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Vitamin D levels in relation to low back pain during adolescence

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Abstract

This study aimed to investigate the association between 25-hydroxyvitamin D (25(OH)D) level and low back pain (LBP) among adolescents while adjusting for potential confounders pertinent to this age group including the weight of school bags, BMI and physical activity. A cross-sectional study was conducted on 760 randomly selected adolescents in middle schools. Data on LBP and the risk factors for LBP were collected from parents by a self-administered questionnaire and from adolescents by face-to-face interview. Blood samples were tested in an accredited laboratory; and 25(OH)D was measured using liquid chromatography-tandem MS. The lifetime prevalence and the 6-month prevalence of LBP were 32·28 (95 % CI 28·97, 35·73) % and 21·26 (95 % CI 18·40, 24·33) %, respectively. There was no difference in the geometric mean of 25(OH)D between those with and without LBP in the past 6 months (28·50 nmol/l and 30·82 nmol/l, respectively; $P = 0·122$). There was no association between 25(OH)D and LBP in the univariable or multivariable analysis whether 25(OH)D fitted as a continuous or as a categorical variable. We found no association between vitamin D level and LBP in adolescents in an area with high prevalence of vitamin D deficiency. Although it is important to have sufficient vitamin D levels during adolescence for several other health benefits, we concluded that vitamin D is not a major determinant for LBP among adolescents in our setting.

Key words: **Low back pain: Vitamin D: Adolescents: School bags: School-aged children**

Low back pain (LBP) is a major public health problem that affects all age groups in high-income, middle-income and low-income countries[1]. It has enormous economic impact on patients, governments and healthcare services[2]. Lifetime prevalence of LBP is 50–80 % in adults[3–5], while the prevalence in children usually becomes similar to that in adults by the age of 15–18 years[6–9]. Additionally, LBP is a major contributor to years lived with disability[10]. In adolescents, LBP is a major cause of school absenteeism and loss of educability[11–13]. LBP in childhood and adolescence is also a significant risk factor for LBP in adulthood, which highlights the importance of prevention at an early age[14].

The underlying causes of non-specific LBP are poorly understood in all age groups, and studies on risk factors associated with LBP have reported controversial results[10]. Having LBP during childhood or adolescence has been consistently reported to be a risk factor for LBP in adulthood[15,16], while all other factors show weak or inconsistent association[17–19]. Recently, vitamin D deficiency has been proposed to be a predisposing factor for LBP, particularly in adults. This has attracted huge attention because vitamin D supplementation would potentially be an easy preventive intervention. Although there is no definitive mechanism to explain how vitamin D levels can influence LBP, there are several plausible mechanisms through which vitamin D deficiency may increase the risk of LBP. First, vitamin D deficiency may have proinflammatory effect, which may contribute to LBP[20]. This is supported by several studies which demonstrated that vitamin D supplementation reduces inflammatory markers[21,22]. Second, vitamin D levels may modulate sensory neuron excitability[23,24] and influence muscle strength[25,26], which could both be related to LBP. Finally, low vitamin D levels decrease the uptake of Ca and reduce bone mineralisation (osteomalacia or osteoporosis), which may potentially lead to back pain[27].

Several epidemiological studies have attempted to establish the association between vitamin D and LBP and reported conflicting results. A recent literature review of nineteen previous studies (eleven cross-sectional studies and eight case–control studies) reported a significant association between vitamin D

Abbreviations: 25(OH)D, 25-hydroxyvitamin D; LBP, low back pain.

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deficiency and LBP, pooled OR 1·6 (95 % CI 1·20, 2·12)[17]. However, when the analysis was stratified by sex and age, the association was not significant in men and was stronger among women <60 years with no association in women ≥60 years. In fact, the authors reported that the association was confined to only studies from the Middle-Eastern/Mediterranean region attributing this to climatic and cultural factors. After this review, another nested case–control study showed no association between vitamin D status and the risk of LBP[28] and another review showed high prevalence of hypovitaminosis D in patients with LBP[29]. A recent review of randomised controlled trials that aimed to investigate the impact of vitamin D supplement on non-specific LBP or LBP resulting from osteoporosis showed that vitamin D supplementation is no more effective than placebo[27] and a major Cochrane Database systematic review has precluded a large beneficial effect of vitamin D in the treatment of painful conditions[30]. Despite these findings, a recent review showed that vitamin D supplementation is effective in reducing the pain score in chronic widespread pain[31].

Most of the studies included in the literature are confined to adult population, and there is paucity of data on adolescents' population. Adolescence is a period of growth; hence, LBP in this age group may have a different risk profile and pathways from that in adulthood. Particular covariates have to be taken into account at this age group, and therefore, results from studies on adults cannot be directly extrapolated to adolescents. As an example, the association between LBP and the weight of school bag has been under a continuous debate[32] but hardly considered in the previous studies. Heavy weight carried in school bags can distort the natural spinal curvature in the middle and lower back causing muscle strain and irritation to the spine joints and the rib cage[33]. Furthermore, carrying school bag with centre of gravity positioned at the thoracic vertebrae region as T7 causes significant forward displacement in body posture[34], while carrying school bag with centre of gravity at the lumbar region usually leads to an increase in spinal flexion as well as reductions in pelvic anteversion and rectus abdominis muscle activity[35]. Previously, from the same data set, we have demonstrated that vitamin D deficiency is very common in adolescents in Kuwait[36]. In this study, we aimed to investigate the association between vitamin D level and LBP among adolescents in public middle schools in Kuwait while adjusting for obesity, physical activity and the weight of school bags.

