

# The relationship between Vitamin D status and Rotator Cuff Muscle Strength in Professional Volleyball Athletes

Do Kyung Kim<sup>1</sup>, Geon Park<sup>1</sup>, Liang-Tseng Kuo<sup>2,3\*†</sup>, Won Hah Park<sup>1\*†</sup>

1 Department of Sports Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

2 Department of Orthopaedic Surgery and Sports Medicine Center, Chang Gung Memorial Hospital, Chiayi, Taiwan

3 School of medicine, College of Medicine, Chang Gung University, Taoyuan, Taiwan

\*Co-Corresponding authors:

Liang-Tseng Kuo

E-mail: light71829@gmail.com,

Address: No. 6 West Sec, Chia-Pu Road, Putz City, Chiayi 613, Taiwan

Tel: +886-5-3621000 ext. 2855, Fax: +886-5-3623002

Won Hah Park, MD

E-mail: pk90007@naver.com

Address: Department of Sports Medicine Center, Samsung Medical Center, Sungkyunkwan University School of Medicine, 81 Irwon-ro, Gangnam-gu, 135-710, Seoul, South Korea

Tel: +82-2-3410-3847, Fax: +82-2-3410-6686

<sup>†</sup>These authors contributed equally to this work.

## Abstract

This study aimed to examine the vitamin D status of professional volleyball athletes and to determine its correlation with shoulder muscle strength. We finally included 52 healthy male professional volleyball players ( $23.2 \pm 4.5$  years), who were categorized by vitamin D status (<20 ng/mL: deficiency, 20-30 ng/mL: insufficiency, and >30 ng/mL: sufficiency). We examined the strength of the internal rotator (IR) and external rotator (ER) muscles of the shoulder by using isokinetic dynamometer. Fourteen players (26.9%) had vitamin D deficiency, 24 players (46.2%) were vitamin D insufficient, and 14 players (26.9%) were vitamin D sufficient. There was no significant correlation between the vitamin D level and shoulder muscle strength at  $60^\circ/\text{s}$  (IR,  $r = 0.159$ ,  $p = 0.26$ ; ER,  $r = 0.245$ ,  $p = 0.08$ ), and at  $180^\circ/\text{s}$  (IR,  $r = -0.093$ ,  $p = 0.51$ ; ER,  $r = -0.037$ ,  $p = 0.79$ ). Moreover, the isokinetic shoulder strengths were not significantly different across the three groups in all settings. In conclusion, vitamin D insufficiency was common in elite volleyball players. Though not being associated with isokinetic muscle weakness, vitamin D should be regularly monitored and supplemented in young elite athletes, considering its importance on musculoskeletal health.

**Keywords:** Vitamin D, Muscle strength, Volleyball, Athletes, Shoulder

## Introduction

Vitamin D is essential for calcium homeostasis and bone metabolism [1]. Vitamin D deficiency is associated with sarcopenia, impaired muscle actions, and decreased muscle strength [2,3]. In a health check-up survey in Korean colleges, more than 80% of undergraduates were found to have vitamin D insufficiency or deficiency [4]. Furthermore, a systematic review of 2,000 young athletes reported that 56% had inadequate vitamin D levels [5,6].

Vitamin D is of particular interest to athletes since the injury rate may decrease with increasing vitamin D levels [7]. Meanwhile, vitamin D is also useful in skeletal muscle repair and remodeling[8]. Further, it is also known to facilitate the recovery of the muscles after high-intensity exercises [8]. These findings imply that adequate vitamin D exposure can optimize the acute adaptive response to damaging physical work [8-10]. A previous systematic review on the effect of vitamin D on muscle functions and strength had shown that muscle strength in individuals with vitamin D deficiency improved when vitamin D levels were elevated by using supplements [11]; Furthermore, studies on older adults consistently also reported that vitamin D had positive effects on muscle strength and functions [12,13]. More recently, vitamin D has shown to have a direct effect on the skeletal muscles through the vitamin D receptor, leading to the recognition that vitamin D may play a role in muscle function, strength, and recovery and potentially in physical and athletic performances [14]. Although the importance of vitamin D among athletes had been emphasized, the results were conflicting among studies [15-18]. Some studies reported that increasing vitamin D levels could increase the quadriceps strength and enhanced vertical jump and sprint performance in athletes with vitamin D insufficiency [15,18], but other studies found that vitamin D levels were not associated with muscle strength and function [16,17]. Therefore, the effect of vitamin D levels on muscle function and sports performance remains uncertain.

