25(OH)D levels in 10,070 study subjects. The average concentration of vitamin D was approximately 25 ng/ml, suggesting that Hypovitaminosis D is prevalent in the population. Of all subjects, 45.9% were found to be deficient in vitamin D and 26.3% were found to have vitamin D insufficiency. The prevalence of Hypovitaminosis D (vitamin D deficiency and insufficiency altogether) was 72.2%, commensurate with the reported prevalence of Hypovitaminosis D in different KSA regions, which is 28–75% [10,48,49]. After conducting a meta-analysis (2008–2015), Al-Alyani et al. reported the prevalence of vitamin D deficiency in the KSA to be around 65% [44]. Although, because of the lack of uniformity in cut-off values applied to differentiate vitamin D deficiency from sufficiency, it is difficult to definitively compare rates of deficiency and sufficiency reported in different studies [50]; 27.8% vitamin D sufficiency was observed in the present study.

The prevalence of vitamin D deficiency in non-Saudi and Saudi subjects was 48.8% and 45.78%, respectively, while that of vitamin D insufficiency in non-Saudi and Saudi subjects was 27.67% and 26.2%, respectively. These results suggest that vitamin D deficiency and insufficiency are more prevalent in the non-Saudi population compared to the Saudi population in the region, which is in contrast to the findings of a cross-sectional study of the population of Al-Madinah Munawara, KSA [51]. This could be due to higher altitude and genetic, nutritional, socioeconomic and environmental factors. Non-Saudi subjects exhibited a 26% (OR=1.26, p=0.04) and 20% (OR=1.2, p=0.08) higher chance of being vitamin D deficient and insufficient, respectively, than Saudi subjects. Although both Saudi and non-Saudi populations living in Albaha experience low sun exposure due to the high altitude climate zone, the higher incidence of Hypovitaminosis D in non-Saudis may be attributed to their genetics and poor socioeconomic status and thereby the insufficient dietary supplementation of vitamin D, which is a major predictor of vitamin D deficiency [52,53].

The prevalence of vitamin D deficiency was marginally higher in females (46.2%) compared to males (45.2%). A higher prevalence of vitamin D deficiency in females in the KSA has been reported previously [41,54,55], however, few other studies have described a higher prevalence of vitamin D deficiency in males too [7,9]. This finding (a higher prevalence of vitamin D deficiency in females in the KSA) is in accordance with those emanating from a cross-sectional multi-stage survey report [2]. Since vitamin D deficiency is a multi-factorial phenomenon, it is important to determine the associated risk factors, particularly those for females, to manage and reduce vitamin D deficiency-related health issues in vulnerable populations.

In the overall child, male child and female child categories, the 12–18 age groups exhibited the lowest vitamin D status (21–23 ng/ml). A higher prevalence of vitamin D deficiency was observed in the 12–18 group (54%) compared to the 7–11 groups (37.6%) in child category. The prevalence of vitamin D deficiency in the male and female 12–18 groups was 48.5% and 58%, respectively. The same group (12–18) also showed the highest prevalence of vitamin D deficiency for Saudi (53.5%) and non-Saudi children (83.3%). In contrast to the 12–18 group, the 7–11, 2–6 and <2 groups were determined to be 50% (OR=0.5, p=0.001), 92% (OR=0.08, p=0.001) and 96% (OR=0.04, p=0.001) less likely to be vitamin D deficient.

Compared with the 12–18 group, the 2–6 and <2 groups showed a lower probability of being vitamin D insufficient by a factor of 0.35 (p=0.001) and 0.15

(p=0.001), respectively. These findings suggest that vitamin D deficiency/insufficiency is chiefly prevalent in adolescent children aged 12–18 years across various categories, which is in agreement with the observations reported in other studies [56,57]. Gordan et al. and Dyson et al. also reported a higher prevalence of vitamin D deficiency in children and adolescents [58,59]. The higher prevalence in non-Saudi children compared with Saudi children may be because of their genetic and socioeconomic status, reflecting insufficient dietary supplementation and limited outdoor activities and sun exposure.

