Seasonal variation of vitamin D levels in Swiss athletes

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Abstract

Introduction: Vitamin D deficiency is very prevalent in world population and growing evidence shows that also athletes are affected. Vitamin D deficiency causes beside bone disorders, musculoskeletal pain, muscle weakness and is associated with many other health disorders. For athletes in particular it may impair training and performance, prolong recovery and increase risk of injury. We therefore analyzed vitamin D levels in Swiss athletes focusing on prevalence according to age, gender, seasonal variations, indoor or outdoor sports, sunscreen use and vitamin D supplementation.

Methods: This study was performed in a convenient sample of 655 Swiss Olympic athletes over one year. Blood samples were obtained and a questionnaire was filled in at Swiss Olympic Medical Centers or Bases during an annual routine exam. Data were then sent to the central laboratory of the Aarau hospital where they were processed and sent to us in an anonymized version. Vitamin D levels were categorized into *deficiency* (≤ 50 nmol/l), *insufficiency* (between 50 and 75 nmol/l) and *adequate levels* (> 75 nmol/l) of 25-hydroxyvitamin D. By means of the questionnaire, we assessed age, gender, type of sport, symptoms possibly related to vitamin D deficiency during the last year, frequency of sunscreen use and vitamin D-containing medications of the athletes.

Results: 13.5% of the participants (total number = 651) presented a vitamin D deficiency, 37.8% a vitamin D insufficiency so that more than half of the athletes (51.2%) had inadequate vitamin D levels. Inadequate vitamin D levels were more prevalent in younger athletes, during seasons with lower sun exposure, in indoor sports during the sun deprived seasons, in athletes without vitamines supplementation and in athletes of lower Swiss Olympic classes compared to their counterparts.

Conclusions: The results of the study show that the prevalence of inadequate vitamin D levels in Swiss athletes is substantial for younger athletes (< 18 years of age) and for indoor athletes during sun deprived periods of the year. However, a general vitamin supplementation containing vitamin D reduced the prevalence of vitamin D inadequacy which is especially relevant during sun deprived seasons.

Keywords:
vitamin D deficiency, sun exposure, type of sport, vitamin supplementation, sunscreen use, muscle pain.

Zusammenfassung

Einführung: Der Vitamin D-Mangel ist generell häufig und zunehmende Daten zeigen, dass auch Athleten davon betroffen sind. Neben Knochenbeschwerden verursacht ein Vitamin D-Mangel muskuloskelettale Schmerzen und Muskelschwäche und ist mit vielen anderen Gesundheitsproblemen assoziiert. Speziell bei Sportlern kann dadurch Training und Leistung beeinträchtigt, die Erholungszeit verlängert und das Frakturrisiko erhöht sein. Wir haben Vitamin D Spiegel bei Schweizer Athleten analysiert, mit der Frage nach Häufigkeit eines Vitamin D-Mangels, Mangelzustände bei verschiedenen Alterskategorien, nach Geschlecht oder Saison, bei in- oder outdoor Sportarten, mit oder ohne Sonnenschutzprophylaxe oder Vitamin D Substitution.

Methoden: Die Studie wurde über ein Jahr bei 655 Swiss Olympic Athleten durchgeführt. Während jährlichen Routine-Untersuchungen hat man in Swiss Olympic Medical Centers und Bases den Athleten Blut entnommen und Fragebögen wurde durch die Athleten ausgefüllt. Die Daten wurden im gleichen Labor geblindet verarbeitet und uns in anonymer Version zugeschickt. Das Serum-Vitamin D wurde in "*deficient*" (≤ 50 nmol/l), "*insufficient*" (zwischen 50 und 75 nmol/l) oder "*adequate levels*" (> 75 nmol/l) von 25-hydroxyvitamin D eingeteilt. Mittels Fragebogen wurden obengenannte Faktoren erfasst.