Methods

Participants

Data were collected within a project that aimed to estimate the prevalence of vitamin D deficiency among middle schoolchildren (11–16 years). The details of the project have been described previously[36]. In brief, a nationally representative sample of students was selected from public middle schools in Kuwait using multistage cluster sampling. Each school was given probability to be selected proportionate to its relative size as judged by the number of students in that school compared with the total number of students in the province (probability proportional to size sampling). The participants were selected from twelve public middle schools. A team of investigators drew blood samples and collected data on socio-demographic factors from the parents of selected adolescents through a self-administered questionnaire. Data were also collected on factors related to lifestyle such as physical activity and smoking through face-to-face interviews with the adolescents. Another team of researchers at a later time (minimum of 12 months from the time of blood collection) was formulated to interview the students and collect data on back pain and its related factors. This was conducted on a subgroup of students (n 762). This study including the original project was approved by The Ethics Committee at the Health Sciences Centre, Kuwait University (no. DR/EC/2338) and The Ethics Committee at The Ministry of Health in Kuwait (no. 2015/248). Data collection was initiated only after written informed consent was obtained from the parents and verbal assents from the adolescents.

Collection of blood samples and laboratory methods

In the original project, 5 ml of venous blood were drawn by a trained nurse. On the same day, the samples were centrifuged and the serum was transferred to Eppendorf tubes and stored at −80°C for analysis. We measured serum 25-hydroxyvitamin D (25(OH)D) concentration, which is known to be the best marker of vitamin D status that reflect both the amount of vitamin D produced in the skin after sun exposure and the amount consumed in foods[37]. We used liquid chromatography-tandem MS to measure 25(OH)D, which is the 'gold standard' method of vitamin D assessment[38,39]. This assay has a detection limit of 2 ng/ml for 25(OH)D_3, with the intra-assay CV of 3·7 % and the inter-assay CV of 5·3–6·0 %. Complete blood count, parathyroid hormone, vitamin B_{12}, Fe, ferritin, transferrin and transferrin saturation were all measured in an accredited clinical biochemistry laboratory in a teaching hospital, where these tests are routinely conducted under strict quality control. Serum intact parathyroid hormone was assessed using the Access Intact PTH chemiluminescent immunoassay with the Unicel DxI 800 Beckman Coulter analyzer using commercial kit (catalogue no. A16972). Serum vitamin B_{12} and erythrocytes folate in haemolysed whole blood were analysed with Roche commercial kits (catalogue no. 04745736 190) and (catalogue no. 03253678 122), respectively.

Data collection on low back pain and covariate assessment

Using a structured questionnaire, three trained data collectors gathered data on LBP through face-to-face interview. The questions on LBP were developed after an extensive literature review of studies that investigated LBP among adolescents. The details of the questionnaire, which has been used in previous studies on LBP in high school students in Kuwait, were published previously[13]. In brief, we collected data on the period prevalence of LBP, including the lifetime, 6-month and 1-month prevalence. A photo card was used to show each participant the exact location of LBP. Lifetime prevalence was evaluated by the question 'Have you ever felt low back pain that lasted a day or longer?

(Yes, No, I don't remember)', while 6-month period prevalence was gauged by the question 'Have you felt low back pain that lasted a day or longer in the last six months? (Yes, No, I don't remember)'. Questions about the frequency of LBP, its impact on daily life activities, treatment needed, absenteeism from school due to LBP, previous back injuries and relatedness of LBP to menstrual cycle (amongst females) were included. A 0–10 Numeric Pain Rating Scale was used to rate the intensity of LBP in past month. Data on depressive symptoms were collected using the Children's Depression Inventory[40], which has been translated and adopted in our setting[41].

Although the association between weight of school bags and LBP is under debate, we measured the weight (kg) of every student's bag using a portable digital luggage scale (SAFEWAYR) that was calibrated before each use. We also collected data on the perceived heaviness of school bags by asking the students the question 'How would you describe the weight of your school bag? (Light, Normal, Heavy, Too heavy)'. Data were also collected on the number of school bags a student carries and the use of lockers to reduce the weight of their bags. The weight of each adolescent was measured to the nearest 0·1 kg and the height to the nearest 0·1 cm in a standardised manner using a digital scale after removing shoes and any heavy clothing.

Statistical analysis

BMI was calculated as weight (kg) divided by height squared (m^2), and BMI-for-age *z*-scores were calculated using WHO growth charts. 25(OH)D status was defined according to the Endocrine Society[42] and the Society for Adolescent Health and Medicine[43] as deficiency <50 nmol/l; insufficiency 50–75 nmol/l; sufficiency ≥75 nmol/l. The association between 25(OH)D and LBP was assessed using unconditional logistic regression with adjustment for potential confounders. Separate analyses were performed with 25(OH)D fitted as a continuous variable and as a categorical variable. We categorised 25(OH)D using acceptable cut-off points[42] or quartiles. First, crude OR were calculated, and then variables with $P < 0·2$ were introduced sequentially to the model while noting the impact of this on the association between 25(OH)D and LBP. Some studies have suggested that the association between 25(OH)D and LBP is dependent on age and sex[17,28]; we, therefore, performed separate tests for the interaction between 25(OH)D and sex as well as age. As a sensitivity analysis, we used stepwise logistic regression to explore if the conclusion on the association between 25(OH)D and LBP would be different with stepwise variable selection. Data analysis was conducted using Stata (StataCorp. 2011, release 12), and factors that showed $P < 0·05$ were deemed to be statistically significant.

Results

Of 1416 adolescents with 25(OH)D measurement, 762 were interviewed to collect data on LBP and its related factors. The mean age was 12·26 (SD 0·81) years, and 386 (SD 50·66 %) were males. The lifetime prevalence of LBP was 32·28 % (95 % CI 28·97, 35·73 %), which was significantly higher among females compared with males (36·44 *v.* 28·24 %; $P = 0·016$). Also, the 6-month prevalence of LBP was 21·26 % (95 % CI 18·40, 24·33 %), which was 24·27 and 18·44 % in females and males, respectively ($P = 0·050$). The 1-month prevalence was 13·25 % (95 % CI 10·93, 15·87 %) and was also significantly higher among females compared with males (16·27 *v.* 10·39 %; $P = 0·017$). Among those who reported LBP during the past month, 66·99 % sought no treatment, 19·42 % used home remedies (e.g. hot packs), 5·83 % used analgesics over the counter and 7·77 % sought medical treatment from a public or a private clinic. In this group, the pain severity was assessed using 0–10 numeric pain rating scale, which showed a mean of 5·52 (SD 1·63) score. The geometric mean of 25(OH)D was 30·26 (SD 1·77) nmol/l, which was significantly lower among females compared with males, 22·22 (SD 1·69) nmol/l *v.* 40·87 (SD 1·55) nmol/l; $P < 0·001$. The prevalence of vitamin D deficiency was 93·88 % among females and 66·84 % among males ($P < 0·001$).

