The effect of a double-blind placebo-controlled 2 weeks β-alanine supplementation of daily dosage of 4g on the performance of the last 40m of 100m sprint of 16-19-year-old *Homo sapiens* males

Research question: “What is the effect of a double-blind placebo-controlled 2 weeks β-alanine supplementation of daily dosage of 4g on the performance of the last 40m of 100m sprint of 16-19-year-old *Homo sapiens* males?”

Subject for which the essay is registered: Biology

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0. Abstract

ß-alanine supplementation has shown to increase carnosine content in human skeletal muscle, since the amino acid is one of carnosine’s building blocks. The effect of ß-alanine supplementation on various physical performances, such as cycling, rowing and 400m sprint has been tested and resulted in increased performance in some of the activities. The aim of this study was, however, to test the effect of ß-alanine on the performance during the last 40m of a 100m sprint performance, since ß-alanine’s effect on this activity type has not yet been tested. 15 human male individuals aged 16-19 participated in the double-blind placebo-controlled study. The probands were divided into 3 groups of 5: One group being subject of a 2 week ß-alanine supplementation of a daily dose of 4g, the second taking a placebo for the same period of time and the third one taking no nutritional supplements at all. The results of the study showed no significant differences between the performances before and after a 2-weeks ß-alanine supplementation period. Similarly, there were no significant differences in the results of the performance of the last 40m between the group that took ß-alanine and the two other groups. Consequently, this study found that supplementing 16-19-year-old human male individuals with a daily dose of 4g of ß-alanine for 2 weeks will contribute to an insignificant decrease in performance of the last 40m of a 100m sprint. This study included a number of limitations which are described more in detail in Chapter 4.3. Further research needs to be done into the examined subject to obtain a higher certainty of the study’s results.
1. Introduction

During high-intensity exercises, anaerobic glycolysis is the main energy source and thus lactic acid is produced. The disassociation of the latter to lactate provides H\(^+\) ions and as the exercise continues, their concentration rises, causing the muscle pH to fall. The decrease in the muscle pH causes inhibition of glycolysis, thus resulting in fatigue and reduced force production\(^1\). Carnosine (β-Alanyl-L-histidine) is a dipeptide, formed from the two amino acids beta-alanine and L-histidine by carnosine synthetase. It is “abundant in human skeletal muscle”\(^2\) and acts as the first defence against pH changes in muscles\(^3\). Hence, β-alanine buffers the production of lactic acid. β-alanine is a non-essential, “nonproteogenic”\(^4\) amino acid\(^5\), which is either obtained from diet, namely through consumption of poultry, red meat and fish\(^6\), or synthesized by the human liver. It is the rate-limiting precursor for carnosine synthesis in muscle fibres, since it is one of the dipeptides’ building blocks\(^3\). Beta-alanine supplementation can therefore increase levels of carnosine content in muscle fibres, which leads to increase in performance. Based on this assumption, a series of studies have been carried out. They provide evidence that beta-alanine supplementation positively affects results in athletes of different sport types\(^7,8\), as well as non-athletes\(^9\).

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6 Berti Zanella, Priscilla et al. (2016): Effects of beta-alanine supplementation on performance and muscle fatigue in athletes and non-athletes of different sports: a systematic review, p. 3.
Humans have two types of muscle fibres: type I and type II. Type II muscle fibres, also referred to as fast-twitch muscle fibres, are responsible for short, rapid movements\textsuperscript{10}. They are present in higher amounts in sprinters than in endurance athletes. The fast-twitch muscle fibres are whiter in appearance\textsuperscript{11}.

100m sprint is a sportive activity and regarding the energy production, it can be divided in two phases. The duration of the first phase is 5-10 sec or 60m. During that time, the phosphagen system is responsible for ATP production. Throughout the second - glycolytic - phase, i.e. the remaining 40m, energy is generated via anaerobic cell respiration, during which lactic acid is produced\textsuperscript{12, 13}.

