Original Communication

Supplemental vitamin D3 does not affect musculoskeletal or psychomotor performance in college aged males

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Abstract: The experiment examined the effects 4 weeks of vitamin D (Vit D) supplementation versus placebo on musculoskeletal and psychomotor performance. Thirty-two college age males (Age: 22 ± 4 y, Height: 177.7 ± 8.3 cm, Weight: 81.5 ± 14.6 kg, BF%: 19.6 ± 7.9, Vit D: 20.0 ± 7.2 ng/ml). Participants were assigned to group (Vit D vs placebo) and remained blind throughout the study. The treatments were 4000 IU of Vit D3 or placebo (dextrose) administered daily for 4 weeks. The participants underwent baseline testing for isometric strength, explosive ability and psychomotor performance, which was repeated at week 2 and week 4. Isometric tests consisted of an Isometric Mid Thigh Pull on a Force Plate (IMTP) and an upper body isometric test (UBIST) using a load cell. Peak force during a countermovement jump (CMJ) was also determined via force plate. A psychomotor vigilance test (PVT) was used to measure sustained reaction time. Analysis of the UBIST data did not reveal a significant group × time interaction (p = 0.14; Vit D pre: 553.7 ± 168.3 N, post: 585.5 ± 150.2 N; Placebo pre: 677.7 ± 182.3 N, post: 649.8 ± 236.9 N). For IMTP no significant group × time interaction (p = 0.83; Vit D pre: 2596.4 ± 342.3 N, post: 2606.9 ± 378.3 N; Placebo pre: 2684.0 ± 432.9 N, post: 2762.6 ± 440.4 N) was found. CMJ analysis did not reveal interaction effects for group × time (p = 0.21; Vit D pre: 4429.7 ± 1619.0 N, post: 4938.5 ± 2374.8 N; Placebo pre: 5537.3 ± 3027.0 N, post: 6266.9 ± 4577.3 N). For PVT (mean reaction time) there was no significant interaction effects for group × time (p = 0.35; Vit D pre: 0.304 ± 0.041 sec, post: 0.301 ± 0.053 sec; Placebo pre: 0.295 ± 0.044 sec, post: 0.284 ± 0.029 sec). In conclusion, four weeks of Vit D supplementation was not effective in increasing musculoskeletal or psychomotor performance.

Keywords: Vitamin D, muscular strength, muscular power, reaction time

Introduction

Vitamin D is ingested or acquired through sun exposure and is one of the fat soluble vitamins. It is critical for the maintenance of calcium homeostasis, with low levels triggering the release of parathyroid hormone causing increases in skeletal muscle reabsorption [1]. There are two primary forms of Vit D, D2 and D3 which were originally thought to be equivalent however more recent evidence suggests that D3 is more effective for increasing serum levels of 25-hydroxyVit D the metabolite used to test for Vit D deficiency [2]. Vit D plays an important role in the musculoskeletal system and additionally is deficient in some segments of the population [3]. It is known that Vit D has receptors that are expressed on human skeletal muscle tissue and that these receptors decline with age [4]. Additionally, there is evidence that Vit D suppresses myostatin expression, and can increase the percentage of Type IIA fibers leading to increases in muscular power [5]. Additionally, in animal models, Vit D deficiency has been associated with changes in behavioral tasks and with genes associated with the neuro-muscular junction [6]. Among older adults, Vit D levels have been associated with reduced gait speed and grip strength [7]. Furthermore, among elderly subjects who have experienced a fall and have reduced psychomotor function those with lower Vit D had the most significant impairments [8]. The changes in psychomotor function could be driven by the effect of Vit D on testosterone [9]. Testosterone therapy has been shown to increase psychomotor function [10]. However, the effects of Vit D supplementation on psychomotor or motor function has mostly been examined in

older cohorts, to date little information is available about the effects of Vit D on these parameters in other segments of the population.