Resultate: 13.5% der Teilnehmer (Gesamtzahl = 651) zeigten ein "vitamin D *deficiency*" und 37.8% ein "vitamin D *insufficiency*". Damit hatten mehr als die Hälfte der Athleten (51.2%) einen unzureichenden Vitamin D-Spiegel. Unzureichende Vitamin D- Spiegel fanden sich signifikant häufiger bei jüngeren Athleten (< 18 Jahre), während Jahreszeiten mit weniger Sonnenexposition, bei indoor Sportarten während den Wintermonaten, sowie bei Athleten mit einer tieferen Swiss Olympic Stufe und bei Sportlern ohne Substition.

Diskussion: Die Resultate zeigen, dass die Prävalenz von unzureichenden Vitamin D- Konzentrationen bei Schweizer Athelten häufig ist, insbesondere bei jüngeren Athleten (< 18 Jahre alt) und bei indoor Athleten während Jahreszeiten mit weniger Sonnenexposition. Eine ergänzende Einnahme von Vitamin D scheint die Prävalenz eines Mangels insbesondere während sonnenarmen Jahreszeiten relevant zu verringern.

Schlüsselwörter:
Vitamin-D-Mangel, Sonnenexposition, Sportart, Vitamin-Substitution, Sonnenschutzprophylaxe, Muskelschmerzen

Introduction

Rickets can be considered the most severe form of a large vitamin D-deficiency problematic. In children, low vitamin D levels can cause growth retardation and skeletal deformities; in adults, vitamin D deficiency can cause several bone disorders such as osteopenia, osteoporosis, osteomalacia and increased risk of fracture [1–3]. In addition, studies have shown that it is significantly linked with multiple other health problems other than bone disorders. Vitamin D regulates the expression of over 900 genes [4,5] and these expressions play a significant role in many physiological processes such as exercise-induced inflammation, cardiovascular health, glucose metabolism, tumour suppressor genes function, neurological function and skeletal muscle performance [3,6–14]. Vitamin D deficiency has even been associated with an increased risk for psychological disorders [15,16], colorectal, breast and prostate cancers [7,14,17] or diabetes mellitus type 1, hypertension and multiple sclerosis [1,18–20]. Furthermore, vitamin D deficiency has catabolic effects on muscle tissue and causes muscle weakness [3,4,21].

Despite all these negative effects of inadequate vitamin D levels it is surprising that a high prevalence of vitamin D deficiency and insufficiency for all age groups is documented worldwide [2,3,6–8,12,22–24] with 88% of the world's population having inadequate vitamin D levels [22].

The athletes' population is progressively analysed and emerging evidence shows that inadequate vitamin D levels could impair training and performance of an athlete, prolong recovery, and even increase risk of injury [4–6,11,12,21,25,26]. A recent meta-analysis including 23 studies with 2313 athletes from all around the world found that 56% of athletes had inadequate vitamin D levels [26]. Due to an increased metabolic and enzymatic activity that is needed with exercise [27], athletes may even be more prone to become vitamin D deficient compared to the general population. Risk factors for a healthy population include inadequate sun exposure due to high skin pigmentation, clothing, sunscreen use, pollution or living in latitudes above 40° [3,8,26].

Methods

Setting and participants

This study was performed in a convenient sample of 655 Swiss Olympic athletes, 3.3% of a total of 20'077 active Swiss Olympic Card holders [Swiss Olympic Card List 2010, Swiss Olympic Talents Report 2014], over one year (5/2014–6/2015). The study population owned a Swiss Olympic card according to their level of performance (i.e. gold, silver, bronze, elite, national, regional). There were no other in- and exclusion criteria. The athletes were examined by a Swiss Olympic Medical Center or Base usually in form of a preparticipation examination including a medical exam and a routine blood analysis that is financially supported by Swiss Olympic once a year. 24 medical centers and bases of a total of 39 existing (61.5%) took part if the leader of the centers and bases were interested in participating. The athletes filled a questionnaire and blood samples were obtained for routine blood testing. The blood samples and the questionnaires were then sent to the central laboratory of the Aarau hospital, where the blood was analyzed and the data processed. The processed results were then sent to us in anonymized form. We computerized the questionnaires, coded answers of every questionnaire item and categorized them where necessary. All of the data were initially put into one spreadsheet and further imported into a statistical program.