Thus, we designed the current study to elucidate the relationship between vitamin D level and muscle functions. This study aimed to examine the vitamin D status of professional volleyball

athletes and to investigate its associations with age, height, body weight, body mass index (BMI), and isokinetic muscle strength including external rotation (ER)/internal rotation (IR) strength of the shoulder.

## Materials and Methods

### Subjects and demographics

This retrospective study was conducted on players from a professional volleyball team. From Jan 2014 to Dec 2018, we enrolled 52 players, all of whom were medically cleared for participation by an orthopedic specialist, in the study. We excluded players with any shoulder surgical history and those taking vitamin D supplements concurrently. All research procedures were reviewed and approved by the bioethical committee of Sungkyunkwan University; the study conformed to the tenets of the Declaration of Helsinki for medical research involving human subjects (IRB no: 2019-03-120).

### Assessment

Vitamin D sufficiency is best determined by measuring the serum 25-hydroxyvitamin D [25(OH)D] level. Herein, the serum 25(OH)D level was measured using the Elecsys Vitamin D Assay (electrochemiluminescence binding assay for in vitro determination of the total 25(OH)D; Roche Diagnostics, Risch-Rotkreuz, Switzerland). Participants were divided into groups according to vitamin D level: deficiency group, < 20 ng/mL; insufficiency group, 19 - 29 ng/mL; and sufficiency group, > 30 ng/mL [3,12,19].

We evaluated the IR and ER strengths and peak torques of the bilateral shoulder muscles using an isokinetic dynamometer (CSMI Medical Solutions, MA, USA). All tests were measured by the same qualified person, who was familiar with a Cybex CSMI isokinetic dynamometer, to ensure the quality and reliability of the test. Concentric shoulder ER and IR peak torques were measured at angular velocities of 60°/s and 180°/s. The participants performed three submaximal familiarization trials. Thereafter, they underwent maximal concentric IR and ER strength tests. We provided standardized and consistent oral encouragement such as “push as hard as possible” and “push as fast as possible.” After a 5-min break, the test was repeated on the other shoulder using the same

protocol [20]. The peak torques (PT) generated from the isokinetic dynamometer were expressed as ft/lb.

### Statistical analysis

All statistical analyses were conducted using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). We evaluated the correlation between the player parameters and vitamin D level using Pearson correlation coefficients. We also compared the concentric ER/IR isokinetic strength of the dominant shoulder between three groups by using one-way ANOVA. Post-hoc Bonferroni test was used to compare the intergroup difference. The level of statistical significance was set at 0.05.

## Results

As shown in Table 1, the mean age of the participants were  $23.8 \pm 2.8$  years (range, 19-32 years). The mean vitamin D level was  $25.2 \pm 8.3$  ng/mL (range, 8.9-44.9 ng/mL). Fourteen players (26.9%) had vitamin D deficiency; 24 players (46.2%) had insufficiency, and the remaining 14 players (26.9%) had vitamin D sufficiency. A total of 38 players (73.1%) had either vitamin D deficiency or insufficiency.

**Table 1 Demographic characteristics of study subjects**

Characteristics	Subjects (n=52)
Age (yr)	$23.8 \pm 2.8$
Height (cm)	$189.9 \pm 8.3$
Weight (kg)	$82.7 \pm 7.5$
BMI (kg/m <sup>2</sup> )	$22.8 \pm 1.2$
Vitamin D level (ng/mL)	$25.2 \pm 8.3$
Position, no (%)	
Spiker	20 (38.7)
Blocker	11 (20.4)
Setter	11 (20.4)
Libero	10 (20.4)

Values are presented as means  $\pm$  standard deviations.