Since carnosine is the first “physicochemical buffer”\textsuperscript{14} in lactic acid production and beta-alanine supplementation has been proved to elevate carnosine levels, anaerobic exercise performance should increase as well. Additionally, the levels of carnosine are higher in type II muscle fibres than in type I muscle fibres\textsuperscript{15, 16}, which proves the significance of the dipeptide for sprint performance. The resulting hypothesis was therefore that a 2-week β-alanine supplementation\textsuperscript{17} would have a positive effect on the

\textsuperscript{8} Berti Zanella, Priscilla et al. (2016).: Effects of beta-alanine supplementation on performance and muscle fatigue in athletes and non-athletes of different sports: a systematic review, p. 13-14.
\textsuperscript{9} Ibid, p.8.
\textsuperscript{13} S. Majumdar, Aditi/ A. Robergs, Robert (2011): The Science of Speed: Determinants of Performance in the 100m Sprint, p. 488-489.
\textsuperscript{16} Harris, R. C. et al. (2006). The absorption of orally supplied β - alanine and its effect on muscle carnosine synthesis in human vastus lateralis, p. 279.
\textsuperscript{17} T. Trexler, Eric et al. (2015). International society of sports nutrition position stand: Beta-Alanine, p.3.
glycolytic phase of the 100m sprint of 16-19-year-old male individuals. Hence, the question the following study investigated was: “What is the effect of a double-blind placebo-controlled 2 weeks β-alanine supplementation with daily dosage of 4g on the performance of the last 40m of 100m sprint of 16-19-year-old *Homo sapiens* males?”. 
2. Methods

2.1 Subjects

15 human male individuals aged 16-19 years were selected for the study. Performance assessment took place at two different locations, since 14 of the participants were from one school and one, \( x_{14} \), from another, located in a different city. Prior to the measurements, all participants were asked to complete a questionnaire on their physical properties and health (see Appendix for 7.1.1). The 15 subjects were divided into 3 equally populated groups, i.e. 5 persons per group: the \( \beta \)-alanine ingesting group (BA), the placebo ingesting group (PL) and the group taking no nutritional supplements at all (NO). Cellulose was used as placebo, since this polysaccharide is not digestible by humans\(^{18,19} \). Hence, it would not be stored in the human body and was predicted not to affect the performances in any different way than the placebo effect\(^{20} \).

BA and PL individuals regularly ingesting nutritional supplements such as whey protein, BCAA or others were asked to renounce those for the time of the experiment in order to prevent any adulterant effect from those substances. Since the study was considered to be double-blind, subjects were randomly divided into the 3 mentioned groups and labelled with codes by a third person.

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\(^{19}\) E. Grimes, Peter (2017). Evolution and World-Systems: Complexity, Energy, and Form, p. 34.

2.2 Preparation of supplements

525 tablets of 800mg of slow release β-alanine, 1050g of cellulose and 525 vegetarian capsules were used for the experiment. Slow-release, also referred to as sustained-release beta-alanine was used in order to minimize the risk of paraesthesia\textsuperscript{21}, \textsuperscript{22}, \textsuperscript{23}. Placebo was put into size 0 vegetarian capsules. 0.35g – 0.40g was chosen as a required mass for every capsule. Consequently, each capsule was first filled with the placebo substance, closed incompletely and then weighed, using an electronic scale. If the required mass was met, the capsule was then closed until a click sound was heard. If the required mass was not met, the capsule was re-opened and its gross mass adjusted and re-weighed until the required mass was achieved. The capsule was then closed until a click sound was heard.