All data were completely anonymized. Athletes filled out a consent form that allowed the laboratory in Aarau to use the analyses of the blood samples and the questionnaires for scientific purposes. Under these circumstances ethical consent was given by participants and no further steps had to be taken.

Laboratory analyses and questionnaire

We report here the blood analyses and questionnaire items relevant for this study.

In the central laboratory of the Aarau hospital, 25-hydroxyvitamin D (25(OH)D) was measured using the technique of Immunoassay. Vitamin D was categorized, according to most experts, into Vitamin D "deficiency" for values ≤50 nmol/l, "insufficiency" for values between 50 and 75 nmol/l and "adequate levels" for values >75 nmol/l [3,7,8,26]. The cutoff levels of vitamin D are based on 25(OH)D levels of 75 to 100 nmol/l (30 to 40 ng/ml) and above that maintain PTH at normal levels [3,28], assure calcium homeostasis in the bone and allow intestinal calcium transport to be maximized [7,29,30]. For some analyses, vitamin D insufficiency and deficiency were pooled into vitamin D "inadequacy" due to a lack of athletes in the deficiency category.

The questionnaire assessed general demographic characteristics as well as a sport and training history and any symptoms that may be related to vitamin D deficiency, e.g. muscle pain. Furthermore, we assessed the type of sport according to predominantly indoor versus outdoor sport (e.g. hockey, gymnastics, swimming for indoor and football, skiing, marathon for outdoor sports), and sun exposure (in hours per week) during summer and winter, and on weekdays and weekends. Only the sun exposure on weekdays during summer was considered for analysis, due to a lack of consistency in the answers of the participants in the other three categories. In addition, all vitamin D containing medications and supplements were assessed; the amount of vitamin D3 contained ranged from 300 IU to 5'000 IU. Those athletes who didn't complete the questionnaire in a consistent way when asked for symptoms such as muscle pain, and didn't fill in any of the answers we proposed (including the option "no symptoms") were excluded for this part of the study.

Statistics

Results with parametric distribution are presented as means ± standard deviation and non-parametric values as medians ± interquartile range (IQR) or numbers and percentage of the study population. Comparisons between the study groups were performed with t-test and chi-square test. A multivariate logistic regression model was used to assess associations between parameters from the quesionnaire and the three vitamin D categories. A p value of <0.05 was considered statistically significant. All statistical analyses were performed with SPSS.

Results

We analyzed blood laboratory results from 651/655 Swiss athletes, as 4 had no vitamin D data and were excluded from the study. Two athtletes didn't give information on the type of sport, 57 athletes didn't fill in the questions on sun exposure and 41 athletes the question on sunscreen use. Therefore they were excluded for the analysis on the respective sections. 211 athletes were excluded for the analysis on symptoms, such as muscle pain, due to a lack of consistency in the answers of that part of the questionnaire.

Table 1 shows the characterists of the study population. The mean value of 25(OH)D was 75.8 nmol/l (SD ±23.1), with a minimum of 22.4 nmol/l and a maximum of 165.0 nmol/l. 13.5% of the participants were vitamin D deficient, 37.6% (245/651) presented a vitamin D insufficiency and 48.8% (318/651) had adequate vitamin D levels. So, more than half of the athletes (51.2%) had inadequate vitamin D levels. The highest value of vitamin D observed was 165.0 nmol/l.

The relative risk for a person under 18 years compared to the older counterpart of having a vitamin D *deficiency* compared to adequate vitamin D levels was 5.18 times higher (CI 3.00–8.95, p<0.0001); the relative risk of having a vitamin D *insufficiency* compared to adequate levels was 3.20 higher (CI 2.26–4.54, p<0.0001) for the same relation.

In univariate analyses the relative risk for males of having a vitamin D *deficiency* compared to adequate vitamin D levels was 0.52 times as high (CI 0.32–0.84, p=0.008) in comparison to females; relative risk of having a vitamin D *insufficiency* compared to adequate levels was 0.58 times as high (CI 0.41–0.82, p=0.002) for the same relation. In multivariate analyses, adjusting for age group, differences between males and females were not significant anymore, while the difference between age groups remained significant after adjusting for gender.