Several recent studies have suggested that adequate Vit D may be linked to muscloskeletal performance. Wyon et al. reported that a dose of 120,000 IU taken over the course of 1 week was associated with a 7.8% increase in isometric strength in a cohort of adolescent dancers [11]. In an earlier study, a 18.7% increase in isometric strength was reported with 2000 IU per day among elite ballet dancers during the winter months [12]. Additionally, an acute dose of Vit D in Judoka athletes was associated with a 13% change in muscle strength [13]. These studies suggest a promising role for Vit D3 in improving musculoskeletal performance, however the studies that have examined this in younger adults are almost exclusive to performing artists or athletic populations. While athletic population can obviously benefit from supplementation targeted at muscular performance, the general population may stand to benefit as well. A recent study of grip strength and pinch strength among Millennials (born 1981–1996) found the results to be significantly below the norms for almost all segments of this age group [14]. Among males a population decline in serum testosterone has also been reported among a large US cohort [15]. As such, there is a need to understand the effect of Vit D supplementation on musculoskeletal performance among non-athletic segments of the population as these characteristics appear to be on the decline. Also, a recent review of the literature on Vit D and muscle performance noted a lack of available evidence regarding the effects of Vit D on muscle function in younger adults [3]. Based upon these last points, it is clear that more research is needed on healthy young adults, particularly on treatments that might enhance musculoskeletal performance. Therefore, in this study we examined the effects of a 4 weeks of Vit D3 on the musculoskeletal function of healthy young adults.

Subjects and methods

Subjects

The participants were 32 college age males (see Table 1). The sample size was based upon the available pool of subjects for the study. Subjects who were not healthy enough to engage in exercise were excluded from consideration as well as those with any known musculoskeletal ailments. All research participants gave written informed consent prior to beginning data collection, and the experimental procedures were reviewed and approved by the institutional review board at the University of Louisiana at Lafayette.

Participants were randomly assigned to group (Vit D vs placebo) and remained blind to the treatment throughout the study. The treatments consisted of 4000 IU of Vit D3 (Swanson Health, Fargo ND) or similarly sized placebo (dextrose, Now Foods, Bloomingdale IL) administered daily for 4 weeks. Compliance was assessed through a messaging system and no subjects reported any side effects from the treatments during the course of the study. The participants underwent baseline testing for isometric strength, explosive ability and psychomotor performance, which was repeated at week 2 (mid supplementation) and week 4. Isometric tests consisted of an Isometric Mid Thigh Pull on a Force Plate (IMTP) and an upper body isometric test (UBIST) using a load cell. Peak force during a countermovement jump (CMJ) was also determined via force plate. A psychomotor vigilance test (PVT) was used to measure sustained reaction time. Baseline Vit D analysis was determined via blood spot testing using LC-MS/MS performed at a clinical lab.

Table 1. Participant characteristics (means ± SD).

Variable	Mean	*SD*
Age (yrs)		
Vit D	22	4
Placebo	22	4
Height (cm)		
Vit D	175	9.1
Placebo	181	6.5
Weight (kg)		
Vit D	79	16
Placebo	85	12.5
BF%		
Vit D	18.5	7.8
Placebo	20.7	8.3
Vit D (ng/ml)		
Vit D	19.5	5.8
Placebo	20.5	8.4

Isometric mid thigh pull and force plate counter movement jump

For the CMJ the participants were asked to perform three maximum effort jumps off an AMTI Force Plate (Advanced Materials Technologies Inc., Watertown MA USA). For this test the participant placed their hands on their hips, to remove the influence of the upper body. Data from the test was analyzed using a software package specific to CMJ analysis (zFlo Inc., Westbrook, ME USA). The average of the three trials was used for subsequent analyses.

The IMTP is a well-validated strength measure [16]. The test equipment consisted of an AMTI forceplate (Advanced Materials Technologies Inc., Watertown MA USA) secured beneath a custom Rouge fitness weighlifting rack (Rogue Fitness Inc, Columbus OH USA). The participants were

instructed to stand with the feet shoulder width apart above the force plate. The height of the bar was adjusted so that the participant was in a position where the torso was upright, the knees achieved between 120–130 degrees of flexion (measured via a goniometer) and the arms were straight while holding the bar. The participants' hands were secured to the bar via weightlifting hooks to remove the variance associated with grip strength. The participants were told to "drive straight up" and to pull as hard as they could against the bar until the force began to noticeably decline. The peak force was assessed in triplicate at a sampling rate of 2000 Hz using an AMTI Force Plate. The average of the three trials was used for subsequent analyses.

