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# Effect of Vitamin D Supplementation on Aerobic Exercise Performance in Healthy Adults; A Randomised Single Blinded Placebo Controlled Pilot Study

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## Abstract

**Background:** 1,25-dihydroxyvitamin D (1,25(OH)D), the biologically active form of vitamin D, is thought to be directly related to exercise induced inflammation and skeletal muscle performance and deficiency has catabolic effects on muscle tissue, causes muscle weakness and impairs cross-bridge formation. 1,25(OH)D may also affect cardiovascular risk factors such as blood pressure (BP), which in turn may have an effect on aerobic exercise; however, at present evidence investigating this association are lacking. Therefore, the aim of this study was to investigate the effect of vitamin D supplementation on aerobic exercise following two weeks of intervention.

**Methods:** A randomised placebo controlled single-blinded pilot study aimed to investigate the short term effects of vitamin D supplementation on aerobic exercise performance in a group of healthy adults. Eleven healthy adults were allocated to receive either 2000IU (50µg/day) of vitamin D or a placebo (sucrose) for 14 days. Physical activity and diet diaries were completed throughout the study. Aerobic exercise performance was assessed at baseline and day 14 following a 15-minute run on a treadmill set at a gradient of 1.5%. Height, weight, systolic/diastolic BP and heart rate (HR) were recorded at baseline and day 14 before running. Parameters of aerobic exercise exertion (BP, %HR and difference in blood lactate) were recorded before and after each run. The rate of perceived exertion (RPE) was recorded after each run.

**Results:** HR reduced significantly by 2.5% ($p = 0.002$) from 91.5 ± 4.5% to 89.0 ± 3.7% in the intervention group, but not in the placebo group (1.2%; 87.8 ± 4.5% to 86.6 ± 5.1%. $p = 0.4$). The difference in blood lactate between pre and post run was smaller in the intervention group [(3.9 ± 3.7 mmol/L; $p = 0.2$ SEM (1.5)] than in the placebo group [(5.5 ± 3.8 mmol/L; $p = 0.1$; SEM (5.9)]; however, this did not statistically differ between [$p = 0.5$; SEM (2.2)] and within the groups. Finally, a statistically significant reduction [($p = 0.001$; SEM (0.7)] in RPE was found in the intervention group only (15.8 ± 1.9 to 14.7 ± 2.2).

**Conclusion:** The significant reduction in both percentage heart rate and rate of perceived exertion found in this study over a two-week period suggest that short term vitamin D supplementation may improve aerobic exercise performance. However, larger scale studies are now warranted to verify these findings.

***Keywords:*** *Vitamin D; Heart rate; Rate of perceived exertion (RPE); Blood lactate; Aerobic exercise*

## Abbreviations

[La−]b: Blood Lactate Concentration; 1,25(OH)2D: 1,25 dehydroxivitamin D; 25(OH)D: 25, hydroxivitamin D; ATP - Adenosine Triphosphate; BMI – Body Mass Index; BMR – Basal Metabolic Rate; BP – Blood Pressure; CVD – Cardiovascular Disease; DBP – Vitamin D Binding Protein; EPO – Erythropoietin; HR – Heart Rate; MHR – Maximum Heart Rate; PAL – Physical Activity Level; PTH – Parathyroid Hormone;

RAS – Renin Angiotensin System; RBC – Red Blood Cells; RPE – Rating of Perceived Exertion; SD – Standard Deviation; SE – Standard Error of the Mean; TEE – Total Energy Expenditure

## Introduction

Exercise performance is determined by both genetic and environmental factors. Particularly, an increasing body of evidence is emerging supporting a role for vitamin D in the regulation of the immune system and skeletal muscle function [1,2]. It is well established that vitamin D is essential for optimal calcium homeostasis and bone mass, and new evidence suggest that 1,25-dihydroxivitamin D (1,25(OH)D), the active form of vitamin D, regulates the expression of more than 900 gene variants, which are controlled by intracellular vitamin D receptors (VDR) present in many tissues including skeletal muscle endothelial cells. Some of these expressions have been associated with skeletal muscle activity and therefore may affect training and exercise performance [3].