We observed a prounonced fluctuation of vitamin D values according to season with lower values during winter and higher values during summer. As shown in Figure 1, vitamin D

		Deficiency		Insufficiency		Adequate levels	
		Number	%	Number	%	Number	%
Total		88	13,5	245	37,6	318	48,8
Age	<18	68	18,9	166	46,1	126	35,0
	≥18	20	6,9	79	27,1	192	66,0
Gender	males	48	11,7	140	34,1	222	54,1
	females	40	16,6	105	43,6	96	39,8
Type of sport	indoor	41	15,4	104	39,0	122	45,7
	outdoor	47	12,3	140	36,6	195	51,0
Swiss Olympic Card	no card	10	14,5	30	43,5	29	42,0
	Regional	14	11,3	61	49,2	49	39,5
	National	9	8,3	46	42,6	53	49,1
	Elite	7	10,1	23	33,3	39	56,5
	Bronze	1	2,4	13	31,7	27	65,9
	Gold and Silver	0	0	4	17,4	19	82,6
	"no idea"	38	19,9	60	31,4	93	48,7
Sun exposure [hours/week]	<5	11	26,8	17	41,5	13	31,7
	≥5, <10	21	14,1	68	45,6	60	40,3
	≥10, <20	31	13,2	79	33,6	125	53,2
	≥20, <30	6	5,8	40	38,8	57	55,3
	≥30	7	10,6	22	33,3	37	56,1
Vit D Substitution	No	72	16,3	166	37,6	204	46,2
	Yes	16	7,7	79	37,8	114	54,5
Season	Fall	14	6,6	91	42,9	107	50,5
	Winter	40	28,6	54	38,6	46	32,9
	Spring	33	17,4	83	43,7	74	38,9
	Summer	1	0,9	17	15,6	91	83,5
Sunscreen use*	≤25%	40	15,6	97	37,9	119	46,5
	≥50%	39	11,0	133	37,6	182	51,4

* Subjective answer from the questionnaire that asked for the frequency of sunscreen use when exposed directly to the sun.

Table 1 shows the characteristics of the study population according to categories of vitamin D levels.

values decrease gradually from summer to fall and further to winter with a small increase observed in spring. In comparison to the summer months, the relative risk of having a vitamin D *inadequacy* compared to adequate vitamin D levels was 10.33 times higher (CI 5.58–19.14, p<0.0001) in winter, 4.96 times higher (CI 2.80–8.80, p<0.0001) during fall and 7.93 times higher (CI 4.42–14.21, p<0.0001) during spring.

In consequence, 83.5% of athletes had normal levels of vitamin D during summer, while in winter only 32.9% of athletes showed values in the normal range (Figure 2). Likewise, inadequate levels were found in 16.5% of athletes during summer while 49.5–67.1% showed inadequacy during the remaining months. Deficient levels of vitamin D during summer were rare (1/651) and increased continuously to 6.6% in fall, 28.6% in winter and 17.4% in spring.

In univariate analyses, there was no difference in vitamin D levels between in- and outdoor sports. However, in subgroup analyses according to season, vitamin D levels were not different during summer, but the relative risk for a person who practiced an indoor sport versus an outdoor sport to have a vitamin D *deficiency* was 2.58 times higher (CI 1.54–4.34, p=0.0003) during fall, winter and spring; the respective relative risk of having vitamin D *insufficiency* was 1.99 times higher (CI 1.33–2.98, p=0.001) for the same relation. Figure 3 shows the differences in vitamin D levels for in- and outdoor sports during the colder months and the similarity during summer between the two groups.