The association between socio-demographic factors and LBP in the past 6 months is shown in Table 1. In this analysis, we excluded two participants who answered 'I don't know' when asked about the LBP during the past 6 months. Except for sex in which females tended to have higher prevalence of LBP, socio-demographic characteristics were not significantly associated with LBP in univariable analysis. Table 2 shows the association between LBP in the past 6 months and lifestyle factors such as consumption of food not prepared at home, sleeping hours during weekdays and weekends and physical activity. The association between LBP in the past 6 months and BMI categories as well as factors related to school bags in addition to depression score is depicted in Table 2. In this analysis, sleeping hours during the weekdays (but not weekends) ($P = 0·024$) and perceived weight of school bag ($P < 0·001$) were associated with LBP in the past 6 months. Neither the absolute weight of school bag ($P = 0·528$) nor the weight of school bag as a percentage of body weight ($P = 0·059$) was significantly associated with LBP in the past 6 months in univariable analysis. However, the weight of school bag as a percentage of body weight became significantly associated with LBP in multivariable analysis (Table 3). The other two factors significantly associated with LBP in univariable analysis were sitting posture (on bed, desk, floor and couch) and depression score. The association between various laboratory measurements and LBP in the past 6 months is demonstrated in Table 4. None of the laboratory results showed significant association with the LBP during the past 6 months in univariable analysis. This was evident whether these laboratory measurements were fitted as continuous or categorical variables.

There was no difference in the geometric mean of 25(OH)D between those with and without LBP in the past 6 months, 28·50 nmol/l and 30·82 nmol/l, respectively ($P = 0·122$). The association between 25(OH)D and LBP during the past 6 months before and after adjusting for potential confounders is shown in Table 5. There was no association between 25(OH)D and LBP in univariable or multivariable analysis whether 25(OH)D was fitted as a continuous, or as a categorised variable using quartiles or acceptable cut-off points. In this analysis, the interaction between sex and 25(OH)D was not significant in all crude ($P \geq 0·157$) or adjusted ($P \geq 0·651$) analyses. We also

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Table 1. Association between low back pain during the past 6 months and socio-demographic factors in 760 adolescents in univariable analysis
(Numbers and percentages; odds ratios and 95 % confidence intervals)

Characteristics	Total	Prevalence of low back pain		OR	95 % CI	*P*
		n	%			
Sex						
Male	385	71	18·44		Ref.	0·050
Female	375	91	24·27	1·42	1·00, 2·01	
Age (years)						
<12	326	61	18·71		Ref.	0·125
12–12·99	294	63	21·43	1·18	0·80, 1·76	
≥13	140	38	27·14	1·62	1·02, 2·58	
Nationality						
Kuwaiti	559	120	21·47		Ref.	0·865
Non-Kuwaiti	201	42	20·90	0·97	0·65, 1·44	
School's governorate						
Capital	123	20	16·26		Ref.	0·118
Hawally	146	37	25·34	1·75	0·95, 3·21	
Farwaniya	93	19	20·43	1·32	0·66, 2·65	
Jahra	80	11	13·75	0·82	0·37, 1·82	
Mubarak Al-Kabeer	86	16	18·60	1·18	0·57, 2·42	
Ahmadi	232	59	25·43	1·76	1·00, 3·08	
Father's education						
Primary/intermediate/no formal education	100	22	22·00		Ref.	0·988
Secondary (high school)	181	37	20·44	0·91	0·50, 1·65	
Diploma	154	33	21·43	0·96	0·52, 1·77	
University and above	310	67	21·61	0·97	0·57, 1·68	
Mother's education						
Primary/intermediate/no formal education	77	17	22·08		Ref.	0·809
Secondary (high school)	161	37	22·98	1·05	0·55, 2·02	
Diploma	165	31	18·79	0·82	0·42, 1·59	
University and above	348	76	21·84	0·99	0·54, 1·79	
Father's income (Kuwaiti dinars)						
<500	54	13	24·07		Ref.	0·660
500–1000	174	34	19·54	0·76	0·37, 1·58	
1001–1500	226	50	22·12	0·90	0·44, 1·80	
1501–2000	112	24	21·62	0·87	0·40, 1·88	
More than 2000	101	26	25·74	1·09	0·51, 2·35	
Do not wish to tell	72	11	15·49	0·58	0·24, 1·42	
Mother's employment						
Housewife	246	50	20·41		Ref.	0·770
Paid employment	385	82	21·35	1·06	0·71, 1·57	
Other	118	28	23·73	1·21	0·71, 2·05	
Type of housing						
Rented flat	291	61	20·96		Ref.	0·204
Rented house	82	11	13·41	0·58	0·29, 1·17	
Owned flat	43	12	27·91	1·46	0·71, 3·01	
Owned house	335	76	22·75	1·11	0·76, 1·62	
Total number of siblings						
≤2	186	39	20·97		Ref.	0·938
3–4	302	64	21·19	1·01	0·65, 1·59	
5 or more	261	58	22·22	1·08	0·68, 1·70	
Passive smoking at home						
No	491	107	21·79		Ref.	0·846
Yes	255	54	21·18	0·96	0·67, 1·39	

Ref., reference.