Vitamin D inadequacy (deficiency (≤ 25 nmol/L) and insufficiency (≤ 50 nmol/L)) is considered an international and public health issue (SACN, 2015). Vitamin D is primarily obtained from sunlight and it can also be absorbed from the diet; however very few foods contain naturally occurring vitamin D [4]. There are many factors that influence the exposure of skin to UVB light including time of the day, season, latitude, air pollution, clouds, reduced vitamin D intake, clothing, skin pigmentation and the use of sunscreen [5]. Additionally, in northern countries, like Scotland (56N), skin synthesis only occurs between April and September and 25(OH)D deficiency has been reported in 46% of adults and 28% of children (SACN 2015). Data reporting 25(OH)D concentration in athletes is scarce and the few published studies report high prevalence of 25(OH)D inadequacy [6,7], which is higher in the winter months [7]. 25(OH)D deficiency causes muscle weakness, breakdown of muscle tissue and the impairment of cross-bridge formation [8], which in turn reduces exercise performance and causes a higher incidence of injuries [6,7]. Therefore, optimal 25(OH)D is essential for healthy muscle tissues and may enhance muscle strength [3].

Most research has investigated the role of vitamin D on resistance exercise; however, there is a paucity of evidence reporting whether 25(OH)D affects aerobic exercise. 1,25(OH)D affects cardiac muscles directly and although 25(OH)D deficiency has been associated with hypertension [9], there is conflicting evidence regarding the effects of 25(OH)D on blood pressure in normotensive individuals [10]. 25(OH)D's effect on aerobic exercise via its role in cardiovascular health remains largely unknown, however a relationship between 25(OH)D and a reduction in systolic BP has previously been described [11,12].

Therefore, the aim of this study was to determine whether Vitamin D supplementation over a 2-week period would affect aerobic performance in healthy adults. The objectives of this study were to determine the effects of vitamin D supplementation upon BP, HR, rating of perceived exertion (RPE) and blood lactate ([La−]b) after 14 days of intervention.

## Materials and Methods

### Participant Recruitment

Healthy individuals, aged between 18 and 50, were recruited from Queen Margaret University in March 2016. Participants were all of a healthy body weight, defined as a body mass index (BMI) of between 18.5 Kg/$m^2$ and 24.9 kg/$m^2$ [13]. Individuals with a blood pressure (BP) of < 90/80 mmHg or > 130/80 mmHg [10], currently pregnant or breast feeding, with any pre-existing health conditions or any pre-existing injuries were excluded. Additionally, participants who declared sun exposure within the last month (abroad or sunbeds) or those consuming supplements containing vitamin D, were also excluded. A health questionnaire ensured subjects met the inclusion criteria, and written informed consent was provided by each participant consistent with the university policy for the protection of human subjects [14]. The protocol of the study was approved by the Research Ethics Committee at Queen Margaret University.

## Study Design

This randomised placebo controlled single blinded trial was conducted over 21 days during which participants attended the research facility on 3 occasions. On each visit anthropometric measurements were recorded; height (cm) was measured using a stadiometer and weight (kg) was obtained using a calibrated electronic weight scale. These measurements were used to determine BMI and participants were randomized to receive either 2000 IU of vitamin D3 (High potency vegan vitamin D3; Cytoplan; Worcestershire; UK) or placebo (un-medicated lactose/sucrose tablets; HSC; Norfolk, UK), to be taken once a day for 14 days. A calibrated automated A&D Medical UA-767 BP monitor (A&D medical, San Jose, CA, USA) was used to measure BP; on each occasion BP was measured three times and an average was taken to increase reliability [15].