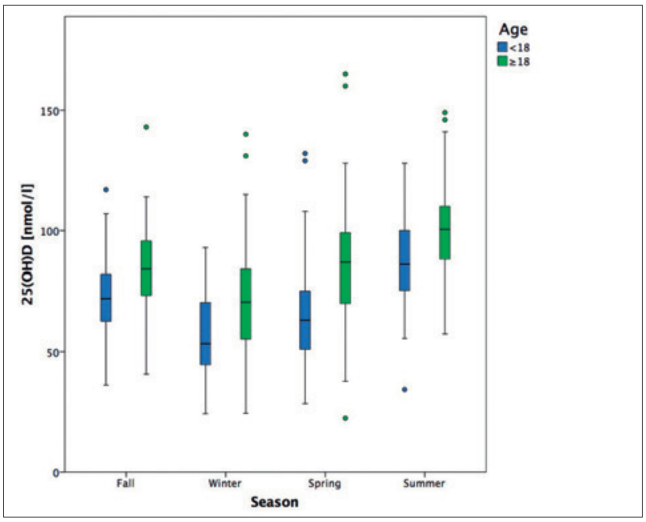

Figure 1: Seasonal variation of 25(OH)D levels according to age group.

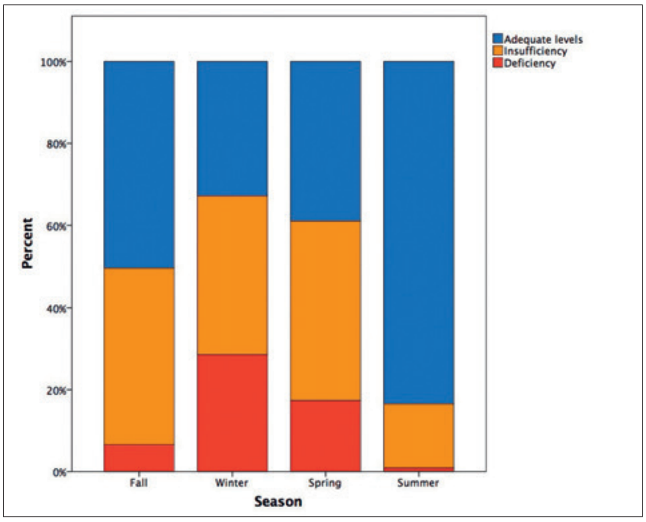

Figure 2: Seasonal distribution of participants' percentages according to the three vitamin D categories.

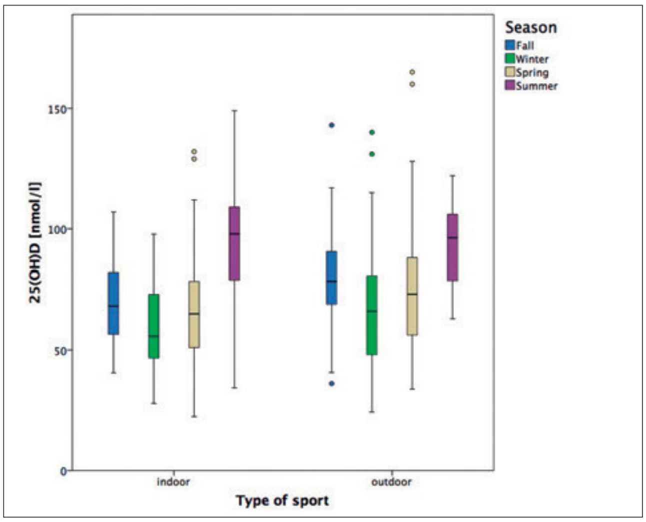

Figure 3: Comparison of 25(OH)D levels between indoor and outdoor athletes, according to seasonal variations.

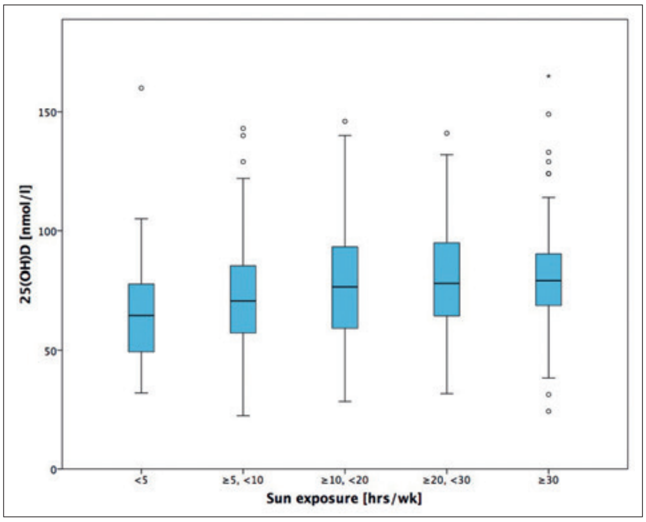

Figure 4: Variations of vitamin D levels according to sun exposure.