used stepwise logistic regression method, in which 25(OH)D was not selected neither in forward nor backward selection. When 25(OH)D was forced in this analysis, it was not significant in any model. Vitamin D binding protein was measured in a subsample of 404 participants; hence, we were able to calculate free vitamin D levels as described by Tsuprykov *et al.*[45]. There was no significant association between free 25(OH)D and LBP in univariable ($P = 0·603$) or multivariable ($P = 0·457$) analysis. We also repeated the above analysis with LBP in the past month or lifetime LBP and found no significant association between 25(OH)D and any of these outcomes. Finally, factors that were significantly associated with LBP in the past 6 months in multivariable analysis were governorate (province) in which the school was allocated ($P = 0·039$), perceived weight of school bag ($P = 0·001$), weight of school bag as a percentage of the body weight ($P = 0·017$) and sleeping hours during weekdays ($P = 0·037$) (Table 3). Using backward and forward stepwise selection, perceived weight of school bag, age of adolescents

Table 2. Association between low back pain during the past 6 months and lifestyle factors, physical activity, BMI and depression score in addition to factors related to school bag in univariable analysis
(Numbers and percentages; odds ratios and 95 % confidence intervals)

Characteristics	Total	Prevalence of low back pain		OR	95 % CI	*P*
		n	%			
Times/week consumed breakfast not prepared at home						
0	338	74	21·89		Ref.	0·923
1–2 times	314	65	20·70	0·93	0·64, 1·36	
3–4	57	14	24·56	1·16	0·60, 2·23	
5 or more	34	7	20·59	0·92	0·39, 2·20	
Times/week consumed lunch not prepared at home						
0	199	42	21·11		Ref.	0·742
1–2 times	442	96	21·72	1·04	0·69, 1·56	
3–4	66	17	25·76	1·30	0·68, 2·48	
5 or more	31	5	16·13	0·71	0·26, 1·98	
Times/week consumed dinner not prepared at home						
0	86	20	23·26		Ref.	0·475
1–2 times	475	102	21·47	0·90	0·52, 1·56	
3–4	137	25	18·25	0·74	0·38, 1·43	
5 or more	37	11	29·73	1·40	0·59, 3·31	
Times/week child has breakfast before going to school						
Every day/5 d/week	311	72	23·15		Ref.	0·701
3–4 d/week	97	20	20·62	0·86	0·49, 1·51	
1–2 d/week	127	23	18·11	0.73	0·44, 1·24	
Never	216	46	21·30	0·90	0·59, 1·36	
Hours of sleep during weekdays						
<7·5 h (lower tertile)	221	61	27·60		Ref.	0·024
7·5 h to <9 h (middle tertile)	273	49	17·95	0·57	0·37, 0·88	
9 h or more (higher tertile)	265	52	19·62	0·64	0·42, 0·98	
Hours of sleep during weekend						
<9 h (lower tertile)	160	37	23·13		Ref.	0·487
9 h to <11 h (middle tertile)	336	65	19·35	0·80	0·50, 1·26	
11 or more (middle tertile)	263	60	22·81	0·98	0·62, 1·57	
Time walking to school per week (going and coming equal two times)						
None	607	129	21·25		Ref.	0·702
1–8 times	102	24	23·53	1·14	0·69, 1·87	
Every day	51	9	17·65	0·79	0·38, 1·67	
Time spent on physical activity per week						
Low (lower tertile)	238	45	18·91		Ref.	0·370
Medium (middle tertile)	255	53	20·78	1·12	0·72, 1·75	
High (higher tertile)	267	64	23·97	1·35	0·88, 2·07	
BMI categories						
Normal weight	331	66	19·94		Ref.	0·645
Overweight	165	35	21·21	1·08	0·68, 1·71	
Obese	252	57	22·62	1·17	0·79, 1·75	
Underweight	12	3	33·33	2·01	0·59, 6·87	
Depression score using CDI						
<19 score	582	115	19·76		Ref.	0·010
≥19 score	110	34	30·91	1·81	1·15, 2·86	
Sitting during study or doing homework on						
Bed	226	62	27·43		Ref.	0·014
Desk	315	52	16·51	0·52	0·34, 0·79	
Floor	153	30	19·61	0·64	0·39, 1·06	
Couch	65	17	26·15	0·94	0·50, 1·75	
Perceived weight of school bag						
Light	79	14	17·72		Ref.	<0·001
Normal	350	48	13·71	0·74	0·38, 1·42	
Heavy	290	84	28·97	1·89	1·01, 3·56	
Very heavy	40	15	37·50	2·78	1·18, 6·60	
Absolute weight of school bag (kg)						
Low (lower tertile) <5·7 kg	249	53	21·29		Ref.	0·528
Medium (middle tertile) 5·7 to <7·0 kg	255	49	19·22	0·88	0·57, 1·36	
High (higher tertile) ≥ 7·0 kg	253	59	23·32	1·12	0·74, 1·71	
Weight of school bag as % of body weight						
≤10 %	222	52	23·42		Ref.	0·059
>10 to <15 %	296	50	16·89	0·66	0·43, 1·02	
≥15 %	239	59	24·69	1·07	0·70, 1·64	

Ref., reference; CDI, Children's Depression Inventory.

Table 3. Factors associated with low back pain during the past 6 months in multivariable analysis (Numbers and percentages; odds ratios and 95 % confidence intervals)