Isometric upper body test

The UBIST used in this study has previously been reported to be both reliable and valid [17] when examined against a criterion (1 RM bench press) and has used in clinical studies [18, 19]. The participants were positioned on three elevated platforms with the chest directly suspended over a load cell anchored into the concrete floor of the lab (iLoad Pro, Loadstar Sensors, Fremont CA USA). The load cell chosen has a capacity of greater than 5000 newtons and a listed accuracy of 0.25% for the full scale of measurement. The participants were placed in a push-up style position, with the hands at 150% of biacromial width, and the elbows at 90 degrees of extension (measured via a goniometer). A thick, non-elastic strap was run over one shoulder and under the opposite shoulder and connected with metal rings to a chain that was tethered to the load cell. The participants were positioned so that no slack was apparent in the chain prior to initiation of data capture.

The participants were instructed to keep their backs flat, and push with their hands maximally until told to stop by the researcher. Prior to data capture the load cell was tared to ensure the weight of the load cell and apparatus were accounted for. The researcher started data collection and verbally instructed the participant to "push as hard as possible". The load cell captured data at maximum rate (150 Hz) until force noticeable declined (drop of 50 N). The average of three trials was used for subsequent analyses.

Psychomotor testing

The Walter Reed PVT was administered to the participants after resting for at least ten minutes in a quiet room. The PVT is a test of simple visual reaction time and was developed at the Walter Reed Army Institute of Research [19] and was used to assess mean reaction time over a 5-minute time course. The test used random periods of time in which a target stimuli were displayed on the screen of a Palm handheld device (Palm V, Palm Inc, Sunnyvale CA). The program was set to display approximately 100 stimuli in the 300-second (5 minutes) period at randomly spaced intervals. This program computes a mean reaction time to each stimulus, as well as major and minor lapses in attention. This instrument has been used in large scale studies conducted by the military and is extensively represented as a valid cognitive measure in the literature [19].

Statistical analysis

Baseline data was analyzed by group (Vit D vs Placebo) for differences using one-way Anova. Repeated measures data (pre, post) were analyzed for group by time differences via repeated measures Anova using JMP 13.0 software (JMP®, Version 13.0. SAS Institute Inc., Cary NC). Normality of residuals from Anova was assessed using Q-Q diagnostic plots, and equal variance was assessed through Levene test of equal variance. Statistical significance was set a priori at $p < 0.05$.

Results

Normality of residuals and equal variance

Levene test of equal variance by group did reveal a significant difference by group for variance in the UBIST measure. This variable was log transformed and variance was not a significantly different by group ($p = 0.16$). The log transformed UBIST data was used for subsequent analysis. Diagnostic Q-Q plots of residuals did not suggest violation of the assumptions of Anova.

Baseline differences by group

No group differences were noted in starting Vit D level ($F = 0.14$, $p = 0.71$, Vit D: 19.5 ± 5.8 ng/ml, Placebo: 20.5 ± 8.4 ng/ml). Additionally, no group differences were noted for Body Fat Percentage ($F = 0.57$, $p = 0.45$, Vit D: 18.5 ± 7.8%, Placebo: 20.7 ± 8.3%) or age ($F = 0.14$, $p = 0.71$, Vit D: 22 ± 4 yrs, Placebo: 22 ± 4 yrs). Finally, no group differences were noted in starting Isometric Mid Thigh Pull Strength ($F = 0.67$, $p = 0.42$, Vit D: 2569.4 ± 97 N, Placebo: 2684 ± 100 N), UBIST ($F = 3.87$, $p = 0.06$, Vit D: 553.7 ± 44 N, Placebo: 677.7 ± 45 N), or psychomotor performance ($F = 0.31$, $p = 0.58$, Vit D: 0.303 ± 0.01 sec, Placebo: 0.295 ± .01 sec).