No significant correlation was found between "Sunscreen use" and "Vitamin D *inadequacy*". As shown in Table 1, 53.5% of the group using sunscreen in less than 25% of the time ("≤25% sunscreen use") had inadequate Vitamin D levels and 51.4% of the

"≥ 50% sunscreen use" had adequate vitamin D levels.

The relative risk for a person without vitamin D supplementation of having a vitamin D *deficiency* compared to adequate vitamin D levels was 2.52 times higher (CI 1.40–4.53, p=0.002) in comparison to a person with vitamin D supplementation; no significant diffference was found when vitamin D *insufficiency* and adequate vitamin D levels were compared for the same relations. These results did not change by additionally adjusting for age group.

The relative risk for a person with <5 hours/week sun exposure of having inadequate vitamin D levels compared to adequate vitamin D levels was 2.75 higher (CI 1.21–6.23,

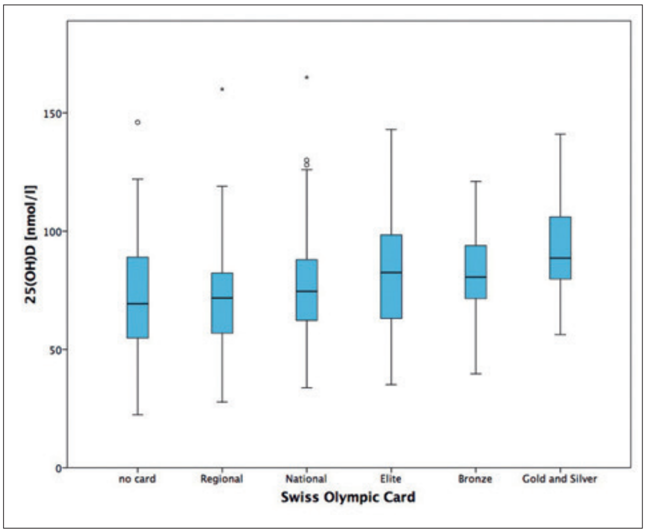

Figure 5: Variations of vitamin D levels according to Swiss Olympic Card-class.

		Muscle pain*		
		no	yes	Total
Inadequate levels	Number	75	137	212
	% within "muscle pain"	44,9%	50,2%	48,2%
	% of Total	17,0%	31,1%	48,2%
Adequate levels	Number	92	136	228
	% within "muscle pain"	55,1%	49,8%	51,8%
	% of Total	20,9%	30,9%	51,8%
Total	Number	167	273	440
	% of Total	38,0%	62,0%	100,0%

* Subjective answer to the questionnaire that asked for any muscle pain during the last year.

Table 2 shows the percentage of athletes that presented muscle pain during last year according to vitamin D levels.

p=0.015) in comparison to a person with ≥30 hours/week sun exposure; the relative risk for a person with ≥5 and <10 hours/week sun exposure was 1.89 higher (CI 1.05–3.40, p=0.033) for the same relation. No significant difference was found for comparisons of the groups "≥10, <20 hours/week" and "≥20, <30 hours/week" with the group "≥30 hours/week". Figure 4 shows the variations of 25(OH)D levels among the five groups.

As shown in Figure 5, a clear tendency for higher vitamin D values in the higher Swiss Olympic categories (Gold, Silver and Bronze) was present. In comparison to a person with a Gold, Silver or Bronze Swiss Olympic Card, the relative risk for of having inadequate vitamin D levels compared to adequate vitamin D levels was 3.53 times higher (CI 1.71–7.28, p=0.01) for a person with no Swiss Olympic Card, 3.91 times higher (CI 2.04–7.52, p<0.0001) for a person with a Regional Swiss Olympic Card and 1.97 times higher (CI 1.37–5.15, p=0.004) for a person with a National Swiss Olympic Card. No significant difference among vitamin D categories was found in the comparison between the group "Elite Swiss Olympic Card" and the group "Gold, Silver or Bronze Swiss Olympic Card".

