Vitamin D status: significance in physical performance and training adaptations

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Molecular forms of vitamin D in human body

- Synthesis in skin ($D_3$) → Serum vitamin D → Liver (vitamin D-25-hydroxylase) → Serum 25(OH)D → Kidney (25(OH)D-1-α-hydroxylase) → Serum 1,25(OH)D
- Food ($D_3$ and $D_2$)

Calcidiol; marker of vitamin D status
Calcitriol; bioactive form of vitamin D
Vitamin D functions in human body

- Vitamin D is a unique nutrient in that physiological sufficiency can be met entirely through endogenous synthesis (Holick, Fed Proc 1987, 46:1878-1882; Zittermann, Br J Nutr 2003, 89:552-572)
- Vitamin D (calcitriol) functions through its nuclear vitamin D receptor (VDR), which is present in most tissues and cells including intestine, bone, brain, heart, immune cells and skeletal muscle (Zittermann, Br J Nutr 2003, 89:552-572)
- Vitamin D status influences
  - immune function (Schwalfenberg, Mol Nutr Food Res 2011, 55:96-108)
  - lung function (Black & Scragg, Chest 2005, 128: 3792-3798)

Serum 25(OH)D levels: sufficient, optimal, toxic

- Sufficient:
  - ≥ 50 nmol · L⁻¹ (Ross et al. J Clin Endocrinol Metab 2011, 96:53-58)
  - ≥ 75 nmol · L⁻¹ (Holick et al. J Clin Endocrinol Metab 2011, 96:1911-1930)
- Optimal level is not yet established, but has been proposed to fall between:
  - 75 to 100 nmol · L⁻¹ (Dahlquist et al. J Int Soc Sports Nutr 2015, 12:1)
- Toxic:
  - > 600 nmol · L⁻¹ (Vieth, J Bone Miner Res 2007, 22 (Suppl.2):V64-V68)
Seasonal changes in serum [25(OH)D]: British study


British men (n = 3725), age 45 years
British women (n = 3712), age 45 years

Great Britain: 50°N - 60°N; Estonia: 57°37’N - 59°49’N

Military training study

(Ööpik et al. Mil Med 2017, 182, 3-4:e1810)

- Our previous study revealed that basic military training (BMT) during autumn-winter season induced anabolic physiological adaptations in conscripts despite high prevalence of vitamin D deficiency.
- High prevalence of vitamin D deficiency could had limited the physiological adaptations observed (and improvement in physical performance capacity) to a suboptimal level.
- However, we had no control group of conscripts possessing normal vitamin D status throughout the BMT period.
Therefore, we collected additional data from a cohort of conscripts who completed BMT during summer-autumn season.

We assumed that vitamin D status of conscripts belonging to summer and autumn cohorts may differ and this difference may influence physiological adaptations to BMT and improvement in performance.

Military training study extended

(Ööpik et al. Mil Med 2017, 182, 3-4:e1810)

In this report we compare physiological and performance responses to 10-week BMT in summer and autumn seasons in Estonian conscripts.

Basic military training:
- marching drills
- combat training
- sport training
- long marches (8 – 30 km)
- field camps involving overnight exercises
- total weight of additional load 10-12 kg, sometimes 20 – 23 kg

Photo: Raivo Tasso
Military training study extended: participants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of conscripts</td>
<td>94</td>
<td>107</td>
</tr>
<tr>
<td>Age (y)</td>
<td>21.0 ± 1.6</td>
<td>20.9 ± 1.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>181.7 ± 6.3</td>
<td>182.1 ± 6.4</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>80.1 ± 11.2</td>
<td>80.5 ± 11.3</td>
</tr>
<tr>
<td>BMI (kg · m⁻²)</td>
<td>24.2 ± 2.9</td>
<td>24.3 ± 3.1</td>
</tr>
</tbody>
</table>