Abbreviation: BMI, body mass index.

Table 2 shows the Pearson correlation analysis of the relationship between the athletes' physical characteristics and vitamin D levels. There was a significantly negative correlation between age and the vitamin D level; the vitamin D level decreased with increasing age ( $r = -0.315, p = 0.02$ , Table 2). The vitamin D levels were not associated with other variates, including height, body weight, and BMI. The analysis of the correlation between the vitamin D level and shoulder ER/IR strength showed no significant findings. No significant correlation was detected between the vitamin D level and shoulder ER/IR strength at the angular velocity of  $60^\circ/\text{s}$  ( $r = 0.159, p = 0.26$  and  $r = 0.245, p = 0.08$ , respectively, Table 2) at the angular velocity of  $180^\circ/\text{s}$  ( $r = -0.093, p = 0.51$  and  $r = -0.037, p = 0.79$ , respectively, Table 2)

**Table 2 Correlation coefficients ( $r$ ) between the vitamin D level and other characteristics**

Characteristics	Vitamin D level (ng/mL)	<i>p</i> value
Age (yr)	-0.315*	0.02
Height (cm)	0.245	0.08
Weight (kg)	0.302	0.11
BMI ( $\text{kg}/\text{m}^2$ )	-0.256	0.06
Shoulder muscle strength (ft/lb)		
60 degree/sec		
External rotation	0.159	0.25
Internal rotation	0.245	0.08
180 degree/sec		
External rotation	-0.093	0.51
Internal rotation	-0.037	0.79

\* $p < 0.05$

Abbreviation: BMI, body mass index

Furthermore, the participants were divided into three groups to examine physical and functional differences according to the vitamin D levels (Table 3). There were no significant differences between the three groups with respect to physical characteristics, except age. There were also no significant differences between groups regarding isokinetic shoulder muscle strength (Figure 1, Table 4).

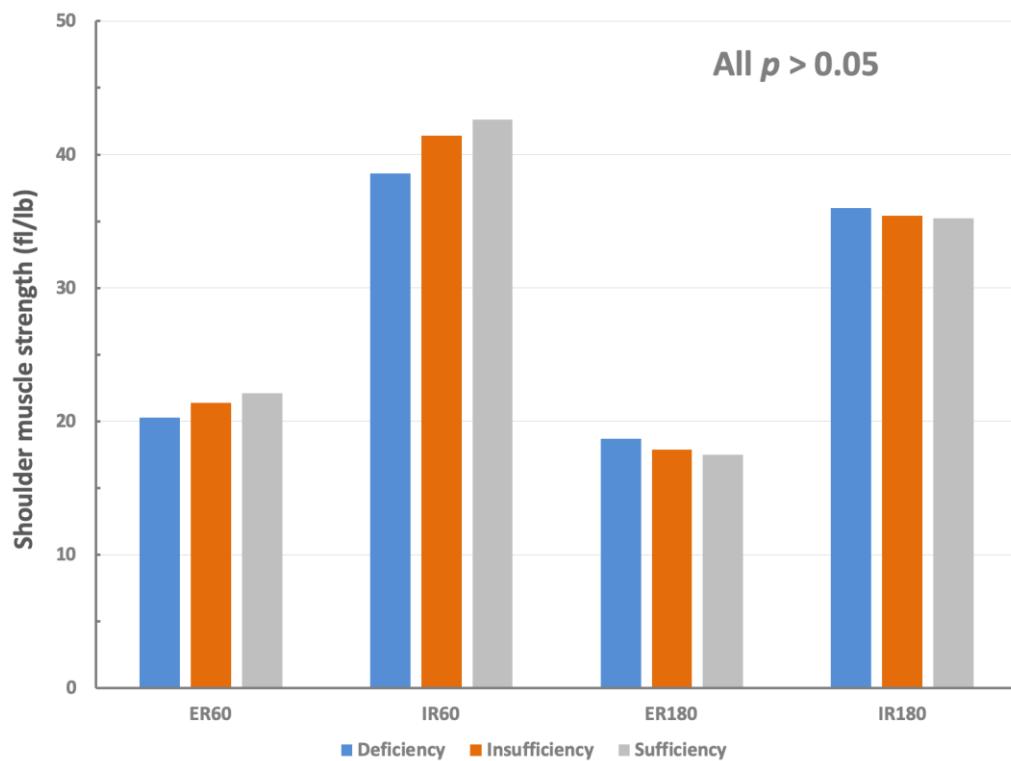
**Table 3** Players demographics for each group of the vitamin D status