Characteristics	Total	Prevalence of low back pain		OR	95 % CI	*P*
		n	%			
Sex						
Male	385	71	18·44		Ref.	0·452
Female	375	91	24·27	1·18	0·77, 1·81	
Age (years)						
<12	326	61	18·71		Ref.	0·064
12–12·99	294	63	21·43	1·38	0·88, 2·17	
≥13	140	38	27·14	1·90	1·10, 3·27	
School's governorate						
Capital	123	20	16·26		Ref.	0·029
Hawally	146	37	25·34	2·07	1·07, 4·00	
Farwaniya	93	19	20·43	1·14	0·51, 2·51	
Jahra	80	11	13·75	0·64	0.26, 1·61	
Mubarak Al-Kabeer	86	16	18·60	1·20	0·54, 2·68	
Ahmadi	232	59	25·43	1·76	0·95, 3·27	
Hours of sleep during weekdays						
<7·5 h (lower tertile)	221	61	27·60		Ref.	0·037
7·5 h to <9 h (middle tertile)	273	49	17·95	0·54	0·33, 0·87	
9 h or more (higher tertile)	265	52	19·62	0·64	0·39, 1·04	
Depression score using CDI						
<19 score	582	115	19·76		Ref.	0·110
≥19 score	110	34	30·91	1·49	1·91, 2·44	
Sitting during study or doing homework on						
Bed	226	62	27·43		Ref.	0·141
Desk	315	52	16·51	0·58	0·36, 0·93	
Floor	153	30	19·61	0·80	0·46, 1·41	
Couch	65	17	26·15	0·97	0·47, 2·00	
Perceived weight of school bag						
Light	79	14	17·72		Ref.	<0·001
Normal	350	48	13·71	0·77	0·38, 1·55	
Heavy	290	84	28·97	1·67	0·83, 3·36	
Very heavy	40	15	37·50	2·61	0·99, 6·83	
Weight of school bag as % of body weight						
≤10 %	222	52	23·42		Ref.	0·015
>10 to <15 %	296	50	16·89	0·58	0·36, 0·94	
≥15 %	239	59	24·69	1·11	0·68, 1·81	

Ref., reference; CDI, Children's Depression Inventory.

Table 4. Association between low back pain during the past 6 months and parathyroid hormone, calcium, vitamin B_{12}, anaemia, ferritin and folate in univariable analysis (Numbers and percentages; odds ratios and 95 % confidence intervals)

Characteristics	Total	Prevalence of low back pain		OR	95 % CI	*P*
		n	%			
Parathyroid hormone (nmol/l)	759	–	–	1·02	0·99, 1·06	0·184
Ca						
≥2·1 (mmol/l)	739	156	21·11		Ref.	0·675
<2·1 (mmol/l)	20	5	25·00	1·24	0·44, 3·48	
Vitamin B_{12}						
≥148 (pmol/l) sufficient	642	141	21·96		Ref.	0·810
<148 (pmol/l) deficient	25	6	24·00	1·12	0·44, 2·86	
Anaemia as defined by WHO[44]						
No	707	148	20·99		Ref.	0·436
Yes	55	14	25·45	1·28	0·68, 2·42	
Fe	759	–	–	1·00	0·96, 1·03	0·822
Ferritin						
Normal ≥ 15 ng/ml	548	117	21·35		Ref.	0·881
Low < 15 ng/ml	211	44	20·85	0·97	0·66, 1·43	
Folate	760	–	–	1·00	1·00, 1·00	0·528

Ref., reference.

Table 5. Association between plasma 25-hydroxyvitamin D (25(OH)D) and low back pain in the past 6 months before and after adjusting for potential confounders
(Numbers and percentages; odds ratios and 95 % confidence intervals)

	Prevalence of low back pain		Crude OR		Adjusted* OR	
Vitamin D status	*n*	%	OR	95 % CI	OR	95 % CI
25(OH)D levels (nmol/l)	–		0·99	0·98, 1·00	0·99	0·98, 1·00
P			0·138		0·316	
Q1 (25(OH)D < 21·2 nmol/l) (*n* 189)	44	23·28		Ref.		Ref.
Q2 (25(OH)D ≥ 21·2 to <30·95 nmol/l) (*n* 190)	46	24·21	1·05	0·66, 1·69	1·12	0·67, 2·02
Q3 (25(OH)D ≥ 30·95 to <45 nmol/l) (*n* 189)	37	19·58	0·80	0·49, 1·31	0·83	0·44, 1·55
Q4 (25(OH)D ≥ 45 nmol/l) (*n* 192)	35	18·23	0·73	0·45, 1·21	0·79	0·39, 1·59
P			0·421		0·592	
Severe deficiency (25(OH)D < 25 nmol/l) (*n* 264)	62	23·48		Ref.		Ref.
Deficiency (25(OH)D ≥ 25 to <50 nmol/l) (*n* 345)	70	20·29	0·83	0·56, 1·22	0·78	0·48, 1·26
Insufficiency (25(OH)D ≥ 50 to <75 nmol/l) (*n* 119)	23	19·33	0·78	0·45, 1·34	0·81	0·40, 1·65
Sufficiency (25(OH)D ≥ 75 nmol/l) (*n* 32)	7	21·88	0·91	0·38, 2·21	0·93	0·31, 2·77
P			0·743		0·768	

Q1–Q3, quartile 1 to quartile 4. Ref., reference.
* Adjusted for all variables with $P < 0·2$ including sex, age, school governorate (province), sleeping hours during weekdays, perceived weight of school bag, the way of sitting during homework or reading, weight of school bag as percentage of the body weight, parathyroid hormone and depression score.

and sleeping hours during weekdays were the only significant predictors for LBP in the past 6 months.

Discussion

In this study, we estimated the prevalence of LBP among adolescents in the middle schools in Kuwait and investigated the association between LBP and vitamin D levels. We found the lifetime prevalence of LBP to be 32 %, while the 6-month prevalence to be 21·26 %. There was no association between 25(OH)D levels and LBP in the past 6 months neither in univariable nor in multivariable analysis. This was evident whether 25(OH)D was fitted as a continuous variable or a categorical variable using acceptable cut-off points or quartiles.

The lifetime and the 6-month prevalence of LBP in middle school students were lower than that reported among high school students in Kuwait[13]. This can be explained by the notion that the prevalence of LBP increases with age and reaches that of the adult population at the age of 15–18 years[8,9]. The prevalence was significantly higher among females compared with males, which is consistent with several other studies[9,46–48]. Prevalence of LBP in adolescence varies considerably between different studies with lifetime prevalence ranges between 11·60 and 85·56 % as reviewed by Calvo-Munoz *et al.*[8]. Some of these differences could be attributed to methodological differences, including the variation in LBP definition and the age of the targeted groups.