Isometric strength assessments-upper body

There was a significant effect of group ($F = 4.52$, $p = 0.04$) but not a significant group × time interaction ($F = 2.09$,

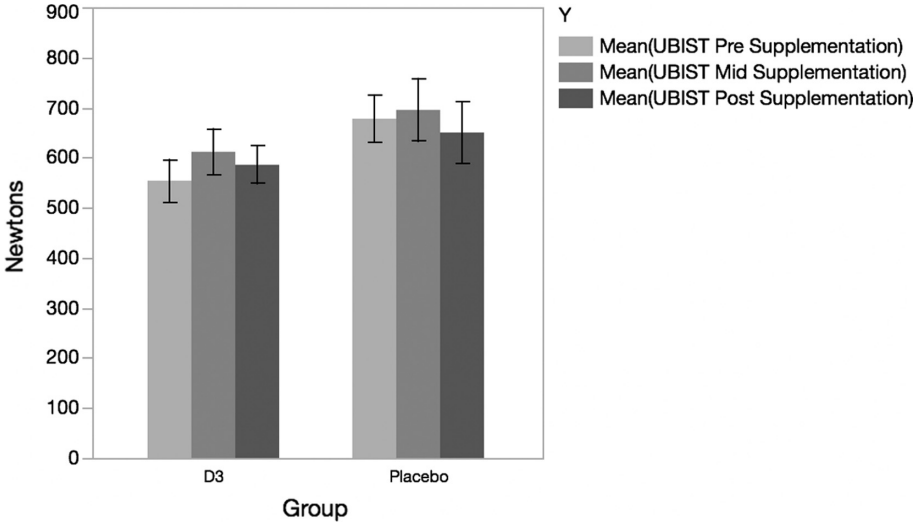

Figure 1. Upper body Isometric Strength (UBIST) by group and time. Error bars represent 1 SEM.

p = 0.14; Vit D pre: 553.7 ± 168.3 N, post: 585.5 ± 150.2 N; Placebo pre: 677.7 ± 182.3 N, post: 649.8 ± 236.9 N). See Figure 1.

Isometric strength assessments-lower body

No significant effect of group (F = 0.92, p = 0.34) nor significant group × time interaction (F = 0.17, p = 0.83; Vit D pre: 2596.4 ± 342.3 N, post: 2606.9 ± 378.3 N; Placebo pre: 2684.0 ± 432.9 N, post: 2762.6 ± 440.4 N) was found. See Figure 2.

Counter Movement Jump

Analysis did not reveal a significant main effect for group (F = 0.75, p = 0.39) or interaction effects for group × time (F = 1.63, p = 0.21; Vit D pre: 4429.7 ± 1619.0 N, post: 4938.5 ± 2374.8 N; Placebo pre: 5537.3 ± 3027.0 N, post: 6266.9 ± 4577.3 N).

Psychomotor vigilance test

There was no significant main effect for treatment (F = 1.29, p = 0.29) or interaction effects for group × time (F = 1.08, p = 0.35; Vit D pre: 0.304 ± 0.041 sec, post: 0.301 ± 0.053 sec; Placebo pre: 0.295 ± 0.044 sec, post: 0.284 ± 0.029 sec).

Discussion

As previously mentioned, there is a lack of information about the effects of Vit D supplementation on young adult subject's muscle function [3]. Many studies have examined the association between Vit D levels and muscle performance [7, 8, 20]. Additionally evidence has been presented about Vit D and children [11, 21]. These populations represent segments of the population where there is either growth that necessitates Vit D, or changes in the diet that result in a higher prevalence of Vit D deficiencies [22]. As such, it is logical to find differences in muscle performance with this segments of the population either by Vit D status or with supplementation. However, young adults of college age have also been reported to have less than optimal Vit D levels and dietary intake, though it should be noted that there is a lack of available data about this segment of the population [23]. In the present investigation we found that Vit D levels were 20.0 ± 7.2 ng/ml across our pool of subjects. In a recent study by Cress and Stiles, a mean of 25.08 was reported for a group of 98 college aged students [23]. The addition of the data from the present study and that reported previously suggests that further investigation into the level of Vit D deficiency in college aged students is warranted. It is known that Vit D levels are associated with depression, though a causal relationship has yet to be established [24]. Given the current concerns with the mental health of college students it is important that future work examines the associations of Vit D deficiency and mental wellness in this population, and determines if there is a causal relationship [25].