Variables	Vitamin D status			<i>p</i> value
	Deficiency (< 20 ng/mL)	Insufficiency (20-30 ng/mL)	Sufficiency (> 30 ng/mL)	
No. of players (%)	14 (26.9)	24 (46.2)	14 (26.9)	
Vitamin D level (ng/mL)	14.1 ± 3.4	25.5 ± 2.4	35.4 ± 4.0	< 0.01*
Age (yr)	24.8 ± 3.5	23.6 ± 2.2	23.1 ± 2.9	0.05
Height (cm)	186.5 ± 8.9	191.6 ± 7.6	190.2 ± 8.3	0.17
Weight (kg)	81.3 ± 7.5	84.3 ± 7.2	81.2 ± 8.0	0.34
BMI (kg/m <sup>2</sup> )	23.3 ± 1.4	22.9 ± 1.1	22.4 ± 1.3	0.19

Values are presented as means ± standard deviations.

\**p* < 0.05

Abbreviation: BMI, body mass index

**Figure 1****Fig. 1 - Internal/external shoulder muscle strength according to the vitamin D status**

The isokinetic shoulder strengths were not significantly different across the three groups in all settings. (ER60, external rotation at 60 degree/s; IR60, internal rotation at 60 degree/s; ER180, external rotation at 180 degree/s; IR, internal rotation at 180 degree/s).

**Table 4. Internal/external Shoulder muscle strength according to the vitamin D status**

Variable	Vitamin D Level			<i>p</i> value
	Deficiency (< 20 ng/mL)	Insufficiency (20-30 ng/mL)	Sufficiency (> 30 ng/mL)	
No. players (%)	14 (26.9)	24 (46.2)	14 (26.9)	
60 degree/sec (ft/lb)				
External rotation	20.3 ± 3.1	21.4 ± 4.4	22.1 ± 4.0	0.51
Internal rotation	38.6 ± 6.6	41.4 ± 7.1	42.6 ± 8.8	0.34
180 degree/sec (ft/lb)				
External rotation	18.7 ± 3.9	17.9 ± 4.1	17.5 ± 4.3	0.73
Internal rotation	36.0 ± 7.2	35.4 ± 7.9	35.2 ± 7.4	0.95

Values are presented as mean ± standard deviation.

## Discussion

In this study, we examined the vitamin D levels and isokinetic shoulder strengths of male professional volleyball players. Our findings showed that 73% of the athletes were either vitamin D insufficient or deficient. However, participants with vitamin D deficiency and insufficiency did not have a significantly weaker isokinetic shoulder muscle strength than those with sufficient vitamin D.

Vitamin D insufficiency or deficiency was not uncommon in elite athletes. In a study on 279 NBA players, 79.3% of the athletes had vitamin D insufficiency or deficiency, of which 90 had vitamin D deficiency (32.3%), and 131 had vitamin D insufficiency (47.0%) [19]. In another investigation on 80 NFL players, 68.8% of the athletes were vitamin D insufficient or deficient, with 21 (26.3%) having vitamin D deficiency and 34 (42.5%) having insufficiency [21]. Similarly, 73.1% of the professional athletes in our study had vitamin D insufficiency or deficiency, suggesting that inadequate levels of vitamin D are not rare in the athletes.