Although there are several plausible pathways in which low vitamin D levels may contribute to LBP, the findings of epidemiological studies on this issue remain controversial. A literature review[27] showed that most studies were on adult populations or included participants with a wide age range (adolescents and adults) without sufficient numbers to conduct an age-stratified analysis. In our study, we found no significant association between 25(OH)D levels or 25(OH)D status and LBP in adolescents. Our results are different from the findings of another study that investigated this issue among school-aged children[48]. In this study, the authors reported a lower mean of 25(OH)D among school-aged children with severe LBP (*n* 45) compared with those with moderate LBP (*n* 85) and no or minimal LBP (*n* 120). In their results, however, arithmetic mean may not represent the centre of the 25(OH)D distribution (e.g. mean = 9·5 ng/ml, while SD = 4·7 ng/ml in the severe LBP group). Our findings match the results of a pilot study among adolescent male ballet dancers[49] as well as a recent nested case–control study among adults (adults 19–55 years)[28]. Both studies showed no significant association between vitamin D status and the risk of LBP. Furthermore, a recent review of studies (mainly on adult population) concluded that there is an association between vitamin D deficiency and LBP overall[17]. However, age- and sex-stratified analysis showed the association existed only in women <60 years with no association in men or in women >60 years. In fact, the authors found the association to be confined to the Middle East/Mediterranean region, with no association between vitamin D and LBP in the studies outside this region. In another recent review of studies on adult population (30–66 years), authors found higher prevalence of hypovitaminosis D in patients with LBP compared with those without LBP[29]. One of the possible explanations for these mixed results of observational epidemiological studies is the difference in the measurement of vitamin D as well as the differences in the definition of LBP. Not only are the results of observational studies conflicting but also the randomised controlled trials that aimed to investigate the impact of vitamin D supplementation on LBP or musculoskeletal pain in general showed mixed results. A recent review of randomised controlled trials showed that vitamin D supplementation is no more effective than placebo in treatment of non-specific LBP or LBP resulting from osteoporosis[27]. A major Cochrane Database systematic review has also precluded a large beneficial effect of vitamin D supplementation in the treatment of painful conditions[30]. Some recent reviews showed no clear benefit of vitamin D

supplementation in treatment of chronic non-specific musculoskeletal pain[50], while other reviews showed that vitamin D supplementation is effective in reducing the pain score in chronic widespread pain[31,51,52]. Currently, vitamin D supplementation cannot be considered as an independent treatment for chronic pain[53].

While the lack of association between 25(OH)D and LBP could be genuine in our study, it could be due to the fact that our adolescents were mostly vitamin D deficient (80·2 % of the study group were vitamin D deficient and only 4·2 % had sufficient vitamin D level). In spite of large study size, the small number of adolescents with sufficient vitamin D level lowered the power of the study to detect small differences in the prevalence of LBP. Power calculation showed that our study has 73 % power to detect a difference of 10 % in the prevalence of LBP between those with and without vitamin D deficiency at 5 % level of significance (two-sided) given that the prevalence of LBP we found in the study was 21 %. However, the study will have more than 90 % power to detect 15 % difference in the prevalence of LBP between those with and without vitamin D deficiency, while all other assumptions remain the same. Furthermore, in children or adolescents even if the association between 25(OH)D and LBP vitamin D deficiency exists, low vitamin D level would have less time to exert its influence on the risk of LBP compared with adults. Finally, the proposed mechanism for low vitamin D to increase the risk of LBP through reducing bone mineralisation (osteomalacia or osteoporosis) seems less likely during adolescence compared with adulthood. This makes the association between vitamin D levels and LBP more elusive in children and adolescents compared with that in adults.

With respect to other risk factors, a recent literature review on risk factors for LBP in children and adolescents showed inconsistent association between all presumed risk factors and LBP[19]. Recently, the association between the weight of school bag and LBP among schoolchildren has attracted huge attention. We have previously reported the importance of the perceived weight of school bag compared with the absolute weight of school bag (or the bag weight as a percentage of body weight) for practical and logical reasons among high school students[13]. In our present study, the perceived weight of school bag was significantly related to LBP in univariable and multivariable analyses. We reiterate our previous recommendation that parents should be encouraged not to allow their children to carry school bags, which their children describe as heavy. Such recommendation would be easy to implement because it does not require weighing the child or the school bag. This does not mean that the weight of school bag as a percentage of body weight is not important. In our previous study, the weight of school bag as a percentage of the body weight was significantly associated with LBP in univariable analysis but not in multivariable analysis among high school students. In the present study, while the weight of school bag as a percentage of body weight was not significantly associated with LBP in univariable analysis ($P = 0{\cdot}059$), it was significant in multivariable analysis ($P = 0{\cdot}017$). It is worth noting that the perceived weight of school bag was not correlated with the weight of school bag as a percentage of body weight but was correlated with the absolute weight of school bag. A recent literature review showed the association between backpack weight and LBP to be inconsistent across studies[19] and that the available evidence does not support that school bags weighing >10 % of the body weight are associated with higher prevalence of LBP among schoolchildren[32].

In our study, physical activity was not significantly associated with LBP neither in univariable nor multivariable analyses. Although we collected data on physical activity by a questionnaire that has been previously validated using accelerometers in high school students (Spearman correlation 0·92; $P < 0{\cdot}001$ for total steps count, not published), self-reported data on physical activity usually carry large amount of non-differential misclassifications. This could bias the association between physical activity and LBP towards the null, which may explain our findings. Previous studies have suggested U-shaped association between physical activity and LBP in adolescents, where both low and high levels of physical activity are associated with higher risk of LBP[9]. Nevertheless, a recent review of the previous studies showed that the association between sport activities and LBP is controversial, with some studies showing positive association or inverse association or no association[19]. Similarly, BMI was not associated with LBP neither in univariable or multivariable analysis in our study. This is consistent with the current literature review which showed that BMI is not a major determinant of LBP in children and adolescents[19].