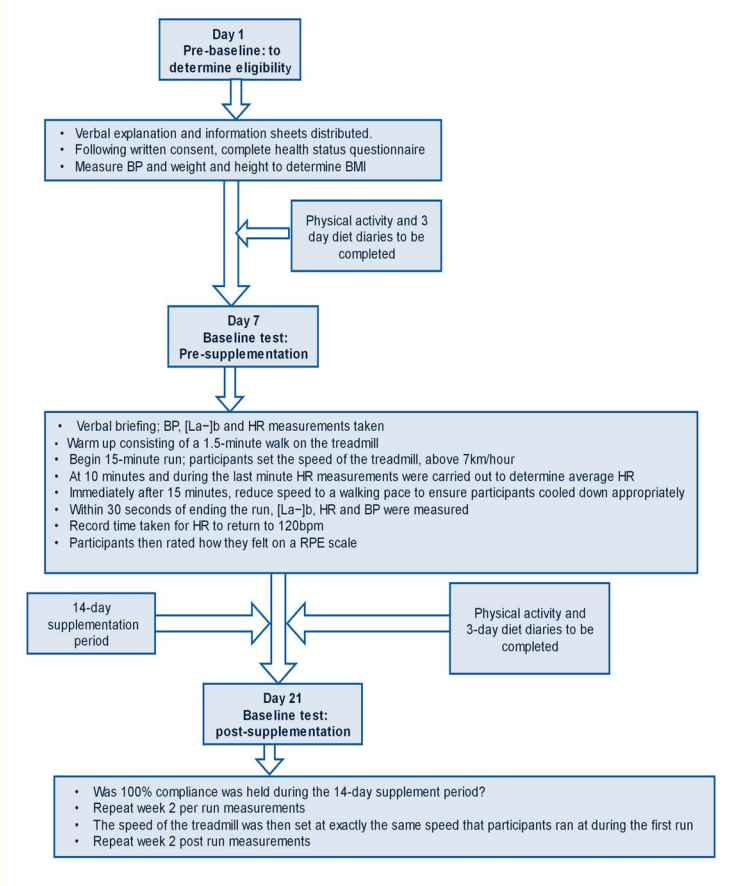


***Figure 1:*** *Study design.*

Heart rate (HR; beats per minute; bpm) was measured using an electronic HR monitor (Polar FT40M), which was worn around the sternum. Maximum HR (MHR) was calculated using the equation 220-Age (years) = MHR [16].

Participants were directed not to change their dietary habits, to avoid vitamin supplements during the study and to limit water intake to 500 ml, caffeine intake and to reframe from strenuous exercise before each trial. Dietary intake was monitored throughout the study period to assess compliance with the dietary instructions and to determine whether the intake of vitamin D containing foodstuffs was different between groups and over the experimental period. Three-day diet diaries were provided to each participant and they were requested to estimate servings of foods over 2 week days and 1 weekend day using household measurements as described in national dietary guidance documents.

To ensure that changes in aerobic performance were not due to individual physical activity levels [17] and also to determine whether or not PAL affects other parameters, PAL was calculated using the equation: PAL = Total Energy Expenditure (TEE) / Basal Metabolic Rate (BMR; [16]). On the subsequent two visits a finger prick blood sample was taken to determine [La−]b (mmol/L) using Blood Lactate scout+ (Supplier).

At baseline BP, [La−]b and HR measurements were recorded and participants undertook a warmup session consisting of a 1.5-minute walk on the treadmill. Each participant then undertook a 15 minute run at a self-regulated speed which had to be above 7 km/hour. At T = 10 minutes and T = 14-15 minutes, HR was measured to determine average HR. Immediately after the 15 minute run the treadmill speed was reduced to a walking pace to ensure participants cooled down appropriately. Within 30 seconds of ending the run, [La−]b, HR and BP were re-measured, and the time taken for HR to return to 120 bpm recorded. Participants perceived rate of exertion (RPE) was then measured using the Borg scale [18].

### Data Analysis

Diet diaries were analysed using Netwisp (V4.0 Timviel software) to estimate daily intake of vitamin D. Statistical analysis was performed using the Statistical Analysis Package for Social Sciences (SPSS V21). Independent t-tests were used to assess differences in BP, HR, [La−]b and RPE between the control and intervention group. Paired t-tests were used to determine differences in BP, HR, [La−]b and RPE before and after either supplementation or placebo. Statistical significance level was determined by p value of ≤ 0.05 and all data is presented as mean ± standard deviation (SD).

## Results

16 healthy and physically active Caucasian individuals with no pre-existing illnesses were interested in the study. Of these 11 were eligible (69%) and completed the study, but 5 (31%) were excluded for the following reasons: 2 were overweight, 1 withdrew due to ill health and 2 changed their minds. Diet diaries revealed that none of the participants were consuming vitamin D supplements and compliance was 100%. There was not statistically significant difference between the placebo and the supplemented group in the baseline characteristics of the population. Both the placebo and supplemented group maintained PAL and vitamin D intake (apart from supplementation) throughout the study.

| | **Supplement** | | **Placebo** | | ***P* Value** |
|---|---|---|---|---|---|
| | n | % | n | % | |
| Males | 3 | 50 | 3 | 60 | 0.77[1] |
| Females | 3 | 50 | 2 | 40 | |
| | Mean | ± SD | Mean | SD | |
| Age | 22.83 | 2.64 | 23.2 | 3.27 | 0.84[2] |
| Height (cm) | 170.28 | 8.44 | 176.26 | 6.1 | 0.22[2] |
| Weight (kg) | 65.77 | 7.13 | 67.14 | 6.27 | 0.75[2] |
| BMI ($kg/m^2$) | 22.95 | 1.55 | 21.22 | 1.72 | 0.11[2] |
| Systolic BP (mmHg) | 112.00 | 14.00 | 124.00 | 9.00 | 0.13[2] |
| Diastolic BP (mmHg) | 67.00 | 14.00 | 73.00 | 7.00 | 0.37[2] |
| Vitamin D intake (IU) | 180.2 | 89.6 | 156.4 | 77.6 | 0.78[2] |
| PAL | 2.58 | 0.56 | 2.62 | 1.04 | 0.94[2] |