Military training study extended: study design

- Observational study
- Analysis of venous blood samples taken four times during both BMT periods
- All the blood samples were drawn on Monday mornings after overnight fast
- The results of physical performance tests carried out at the beginning (Test 1) and at the end of BMT (Test 2) were recorded
Military training study extended: serum 25(OH)D concentration

Overall Summer vs Autumn: 61.4 ± 16.1 vs 48.5 ± 20.7 nmol · L⁻¹ (p < 0.0001)

Prevalence of vitamin D insufficiency:
- Summer 76.5 → 87.1 %
- Autumn 78.8 → 98.0 %

P < 0.05: * vs week 1 # vs preceding time point $ vs Summer

Military training study extended: serum testosterone and cortisol

P < 0.05: * vs week 1 # vs preceding time point $ vs Summer
Military training study extended: serum testosterone to cortisol ratio

![Graph showing serum testosterone to cortisol ratio over weeks.](image)

P < 0.05: * vs week 1  # vs preceding time point  $ vs Summer

Military training study extended: correlation between [25(OH)D] and performance (a)

![Graph showing correlation between 25(OH)D and performance.](image)

Test 1

$R^2 = 0.121$

$n = 196$

$p = 0.000$

Test 2

$R^2 = 0.162$

$n = 181$

$p = 0.000$
Military training study extended: correlation between [25(OH)D] and performance (b)

Test 1
$R^2 = 0.090$
$n = 195$
$p = 0.000$

Test 2
$R^2 = 0.038$
$n = 181$
$p = 0.009$

Military training study extended: correlation between [25(OH)D] and performance (c)

Test 1
$R^2 = 0.080$
$n = 193$
$p = 0.000$

Test 2
$R^2 = 0.112$
$n = 181$
$p = 0.000$
### Military training study extended: correlation between serum 25(OH)D and performance at the beginning of BMT

<table>
<thead>
<tr>
<th>Participants</th>
<th>Push-ups</th>
<th>Sit-ups</th>
<th>3200 m run</th>
</tr>
</thead>
<tbody>
<tr>
<td>All participants</td>
<td>r = 0.300</td>
<td>r = 0.348</td>
<td>r = –0.282</td>
</tr>
<tr>
<td></td>
<td>R² = 0.090</td>
<td>R² = 0.121</td>
<td>R² = 0.080</td>
</tr>
<tr>
<td></td>
<td>p = 0.000</td>
<td>p = 0.000</td>
<td>p = 0.000</td>
</tr>
<tr>
<td></td>
<td>n = 195</td>
<td>n = 196</td>
<td>n = 193</td>
</tr>
<tr>
<td>Participants with 25(OH)D ≥75 nmol·L⁻¹</td>
<td>r = 0.156</td>
<td>r = 0.252</td>
<td>r = –0.236</td>
</tr>
<tr>
<td></td>
<td>R² = 0.024</td>
<td>R² = 0.064</td>
<td>R² = 0.056</td>
</tr>
<tr>
<td></td>
<td>p = 0.323</td>
<td>p = 0.108</td>
<td>p = 0.133</td>
</tr>
<tr>
<td></td>
<td>n = 42</td>
<td>n = 42</td>
<td>n = 42</td>
</tr>
</tbody>
</table>

### Military training study extended: correlation between serum 25(OH)D and performance at the end of BMT

<table>
<thead>
<tr>
<th>Participants</th>
<th>Push-ups</th>
<th>Sit-ups</th>
<th>3200 m run</th>
</tr>
</thead>
<tbody>
<tr>
<td>All participants</td>
<td>r = 0.194</td>
<td>r = 0.403</td>
<td>r = –0.335</td>
</tr>
<tr>
<td></td>
<td>R² = 0.038</td>
<td>R² = 0.162</td>
<td>R² = 0.112</td>
</tr>
<tr>
<td></td>
<td>p = 0.009</td>
<td>p = 0.000</td>
<td>p = 0.000</td>
</tr>
<tr>
<td></td>
<td>n = 181</td>
<td>n = 181</td>
<td>n = 181</td>
</tr>
<tr>
<td>Participants with 25(OH)D ≥75 nmol·L⁻¹</td>
<td>r = –0.113</td>
<td>r = 0.065</td>
<td>r = –0.102</td>
</tr>
<tr>
<td></td>
<td>R² = 0.013</td>
<td>R² = 0.004</td>
<td>R² = 0.010</td>
</tr>
<tr>
<td></td>
<td>p = 0.582</td>
<td>p = 0.751</td>
<td>p = 0.621</td>
</tr>
<tr>
<td></td>
<td>n = 26</td>
<td>n = 26</td>
<td>n = 26</td>
</tr>
</tbody>
</table>
Military training study extended: improvement of performance (a)