In the subgroup of athletes that gave information about muscle pain, the Chi-Square test showed no significant correlation between "Muscle pain" and vitamin D *inadequacy* (Chi-Square = 1.15, p=0.28). However 50.2% of the population with muscle pain had inadequate vitamin D levels and 62.0% of the total population had muscle pain during last year.

Discussion

Our results show that vitamin D inadequacy is prevalent in Swiss athletes with 51.2% of the athletes presenting a vitamin D inadequacy (values <75 nmol/l) and 13.5% of athletes with a vitamin D deficiency (values <50 nmol/l). Vitamin D deficiencies and insufficiencies were more prevalent in younger (<18 years) than older athetes, during the seasons with lower compared to higher sun exposure, in indoor versus outdoor sports during the sun deprived seasons, in athletes without vitamines supplementation and in athletes of lower Swiss Olympic classes.

The prevalence rates of our study are very consistent with a recent meta-analysis that showed vitamin D inadequacy in 56% of a global population of athletes [26].

A significant difference of inadequate vitamin D levels was found between younger and older athletes with athletes below 18 years presenting significantly lower vitamin D levels. Past studies showed high prevalences of vitamin D deficiency in adolescent and children (18% up to 54%), but usually prevalences were similar to the adult population [31,32]. The significant difference in our study could be explained by the fact that older athletes pay more attention to their lifestyles and are more focused on obtaining the best performance from their bodies, therefore vitamin substitution and correct nutrition could be more consistent in the elite athletes who were also older. The fact that athletes with a more "prestigious" Swiss Olympic card (Gold, Silver or Bronze) presented higher vitamin D levels than athletes with no card or "lower class" Swiss Olympic cards (normally younger athletes) supports this explanation (see Table 1). This age-related difference in vitamin D levels shows that our athletes population doesn't reflect a normal population, where adults and children do not show any difference in vitamin D variations. Other factors that could have led to vitamin D inadequacy in younger athletes may have been an increase in time spent inside or an increase in the sensibilisation of parents on the adverse effects of direct sun exposure demanding sun protection. Vitamin D levels for athletes, who said that their weekly sun exposure was under 10 hours, were significantly lower; it is impressive how accurate a higly subjective estimate of sun exposure by the athletes can discover a difference in vitamin D levels, suggesting that a lack of sun exposure may indeed by harmful in certain respects such as adequate vitamin D levels.

A highly significant finding was the marked variation of vitamin D levels among seasons. Nearly 70% of the athletes presented inadequate vitamin D levels during winter, more than 60% during spring and nearly 50% during fall, while only 15% of the athletes had a vitamin D inadequacy during summer. During winter almost 30% were even vitamin D deficient while this was merely inexisting in summer. Our results reflects those of many studies on global populations

[4,26]. The relative risk of presenting with a vitamin D inadequacy compared to adequate vitamin D levels during the winter compared to the summer months was 10-fold higher. This finding shows how easy it is to present inadequate vitamin D levels during 3/4 of the year, even for athletes in Switzerland, where outdoor winter sports are extremely popular. More so, the latitude in Switzerland isn't prohibitive for effective vitamin D synthesis and a good nutrition is easy to accomplish. Therefore, vitamin D substitution during fall, winter and spring may be given to Swiss athletes, especially during winter.

Differences in vitamin D levels were also found by comparing indoor with outdoor sports. Yet, these variations were only found during fall, winter and spring when athletes who practice indoor sports present low vitamin D levels. During summer the two groups showed no difference in vitamin D levels. Our results are consistent with a recent meta-analysis that, in addition to our study, showed how indoor athletes living at >40°N latitudes have higher risk of presenting inadequate vitamin D levels when compared to outdoor athletes [26]. This finding may be explained, by the organisation of the athletes' training sessions. Most indoor sports, hockey for example, train outside during the off-season, which usually takes place during the summer months. Another factor may simply be the fact that younger athletes, often still at school, have school holidays in summer which increases the potential time for sun exposure and may lead to a more adequate vitamin D synthesis.