According to the report from 2008-2013 KNHANES, the vitamin D levels of 34,587 individuals in the general Korean population ranged from 16.8 to 19.4 ng/mL [4]; the mean vitamin D levels in our study population (i.e., volleyball athletes) was  $25.2 \pm 8.3$  ng/m. These findings indicate that athletes have a higher vitamin D level than the general population. This is similar to previous findings that the vitamin D levels are relatively higher among athletes than among the general population [7,15]. This is because athletes are more exposed to sunlight during training; further, athletes of indoor sports are known to have lower vitamin D levels than those of outdoor sports [6,15]. Sunlight, particularly ultraviolet radiation, is crucial for vitamin D synthesis. Athletes of indoor sports are relatively less exposed to sunlight and thus have a lower vitamin D level, and there are also seasonal effects on vitamin D owing to the varying amounts of sunlight exposure[22]. Moreover, many studies report that older individuals are more likely to have vitamin D insufficiency because they engage less in outdoor activities that expose them to sunlight and have reduced ability for vitamin D

synthesis in the skin and calcium absorption in the intestines [3,11]. Our study also found that vitamin D is associated with age but not with height, body weight, nor BMI.

Whether vitamin D impacts the musculoskeletal functions of athletes is still controversial. Although the importance of vitamin D in the muscle functions of athletes has been proposed, there are only a few studies conducted on athletes, and most discussions are focused on data from non-athletes. In an assessment of muscle strength, including grip strength, in healthy young adults after vitamin D supplementation who performed the single-repetition maximum bench press and single-repetition maximum leg press, vitamin D was found to have a positive effect on muscle strength [23]. Moreover, Close et al. reported that increasing vitamin D intake for eight weeks in athletes and non-athletes could decrease 10-m sprint times and enhanced exercise abilities, such as vertical jump performance [15,21]. This suggests that vitamin D modifies the transportation of calcium in the sarcoplasmic reticulum by increasing the efficiency of calcium bindings involved in muscle contraction [7]. As a result, the supply of vitamin D increased the size and amount of type II (fast-twitch) muscle fibers, thereby impacting muscle strength [7,8,24]. However, in a study on 314 professional soccer athletes who performed isokinetic exercises, there was no association between lower-limb muscle strength and vitamin D levels [16]; another study also reported that the associations of muscle strength and exercise abilities with vitamin D levels in athletes could not be adequately explained [17,25].

Vitamin D insufficiency affects exercise performance and injury prevention; thus, it is an essential topic of interest among athletes. Moreover, it is also known to impact athletic performance; however, most previous studies have assessed jumping and running performances. Thus, our study is the first study to analyze the association between vitamin D levels and shoulder rotator cuff strength, which is used in one of the most forceful movements in volleyball, i.e., spiking. In our study, the vitamin D levels did not affect the rotator cuff strength; thus, we cannot suggest that vitamin D increases rotator cuff strength. We speculate that elite athletes are highly trained

and have minimal margins for improvement for enhancement of muscle strength. However, it has already been established that a low vitamin D level increases the incidence of bone fractures and delays muscle recovery in athletes [8,10,21]. Therefore, while it is challenging to link vitamin D levels to athletic performance in this capacity, it merits consideration.

Our study has a few limitations. First, external validity was limited. Since the participants of the study were limited to male volleyball athletes, the result of this study might not be able to apply to other settings. Second, the vitamin D levels were not repeatedly confirmed on a long-term basis and were only examined at the one-time point. Third, the factors that affect the vitamin D levels, such as duration of exercise, degree of sun exposure, and diet, were not completely controlled. Though we only included young, healthy athlete and excluded those who regularly had vitamin D supplements and those with diseases interfering the metabolism of vitamin D, the bias should still be considered while applying the results of this study into practice.

## Conclusions

According to the findings of the current study, the vitamin D level was insufficient in more than 70% volleyball players. Though not being associated with isokinetic muscle weakness, vitamin D should be regularly monitored and supplemented in young elite athletes, considering its importance on musculoskeletal health.

**Author Contributions:**

Conceptualization, DKK and GP; methodology, DKK; investigation and data curation, DKK and GP; analysis and interpretation, DKK and LTK; writing—original draft preparation, GP and DKK; writing—review and editing, LTK; supervision, WHP.