The present investigation did not reveal changes in any measures of isometric or dynamic (counter movement jump) muscle performance with Vit D supplementation. Additionally, no changes were noted in psychomotor performance. Given that the subjects were not in state of sufficient Vit D, it may be that in this age group the body is generally in a state of peak performance, i.e. post peak vertical height change but prior to the majority of the losses due to aging. This could place a ceiling effect on the

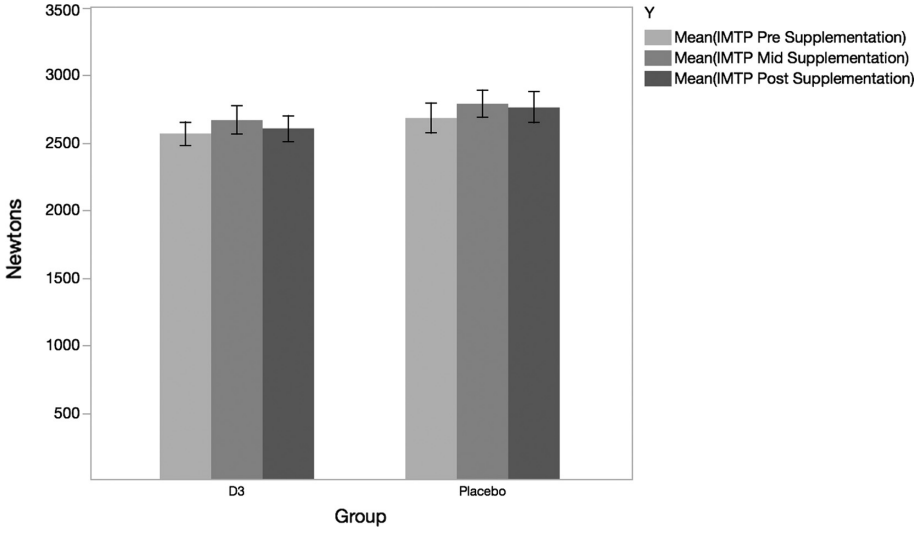

Figure 2. Isometric Mid Thigh Pull (IMTP) by group and time. Error bars represent 1 SEM.

potential for improvement in these measures with Vit D supplementation.

While this study provides some evidence into the use of Vit D supplements to target muscle performance improvements in younger adults there are strengths and weaknesses to consider. The strength of the study was the use of highly precise and valid instruments for the assessment of both muscular performance and psychomotor performance. Additionally, another strength was the variation in muscular performance testing, assessing both power and upper and lower body isometric strength. This builds a comprehensive set of data from which to draw conclusions. Additionally, the PVT test is well validated and has been used extensively in research studies. However; the findings need to be replicated using similar quality instrumentation to increase the amount of data. Secondly, post Vit D measures were not taken to document changes in concentration over the course of the study. However, the dose used (4000 IU) is considered to a large does (yet safe for consumption) and has been shown to increase Vit D levels [26]. Additionally, only 17 of the subject were Vit D deficient at the onset of the study, meaning that some participants had adequate levels at the onset of the study. Finally, the time course of the Vit D supplementation (4 weeks) and the use of only healthy individuals could be a limiting factor. Future trials in this population should examine a longer time course of supplementation.

Conclusion

Four weeks of Vit D supplementation was not effective in increasing musculoskeletal or psychomotor performance in college aged males. It should be noted that blood spot Vit D testing suggested that the majority of the students assessed fell below the reference level for Vit D at the onset of the study. Further research is needed to clarify the effect of Vit D on recreationally active persons.

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