To our knowledge, this is the largest study that investigated the association between vitamin D levels and LBP among adolescents in the Middle East. We have measured 25(OH)D using liquid chromatography-tandem MS, which is the 'gold standard' method[38,39] in an accredited laboratory. We collected data on all potential confounders in this age group including the measurement of the weight of school bags, physical activity, BMI and depression. In order to draw a robust conclusion, we analysed the association between 25(OH)D and LBP dealing with 25(OH)D as a continuous variable and as a categorical variable using quartiles or acceptable cut-off point. This is an important analytical aspect because the results of the previous studies on this issue were dependent on how the variables were analysed[27]. We also calculated free vitamin D and investigated its association with LBP for the first time. Inevitably, data collection on LBP relied on recall, which may have caused non-differential misclassification in the outcome hence biased our findings towards the null. Finally, we did not collect data on other musculoskeletal conditions that may interfere with LBP such as hypermobility syndrome, connective tissue disorder and juvenile-onset scoliosis.

In conclusion, we have demonstrated that approximately one-third of children in middle schools in Kuwait had experienced LBP in their lifetime and one-fifth had LBP during the past 6 months. We found no significant association between vitamin D levels and LBP in adolescents in an area with high prevalence of vitamin D deficiency. Although it is important to have sufficient vitamin D level during childhood and adolescence for several health benefits, we concluded that vitamin D is not a major determinant for LBP among adolescents in our setting. We also concluded that the weight of school bag

as a percentage of body weight is associated with LBP in adolescence.

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The authors declare that there are no conflicts of interest.

References

1. Hartvigsen J, Hancock MJ, Kongsted A, *et al.* (2018) What low back pain is and why we need to pay attention. *Lancet* **391**, 2356–2367.
2. Steffens D, Maher CG, Pereira LS, *et al.* (2016) Prevention of low back pain: a systematic review and meta-analysis. *JAMA Intern Med* **176**, 199–208.
3. Andersson GB (1998) Epidemiology of low back pain. *Acta Orthop Scand Suppl* **281**, 28–31.
4. Frymoyer JW (1988) Back pain and sciatica. *N Engl J Med* **318**, 291–300.
5. Hoy D, Bain C, Williams G, *et al.* (2012) A systematic review of the global prevalence of low back pain. *Arthritis Rheum* **64**, 2028–2037.
6. Kovacs FM, Gestoso M, Gil del Real MT, *et al.* (2003) Risk factors for non-specific low back pain in schoolchildren and their parents: a population based study. *Pain* **103**, 259–268.
7. Masiero S, Carraro E, Celia A, *et al.* (2008) Prevalence of non-specific low back pain in schoolchildren aged between 13 and 15 years. *Acta Paediatr* **97**, 212–216.
8. Calvo-Munoz I, Gomez-Conesa A & Sanchez-Meca J (2013) Prevalence of low back pain in children and adolescents: a meta-analysis. *BMC Pediatr* **13**, 14.
9. MacDonald J, Stuart E & Rodenberg R (2017) Musculoskeletal low back pain in school-aged children: a review. *JAMA Pediatr* **171**, 280–287.
10. Forouzanfar MH, Alexander L, Anderson HR, *et al.* (2015) Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **386**, 2287–2323.
11. O'Sullivan PB, Beales DJ, Smith AJ, *et al.* (2012) Low back pain in 17 year olds has substantial impact and represents an important public health disorder: a cross-sectional study. *BMC Public Health* **12**, 100.
12. Bejia I, Abid N, Ben Salem K, *et al.* (2005) Low back pain in a cohort of 622 Tunisian schoolchildren and adolescents: an epidemiological study. *Eur Spine J* **14**, 331–336.
13. Akbar F, AlBesharah M, Al-Baghli J, *et al.* (2019) Prevalence of low back pain among adolescents in relation to the weight of school bags. *BMC Musculoskelet Disord* **20**, 37.
14. Hestbaek L, Leboeuf-Yde C, Kyvik KO, *et al.* (2006) The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. *Spine* **31**, 468–472.
15. Taylor JB, Goode AP, George SZ, *et al.* (2014) Incidence and risk factors for first-time incident low back pain: a systematic review and meta-analysis. *Spine J* **14**, 2299–2319.
16. Hestbaek L, Leboeuf-Yde C & Kyvik KO (2006) Is comorbidity in adolescence a predictor for adult low back pain? A prospective study of a young population. *BMC Musculoskelet Disord* **7**, 29.
17. Zadro J, Shirley D, Ferreira M, *et al.* (2017) Mapping the association between Vitamin D and low back pain: a systematic review and meta-analysis of observational studies. *Pain Physician* **20**, 611–640.
18. Hill JJ & Keating JL (2010) Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. *J Physiother* **56**, 237–244.
19. Calvo-Munoz I, Kovacs FM, Roque M, *et al.* (2018) Risk factors for low back pain in childhood and adolescence: a systematic review. *Clin J Pain* **34**, 468–484.
20. DeLuca HF (2004) Overview of general physiologic features and functions of vitamin D. *Am J Clin Nutr* **80**, 1689s–1696s.
21. Grossmann RE, Zughaier SM, Liu S, *et al.* (2012) Impact of vitamin D supplementation on markers of inflammation in adults with cystic fibrosis hospitalized for a pulmonary exacerbation. *Eur J Clin Nutr* **66**, 1072–1074.
22. Hopkins MH, Owen J, Ahearn T, *et al.* (2011) Effects of supplemental vitamin D and calcium on biomarkers of inflammation in colorectal adenoma patients: a randomized, controlled clinical trial. *Cancer Prev Res* **4**, 1645–1654.
23. Garcion E, Wion-Barbot N, Montero-Menei CN, *et al.* (2002) New clues about vitamin D functions in the nervous system. *Trends Endocrinol Metab* **13**, 100–105.
24. Stumpf WE & O'Brien LP (1987) 1,25 (OH)2 vitamin D3 sites of action in the brain. An autoradiographic study. *Histochemistry* **87**, 393–406.
25. Rosendahl-Riise H, Spielau U, Ranhoff AH, *et al.* (2017) Vitamin D supplementation and its influence on muscle strength and mobility in community-dwelling older persons: a systematic review and meta-analysis. *J Hum Nutr Diet* **30**, 3–15.
26. Stockton KA, Mengersen K, Paratz JD, *et al.* (2011) Effect of vitamin D supplementation on muscle strength: a systematic review and meta-analysis. *Osteoporos Int* **22**, 859–871.
27. Zadro JR, Shirley D, Ferreira M, *et al.* (2018) Is vitamin D supplementation effective for low back pain? A systematic review and meta-analysis. *Pain Physician* **21**, 121–145.
28. Heuch I, Hagen K, Mai XM, *et al.* (2017) Is there an association between vitamin D status and risk of chronic low back pain? A nested case–control analysis in the Nord-Trondelag Health Study. *BMJ Open* **7**, e018521.
29. Bansal D, Boya CS, Vatte R, *et al.* (2018) High prevalence of hypovitaminosis D in patients with low back pain: evidence from meta-analysis. *Pain Physician* **21**, E389–e399.
30. Straube S, Derry S, Straube C, *et al.* (2015) Vitamin D for the treatment of chronic painful conditions in adults. *Cochrane Database Syst Rev*, issue 5, CD007771.
31. Yong WC, Sanguankeo A & Upala S (2017) Effect of vitamin D supplementation in chronic widespread pain: a systematic review and meta-analysis. *Clin Rheumatol* **36**, 2825–2833.
32. Calvo-Munoz I, Kovacs F, Roque M, *et al.* (2019) The association between the weight of schoolbags and low back pain