**Funding:** This research was funded by Chang Gung Memorial Hospital Grant (CORPG6G0291, CORPG6G0292).

**Acknowledgments:** None.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Ceglia, L.; Harris, S.S. Vitamin D and its role in skeletal muscle. *Calcif Tissue Int* **2013**, *92*, 151-162, doi:10.1007/s00223-012-9645-y.
2. Holick, M.F. High prevalence of vitamin D inadequacy and implications for health. *Mayo Clin Proc* **2006**, *81*, 353-373, doi:10.4065/81.3.353.
3. Hosseini-nezhad, A.; Holick, M.F. Vitamin D for health: a global perspective. *Mayo Clin Proc* **2013**, *88*, 720-755, doi:10.1016/j.mayocp.2013.05.011.
4. Tran, B.T.; Jeong, B.Y.; Oh, J.K. The prevalence trend of metabolic syndrome and its components and risk factors in Korean adults: results from the Korean National Health and Nutrition Examination Survey 2008-2013. *BMC Public Health* **2017**, *17*, 71, doi:10.1186/s12889-016-3936-6.
5. Farrokhyar, F.; Tabasinejad, R.; Dao, D.; Peterson, D.; Ayeni, O.R.; Hadioonzadeh, R.; Bhandari, M. Prevalence of vitamin D inadequacy in athletes: a systematic-review and meta-analysis. *Sports Med* **2015**, *45*, 365-378, doi:10.1007/s40279-014-0267-6.
6. Willis, K.S.; Peterson, N.J.; Larson-Meyer, D.E. Should we be concerned about the vitamin D status of athletes? *Int J Sport Nutr Exerc Metab* **2008**, *18*, 204-224.
7. Ogan, D.; Pritchett, K. Vitamin D and the athlete: risks, recommendations, and benefits. *Nutrients* **2013**, *5*, 1856-1868, doi:10.3390/nu5061856.
8. Owens, D.J.; Sharples, A.P.; Polydorou, I.; Alwan, N.; Donovan, T.; Tang, J.; Fraser, W.D.; Cooper, R.G.; Morton, J.P.; Stewart, C., et al. A systems-based investigation into vitamin D and skeletal muscle repair, regeneration, and hypertrophy. *Am J Physiol Endocrinol Metab* **2015**, *309*, E1019-1031, doi:10.1152/ajpendo.00375.2015.
9. Barker, T.; Henriksen, V.T.; Martins, T.B.; Hill, H.R.; Kjeldsberg, C.R.; Schneider, E.D.; Dixon, B.M.; Weaver, L.K. Higher serum 25-hydroxyvitamin D concentrations associate with a faster recovery

of skeletal muscle strength after muscular injury. *Nutrients* **2013**, *5*, 1253-1275, doi:10.3390/nu5041253.

10. Barker, T.; Schneider, E.D.; Dixon, B.M.; Henriksen, V.T.; Weaver, L.K. Supplemental vitamin D enhances the recovery in peak isometric force shortly after intense exercise. *Nutr Metab (Lond)* **2013**, *10*, 69, doi:10.1186/1743-7075-10-69.

11. Stockton, K.A.; Mengersen, K.; Paratz, J.D.; Kandiah, D.; Bennell, K.L. Effect of vitamin D supplementation on muscle strength: a systematic review and meta-analysis. *Osteoporos Int* **2011**, *22*, 859-871, doi:10.1007/s00198-010-1407-y.

12. Holick, M.F. Vitamin D status: measurement, interpretation, and clinical application. *Ann Epidemiol* **2009**, *19*, 73-78, doi:10.1016/j.annepidem.2007.12.001.

13. Janssen, H.C.; Samson, M.M.; Verhaar, H.J. Vitamin D deficiency, muscle function, and falls in elderly people. *Am J Clin Nutr* **2002**, *75*, 611-615, doi:10.1093/ajcn/75.4.611.

14. Dzik, K.P.; Kaczor, J.J. Mechanisms of vitamin D on skeletal muscle function: oxidative stress, energy metabolism and anabolic state. *Eur J Appl Physiol* **2019**, *119*, 825-839, doi:10.1007/s00421-019-04104-x.