Sit-ups (repetitions \cdot 2 \text{ min}^{-1})

<table>
<thead>
<tr>
<th></th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P < 0.05: * vs Test 1  # vs Summer

Military training study extended: improvement of performance (b)

Push-ups (repetitions \cdot 2 \text{ min}^{-1})

<table>
<thead>
<tr>
<th></th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P < 0.05: * vs Test 1  # vs Summer
Military training study extended: improvement of performance (c)

![Graph showing 3200-m run time (s) comparison between Summer and Autumn for Test 1 and Test 2.](chart)

- Test 1 vs Test 2: P < 0.05
- * vs Test 1
- 9% decrease in Summer
- 10% decrease in Autumn

Strength training study: participants and general design

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PLC (n = 12)</th>
<th>Vit D (n = 13)</th>
<th>Pooled (n =25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>24.0 ± 2.7</td>
<td>24.0 ± 2.3</td>
<td>24.0 ± 2.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>184.5 ± 5.7</td>
<td>182.3 ± 6.2</td>
<td>183.4 ± 5.9</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>81.26 ± 9.60</td>
<td>79.76 ± 9.44</td>
<td>80.48 ± 9.35</td>
</tr>
<tr>
<td>BMI</td>
<td>23.9 ± 2.7</td>
<td>24.0 ± 2.4</td>
<td>23.9 ± 2.5</td>
</tr>
<tr>
<td>25(OH)D (nmol·L⁻¹)</td>
<td>46.4 ± 12.3</td>
<td>50.0 ± 10.7</td>
<td>48.3 ± 11.4</td>
</tr>
</tbody>
</table>

**Preparatory phase (December)**

- Blood sample

**Main phase (January – April)**

- Strength test
- Body composition

PLC or Vit D
Strength training study: serum 25(OH)D concentration

![Graph showing serum 25(OH)D concentration over time with significance notes](image1)

P < 0.05: * vs 01.12.16 # vs preceding time point $ vs PLC

Strength training study: parathormone and Ca$^{2+}$

![Graphs showing parathormone and Ca$^{2+}$ concentrations over time with significance notes](image2)

P < 0.05: * vs 09.01.17 # vs preceding time point
Strength training study: testosterone and cortisol

Testosterone (mmol ∙ L$^{-1}$)

Cortisol (mmol ∙ L$^{-1}$)

Strength training study: testosterone to cortisol ratio

TESTO/CORT (mmol ∙ L$^{-1}$)
**Strength training study: muscular strength**

![Graph showing muscular strength](image)

* P < 0.05 vs Test 1

**Summary**

- There is clear impact of season on vitamin D status of Estonian young men
- Positive correlation occurs between vitamin D status and physical performance up to serum 25(OH)D concentration of 75 nmol · L⁻¹
- Despite the impact of season on vitamin D status and the correlation between vitamin D status and physical performance, there is no impact of vitamin D status on physiological and performance responses to BMT or strength training in young men
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Tartu, November 08, 2017

Thank you for your attention!

Research team: Vahur Ööpik, Saima Timpmann, Eve Unt, Lauri Savolainen, Martin Mooses, Luule Medijainen, Leho Rips, Indrek Olveti, Hanno Mölder, Ahti Varblane, Hele-Reet Lille, Helena Gapeyeva