***Table 1:*** *Baseline characteristics of the population.*

*[1]Chi-square test; [2]Independent t-test; statistical significance established at p < 0.05.*

No statistically significant changes were recorded in systolic (placebo: run one 171.8 ± 20.2 to run two 140.0 ± 8.0 mmHg; supplemented group: run one 161.2 ± 21.2 to run two 143.8 ± 11.2 mmHg) and diastolic BP (placebo: run one 116.2 ± 29.1 to run two 90.0 ± 8.8 mmHg; supplemented group: run one 112.3 ± 22.2 to run two 91.0 ± 8.8 mmHg) in either the placebo or the vitamin D supplemented group ($p > 0.05$) following intervention. Values are presented as mean ± SEM.

There was a statistically significant reduction in MHR percentage after Vitamin D supplementation ($P = 0.02$) but not after placebo ($P = 0.41$). Vitamin D supplementation reduced MHR percentage by 2.5%, from 91.5 ± 4.46% to 89 ± 3.74%. The placebo group reduced MHR percentage by 1.2%, from 87.8 ± 4.55% to 86.6 ± 5.13%.

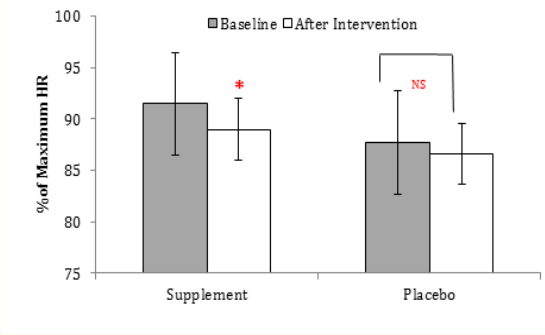


***Figure 2:*** *The effect of vitamin D supplements and placebo on percentage of MHR during run, at baseline and intervention phase.*

*Values are presented as mean ± SEM. NS: non-significant.*

There was a statistically significant difference in RPE before (15.83 ± 1.94) and after (14.67 ± 2.16) Vitamin D supplementation ($P = 0.001$). No significant differences were found before (14.8 ± 2.28) and after (13.8 ± 2.77) the intervention following placebo ($P = 0.142$). An independent t-test demonstrated no significant differences in RPE between the supplement and placebo group after the intervention ($P = 0.57$).

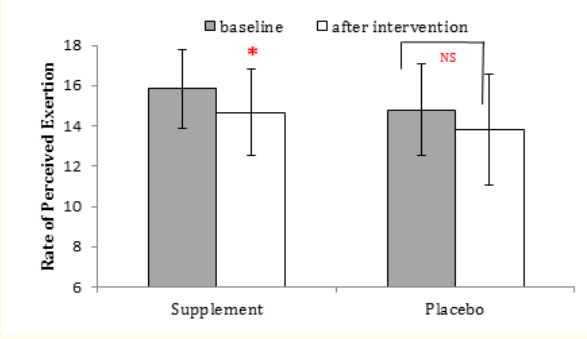


***Figure 3:*** *Effect of vitamin D supplements and placebo on rate of perceived exertion following run (one) at baseline and run two at intervention phase.*

*Values are presented as mean ± SEM; $p < 0.001$.*

[La−]b reduced by 2.43 ± 3.68 mmol/L from 10.45 ± 4.4 mmol/L to 8.02 ± 2.75 mmol/L after supplementation (p = 0.17). Although this is not statistically significant, the supplement group showed a greater decrease in [La−]b than the placebo group, which only had a reduction of 0.42 ± 4.27mmol/L (P = 0.84).

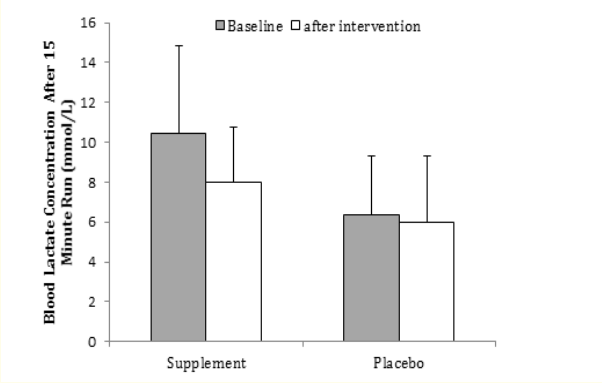


***Figure 4:*** *Effect of vitamin D and placebo on [La−]b (mmol/L) after 15-minute run, at baseline and after intervention.*

*Values are presented as mean ± SEM. There are not statistically significant differences in [La−]b following the run between the supplement and placebo group, p = 0.29.*

## Discussion

The findings from this pilot study indicate that short term supplementation of Vitamin D (2000 IU) enhances aerobic performance in this group of healthy adults by significantly reducing RPE and the percentage of MHR. Although not statistically significant, Vitamin D also caused a reduction in average HR during aerobic exercise followed by a reduction in [La−]b and BP post exercise.