We observed higher vitamin D levels in athletes who did take vitamin supplements containing vitamin D during the last 3 months compared to athletes who did not take any supplements. The dose of vitamin D in most of the vitamin supplements taken by Swiss athletes was relatively low (300 IU/day), but seemingly sufficient to substantially lower the risk for vitamin D deficiency. Yet, no significance was found when analyzing the risk for vitamin D insufficiency compared to normal levels, suggesting that the general vitamin supplements are insufficent for a complete vitamin D substitution. Therefore, the effect from the simple use of a combined supplement may not be powerful enough for completely securing adequate vitamin D levels. For adults with inadequate sun exposure, experts recommend 800–1000 IU vitamin D/day for preventing vitamin D deficiency [3].

No significant difference in vitamin D levels was found for different categories of sunscreen users. The tendency of our results was diametrically the opposite of what we hypothesized. Athletes who used sunscreen more frequently, had also slightly higher vitamin D values. The fact that our study included many types of sports and was performed through four seasons, could have influenced and confounded the subjective answer to our sunscreen-related question. Wintersport athletes wore winter-clothing that may also play a significant role in sun protection beside sunscreen use. While this question has never been answered in an athlete population, there is a consistent literature showing that a correct application of sunscreen with sun protection factor of 15 absorbs 99% of UVB radiations which decreases the vitamin D production also by 99% [2,33].

As muscle pain can be a symptom of vitamin D deficiency, we searched for a variation in vitamin D levels according to reported muscle pain during the last year. We didn't find a significant correlation between muscle pain and vitamin D deficiency/insufficiency. Because muscle pain was such a common problem for atheltes occuring in 62.2% of our population, it is possible that confounding by other extremely prevalent factors such as sore muscles with intense training may have occurred. Persistent and non-specific muscle pain has been studied in the past and was significantly correlated with low vitamin D levels [11]. Another study showed a significant reduction in back pain, in patient with vitamin D deficiency, after 3 months of treatment with 5'000–10'000 IU/day [34]. In addition, a study from England observed a significant improvement in muscle performance of athletes who took 5000 IU/d of vitamin D supplementation for 8 weeks. Specifically they found a significant increase in vertical jump and in 10 meters sprint times while no significant change was found in the placebo group [25].

There are some limitations in our study that have to be acknowledged. The vitamin D analysis in Swiss athletes was part of a greater laboratory study and because of that the questionnaire was not specifically focusing on questions related to vitamin D deficiency. This limitation prevented us from observing more specific symptoms of vitamin D deficiency such as persistent muscle pain at rest, muscle weakness during training or past bone fractures. The type of study also prevented us from performing some tests to assess muscle performance and test whether a reduced muscle performance may be found in athletes with vitamin D insufficiency or deficiency as suggested. For statistical purpose, we did not separate the few athletes who were taking a true vitamin D substitution from those who were only taking a general vitamin supplementation.

In our multivariable models, we tried to adjust for relevant variables, but it is always possible to still have residual confounding. Unmeasured characteristics related to vitamin D deficiency, rather than vitamin D deficiency itself, could explain parts of our results.

We did not assess parathyroid hormone levels, therefore we cannot determine whether some athletes presented primary or secondary hyperparathyroidism at the time of the examination, which could influence our vitamin D analysis.

It is important to know that our study has a cross-sectional design and cannot give follow-up informations as much as a longitudinal study.

Conclusion

In summary, the results of the present study show that vitamin D inadequacy for Swiss athletes is highly prevalent. The vitamin D inadequacy is higher in females and in younger athletes (<18 years of age), much higher during the sun deprived seasons and higher for indoor than outdoor athletes. However, the prevalence of inadequate vitamin D levels was reduced with a general vitamin supplementation containing vitamin D. Athletes may profit of a vitamin D substitution especially during the sun deprived seasons. Further studies are needed to evaluate vitamin D deficiency-related symptoms and its relevance as performance limiting factor, on which athletes specific cutpoints should be based on.

Acknowledgement and Conflict of Interest

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