among schoolchildren. A systematic review, meta-analysis and individual patient data meta-analysis. *Eur J Pain* **24**, 91–109.
33. Chow DH, Ou ZY, Wang XG, *et al.* (2010) Short-term effects of backpack load placement on spine deformation and repositioning error in schoolchildren. *Ergonomics* **53**, 56–64.
34. Grimmer K, Dansie B, Milanese S, *et al.* (2002) Adolescent standing postural response to backpack loads: a randomised controlled experimental study. *BMC Musculoskelet Disord* **3**, 10.
35. Devroey C, Jonkers I, de Becker A, *et al.* (2007) Evaluation of the effect of backpack load and position during standing and walking using biomechanical, physiological and subjective measures. *Ergonomics* **50**, 728–742.
36. Al-Taiar A, Rahman A, Al-Sabah R, *et al.* (2018) Vitamin D status among adolescents in Kuwait: a cross-sectional study. *BMJ Open* **8**, e021401.
37. Holick MF (2007) Vitamin D deficiency. *N Engl J Med* **357**, 266–281.
38. Yetley EA, Pfeiffer CM, Schleicher RL, *et al.* (2010) NHANES monitoring of serum 25-hydroxyvitamin D: a roundtable summary. *J Nutr* **140**, 2030s–2045s.
39. de la Hunty A, Wallace AM, Gibson S, *et al.* (2010) UK food standards agency workshop consensus report: the choice of method for measuring 25-hydroxyvitamin D to estimate vitamin D status for the UK National Diet and Nutrition Survey. *Br J Nutr* **104**, 612–619.
40. Kovacs M (1985) The Children's Depression Inventory (CDI). *Psychopharmacol Bull* **21**, 995–998.
41. Al-Balhan EM (2006) The Children's Depression Inventory as a reliable measure for post-Iraqi invasion Kuwaiti youth. *Soc Behav Personal* **34**, 351–366.
42. Holick MF, Binkley NC, Bischoff-Ferrari HA, *et al.* (2011) Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. *J Clin Endocrinol Metab* **96**, 1911–1930.
43. Society for Adolescent Health and Medicine (2013) Recommended vitamin D intake and management of low vitamin D status in adolescents: a position statement of the Society for Adolescent Health and Medicine. *J Adolesc Health* **52**, 801–803.
44. World Health Organization (2011) *Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity. Vitamin and Mineral Nutrition Information System*. Geneva: WHO.
45. Tsuprykov O, Chen X, Hocher CF, *et al.* (2018) Why should we measure free 25(OH) vitamin D? *J Steroid Biochem Mol Biol* **180**, 87–104.
46. Sundell CG, Bergstrom E & Larsen K (2019) Low back pain and associated disability in Swedish adolescents. *Scand J Med Sci Sports* **29**, 393–399.
47. Jones GT, Watson KD, Silman AJ, *et al.* (2003) Predictors of low back pain in British schoolchildren: a population-based prospective cohort study. *Pediatrics* **111**, 822–828.
48. Alghadir AH, Gabr SA & Al-Eisa ES (2017) Mechanical factors and vitamin D deficiency in schoolchildren with low back pain: biochemical and cross-sectional survey analysis. *J Pain Res* **10**, 855–865.
49. Ducher G, Kukuljan S, Hill B, *et al.* (2011) Vitamin D status and musculoskeletal health in adolescent male ballet dancers a pilot study. *J Dance Med Sci* **15**, 99–107.
50. Gaikwad M, Vanlint S, Mittinity M, *et al.* (2017) Does vitamin D supplementation alleviate chronic nonspecific musculoskeletal pain? A systematic review and meta-analysis. *Clin Rheumatol* **36**, 1201–1208.
51. Wu Z, Malihi Z, Stewart AW, *et al.* (2016) Effect of Vitamin D supplementation on pain: a systematic review and meta-analysis. *Pain Phys* **19**, 415–427.
52. Helde-Frankling M & Bjorkhem-Bergman L (2017) Vitamin D in pain management. *Int J Mol Sci* **18**, 2170.
53. Martin KR & Reid DM (2017) Is there role for vitamin D in the treatment of chronic pain? *Ther Adv Musculoskelet Dis* **9**, 131–135.