In agreement with the present pilot study, [12] also found that healthy individuals improved RPE following two weeks of vitamin D supplementation in which the same daily dose was given (2000 IU). Although, both interventions investigated aerobic exercise, it is important to note that the present study used running as opposed to cycling and there might be some differences. Similarly, [19] in a cross sectional study demonstrated a positive correlation between plasma 25(OH)D and VO2 max (the amount of oxygen uptake achieved during maximal exercise intensity) in 77 professional football players suggesting that higher plasma 25(OH)D concentration increases VO-2max or oxygen capacity and therefore improves cardiovascular fitness. These findings are also supported by a large double-blind clinical trial, in which 200 healthy adults took statins for two weeks and 25(OH)D concentration and physical fitness were also investigated [20]. This study added that serum 25(OH)D had a greater effect on aerobic exercise performance among subjects who were more sedentary. For each SD increase in serum 25(OH)D among inactive individuals, VO2max increased by 8%, whereas VO2max only increased by 0.2% in active individuals [20]. Although 25(OH)D concentration was not investigated in the current study, the improvement in aerobic exercise could be explained by the effect that 25(OH)D has on muscle skeletal muscle fibres [21]. Low physical activity combined with hypovitaminosis D causes muscular atrophy and a change in muscle fibres from type IIa to type IIb [20]. Muscle fibre type IIa is very resistant to fatigue and is used for aerobic metabolism, whereas muscle fibre type IIb is very easily fatigued [22]. Hypovitaminosis D causes changes to muscle fibres due to its role within musculoskeletal functions. A deficiency causes large interfibrillar spaces and muscular infiltration of fat [23], leading to muscular atrophy and changes in muscle type. Whilst vitamin D supplementation significantly increase the diameter and number of type II muscle fibres [20,23].

Conversely, Close., *et al*. [24] in a single-blind clinical trials in which 30 club level athletes were supplemented with either placebo, 20.000 or 30.000 IU vitamin D for 12 weeks did not find any improvement in exercise performance. Differences and the present study may be due to baseline 25(OH)D concentration as this study excluded any individuals who had been abroad in the previous 3 months or UVB sunbeds or, were taking vitamin D supplementation. Of note the current study did not measure 25(OH)D concentration.

Like Roy., *et al*. [25], this study showed that [La−]b reduced following Vitamin D supplementation. Although this was not statistically significant, these findings are in line with RPE and imply that participants felt the second run was less exerting than the first following supplementation rather than placebo. [La−]b becomes apparent in the blood during exercise when oxygen delivery is insufficient to meet the demands of the working muscles [26]. In normal circumstances oxygen converts [La−]b into pyruvate for ATP (Adenosine Triphosphate) production resulting in low [La−]b [27]. [La−]b reduced by 2.43 ± 3.68 mmol/L following supplementation. This suggests that vitamin D may have enhanced aerobic performance by improving the supply of oxygen to the muscles and by slightly reducing BP.

This study found that both systolic and diastolic BP were reduced following two-week intervention in both groups. But, unlike Al-Dujaili., *et al*. 2016, this change was not statistically significant. This could be attributed to the small sample size as Tomaschitz., *et al*. [28] conducted a large prospective cohort study on 3296 male and female participants and demonstrated that low serum 25(OH)D is independently associated with an upregulated renin-angiotensin system, with mean angiotensin II values significantly increasing as 25(OH) D decreases, thus increasing BP.

Several limitations have been identified in this pilot study. Firstly, serum 25(OH)D concentration was not measured; however, this study was performed in March and excluded any individual who had been taking vitamin D supplementation or had been exposed to UBV, thus participants were likely to have insufficient 25(OH)D levels. Secondly, under or overestimation of vitamin D and physical activity level might have occurred as a result of the use of diet and activity diaries as over/underreporting is common [29].

## Conclusion

The significant reduction in both percentage heart rate and rate of perceived exertion found in this study over a two-week period suggest that short term vitamin D supplementation may improve aerobic exercise performance. This study warrants future research in which a larger sample size, the effects of different doses of vitamin D over a longer period of time and the inclusion of other parameters such as VO2 max and skeletal muscle fibres are also investigated.

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