In adults, 57.3% in the 19–39 age group and 42.9% in the 40–59 group were found to have vitamin D deficiency. In the overall adult, male adult (60.6%) and female adult (56.2%) categories, the 19–39 group exhibited the highest prevalence of vitamin D deficiency. The 19–39 group was found to be 3.3 times (OR=3.3, p<0.001) and 1.5 times (OR=1.5, p<0.001) more likely to be deficient and insufficient, respectively, with respect to the >60 group. The second highest degree of prevalence of Hypovitaminosis D was found in the 40–59 group, with 70% (OR=1.7, p<0.001) and 30% (OR=1.3, p=0.001) higher probability of being vitamin D deficient and insufficient, respectively, in comparison to the >60 group. A similar finding of a significantly higher risk of vitamin D deficiency (almost twice) in women aged 30–49 years compared with women aged 50–65 years (OR=2.01, p=0.03) has been reported in a study of Riyadh, KSA [60]. Tuffaha et al. reported a prevalence of vitamin D deficiency of 62.65% and 40% in Saudi adult females and males older than 15 years [2]. The prevalence of vitamin D sufficiency was 37% in the >60 age group (Table 3). This observation aligns with the finding of Naugler et al. who reported a lesser degree of prevalence of vitamin D deficiency in old age categories [61]. A similar degree of vitamin D deficiency was recorded in both Saudi (57.1%) and non-Saudi adults (59.4%) in the 19–39 age groups. In contrast with the >60 group, the 19–39 group of non-Saudi adults exhibited a greater likelihood of being deficient and insufficient by factors of 6.7 (p=0.001) and 1.6 (p=0.001), respectively. Whereas, compared with the >60 group, the 19–39 and 40–59 groups of Saudi adults were deficient by factors of 2.8 (p=0.001) and 1.5 (p=0.001), respectively. Previous studies have demonstrated a higher prevalence of vitamin D deficiency in the Saudi population [46,62]. The documented greater prevalence of vitamin D deficiency in the Saudi population across age groups could be due to genetics, urbanization of lifestyles and changes in dietary habits. Compared to the 12–18 age group, all other Saudi child groups were less likely to develop Hypovitaminosis D to a greater extent.

CONCLUSION

Overcoming health disparities has been a topic of discussion among the scientific community in recent years. Hypovitaminosis D is a common health-related problem both nationally and globally. In conclusion, the current study revealed that vitamin D deficiency and insufficiency were marginally greater in non-Saudis compared to Saudis. Vitamin D deficiency was found to be comparatively more prevalent in females. Males, females, Saudis and non-Saudis aged 19–39 exhibited a significantly higher prevalence of vitamin D deficiency in comparison to those aged >60 years. This study also suggests a higher prevalence of vitamin D deficiency and insufficiency in children and adolescents, especially those aged 12–18 years, compared to those of younger ages. The present study also suggests that the highest prevalence of vitamin D sufficiency is found in children aged <2 years (compared to all other child age groups) and in adults aged >60 years (compared to all other adult age groups). This indicates that individuals in the early and advanced stages of life in Albaha are comparatively less impacted by Hypovitaminosis D. Raising nationwide awareness about vitamin D fortification and supplementation and adequate sun exposure and outdoor activities among adolescents and adults may be worthwhile to reduce Hypovitaminosis D.

SUPPLEMENTARY MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

Conceptualization: AS and MA

Methodology: AS and MA

Formal analysis: AS and MA

Investigation: AS, SA, RA, FA, MA

Data curation: AS, MA, MS

Writing-Original draft preparation: AS, MI, NA

Writing, Review and Editing: AA, OS

Visualization: AS, AA, OS

Project administration: AS

Funding acquisition: AS

All authors have read and agreed to the published version of the manuscript.

FUNDING

This research was funded by the Deanship of Scientific Research at Albaha University in Saudi Arabia, grant number 223202-11-1439.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the Saudi Ministry Health, and approved by the Deanship of Scientific Research at Albaha University (1441-28-41206495-2) and the Scientific and Research Committee of King Fahad Hospital, Albaha, Saudi (protocol code 6972).

INFORMED CONSENT STATEMENT

Not applicable.

ACKNOWLEDGMENTS

We would like to acknowledge the Deanship of Scientific Research at Albaha University in Saudi Arabia for funding this study and all members who facilitated this research in different primary healthcare centers and general hospitals at Albaha city.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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