15. Close, G.L.; Russell, J.; Cobley, J.N.; Owens, D.J.; Wilson, G.; Gregson, W.; Fraser, W.D.; Morton, J.P. Assessment of vitamin D concentration in non-supplemented professional athletes and healthy adults during the winter months in the UK: implications for skeletal muscle function. *J Sports Sci* **2013**, *31*, 344-353, doi:10.1080/02640414.2012.733822.

16. Hamilton, B.; Whiteley, R.; Farooq, A.; Chalabi, H. Vitamin D concentration in 342 professional football players and association with lower limb isokinetic function. *J Sci Med Sport* **2014**, *17*, 139-143, doi:10.1016/j.jsams.2013.03.006.

17. Ksiazek, A.; Zagrodna, A.; Dziubek, W.; Pietraszewski, B.; Ochmann, B.; Slowinska-Lisowska, M. 25(OH)D3 Levels Relative to Muscle Strength and Maximum Oxygen Uptake in Athletes. *J Hum Kinet* **2016**, *50*, 71-77, doi:10.1515/hukin-2015-0144.

18. Wyon, M.A.; Koutedakis, Y.; Wolman, R.; Nevill, A.M.; Allen, N. The influence of winter vitamin D supplementation on muscle function and injury occurrence in elite ballet dancers: a controlled study. *J Sci Med Sport* **2014**, *17*, 8–12, doi:10.1016/j.jsams.2013.03.007.
19. Fishman, M.P.; Lombardo, S.J.; Kharrazi, F.D. Vitamin D Deficiency Among Professional Basketball Players. *Orthop J Sports Med* **2016**, *4*, 2325967116655742, doi:10.1177/2325967116655742.
20. Witvrouw, E.; Cools, A.; Lysens, R.; Cambier, D.; Vanderstraeten, G.; Victor, J.; Sneyers, C.; Walravens, M. Suprascapular neuropathy in volleyball players. *Br J Sports Med* **2000**, *34*, 174–180, doi:10.1136/bjsm.34.3.174.
21. Maroon, J.C.; Mathyssek, C.M.; Bost, J.W.; Amos, A.; Winkelman, R.; Yates, A.P.; Duca, M.A.; Norwig, J.A. Vitamin D profile in National Football League players. *Am J Sports Med* **2015**, *43*, 1241–1245, doi:10.1177/0363546514567297.
22. Wolman, R.; Wyon, M.A.; Koutedakis, Y.; Nevill, A.M.; Eastell, R.; Allen, N. Vitamin D status in professional ballet dancers: winter vs. summer. *J Sci Med Sport* **2013**, *16*, 388–391, doi:10.1016/j.jsams.2012.12.010.
23. Tomlinson, P.B.; Joseph, C.; Angioi, M. Effects of vitamin D supplementation on upper and lower body muscle strength levels in healthy individuals. A systematic review with meta-analysis. *J Sci Med Sport* **2015**, *18*, 575–580, doi:10.1016/j.jsams.2014.07.022.
24. Farrokhyar, F.; Sivakumar, G.; Savage, K.; Koziarz, A.; Jamshidi, S.; Ayeni, O.R.; Peterson, D.; Bhandari, M. Effects of Vitamin D Supplementation on Serum 25-Hydroxyvitamin D Concentrations and Physical Performance in Athletes: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Sports Med* **2017**, *47*, 2323–2339, doi:10.1007/s40279-017-0749-4.

Peer-reviewed version available at *Nutrients* 2019, 11, 2768; doi:10.3390/nu11112768

25. Ksiazek, A.; Dziubek, W.; Pietraszewska, J.; Slowinska-Lisowska, M. Relationship between 25(OH)D levels and athletic performance in elite Polish judoists. *Biol Sport* 2018, 35, 191-196, doi:10.5114/biolsport.2018.74195.

## Figure legend

### Fig. 1 - Internal/external shoulder muscle strength according to the vitamin D status

The isokinetic shoulder strengths were not significantly different across the three groups at all settings (ER60, external rotation at 60 degree/s; IR60, internal rotation at 60 degree/s; ER180, external rotation at 180 degree/s; IR, internal rotation at 180 degree/s).