2.3 Groups & Supplementation

The BA group subjects’ average age, height, weight and BMI were 17y ± 1y, 1.80m ± 0.06m, 69kg ± 10kg and 21.21 ± 2.15. According to the pre-supplementation questionnaire, all BA individuals were involved in sportive activities on a weekly basis outside of school. $x_1$, $x_2$ and $x_3$ believed that β-alanine supplementation would improve their 100m sprint results and all 5 BA individuals thought that supplementing β-alanine would improve their general fitness. $x_3$ had asthma, yet this condition did not prohibit him from participating in the study. The BA group ingested a daily dose of 4g of β-alanine throughout 14 days of their supplementation period. BA participants ingested 4

\textsuperscript{21} Décombaz, Jacques et al. (2012): Effect of slow-release β-alanine tablets on absorption kinetics and paresthesia, pp. 74-75.
\textsuperscript{23} Stellingwerff, Trent et al. (2012): Optimizing human in vivo dosing and delivery of β-alanine supplements for muscle carnosine synthesis, p. 60.
tablets, i.e. 3.2g on their first supplementation day (“Day F”) and 1 tablet, i.e. 0.8g on their last supplementation day (“Day L”). The total mass ingested was 56g. According to Eric T. Trexler et al., this dose is a minimum requirement for an increase in muscle carnosine content and an increase in performance. Additionally, Eric T. Trexler et al. state that the following dosage would not be of danger to individuals. Participants were asked to have 3-4 hour breaks between each ingestion, to further minimise the risk of paraesthesia. Each participant received a non-transparent, 3l plastic sack containing 22 small, closable plastic packages. 20 of them contained 5 tablets of 0.8g of slow-release β-alanine and were not labelled. 2 other packages were labelled with “Day F” and “Day L”. “Day F” contained 4 tablets, whereas “Day L” contained 1 tablet. 22 small packages were given, in order to be prepared for an additional week of supplementation, in case of unsuitable weather conditions. Each tablet was washed down with a glass of water.

The PL group subjects’ average age, height, weight and BMI were 17y ± 1y, 1.84m ± 0.06m, 73kg ± 9kg and 21.64 ± 2.55. According to the pre-supplementation questionnaire, x8, x9 and x10 of the subjects did sports outside of school on a weekly basis, whereas probands x6 and x7 did not. Subjects x6 and x8 of the PL group believed that β-alanine supplementation would improve their 100m sprint results and x6, x9 and x10 thought that supplementing β-alanine would improve their general fitness. x7 had hay fever, yet this condition did not prohibit him from participating in the study. For the study to be considered accurate and in order to have control over the placebo effect in

both the BA and PL group, a similar supplementation strategy was performed by the PL individuals. The nutritional supplement ingested, i.e. cellulose instead of β-alanine, was the first difference to the BA supplementation strategy. The form of the supplement, i.e. capsules instead of tablets, was the second one. According to Professor of medicine Vladimir Chekhonin, a dosage of 20g of cellulose could be used without any risks of negative side-effects\textsuperscript{27}. Since the dosage used in this study did not exceed the value. This means the risk of overdosing was avoided.

The NO group subjects’ average age, height, weight and BMI were 17\textsuperscript{y} ± 1\textsuperscript{y}, 1.82\text{m} ± 0.09\text{m}, 71\text{kg} ± 10\text{kg} and 21.62 ± 3.94 respectively. According to the pre-supplementation questionnaire, 2 of the participants were involved in weekly sport activities apart from the sports lesson at school and 3 were not. The NO group took no nutritional supplements throughout the duration of the experiment. Its purpose was to ensure that the effect of β-alanine supplementation in the BA group was due to β-alanine supplementation or the placebo effect and not due to other reasons.

In order to ensure that the placebo effect is taking place, all BA and PL subjects were asked to keep their supplement anonymous. Furthermore, BA and PL individuals were told that some capsules contained β-alanine and some did not, in order to maintain the placebo effect\textsuperscript{28}.

\textsuperscript{27} Personal communication: Professor of medicine Vladimir Chekhonin, Russian scientist; Specialization: Immunochemistry and biochemistry of nervous system; Vice President of the Russian Academy of Science.

2.4 Performance assessment

2.4.1 Warm Up

The experiment was performed at two regular 400m stadiums with all 3 groups. Two stadiums were used, since x_{14} is from a different city and therefore was assessed separately from the rest of the probands. The assessment methods described in 2.4.3 and 2.4.4 were the same for all the subjects. All individuals first performed a short 2-3 km run at their comfortable pace as a warm up. At the stadium, subjects were asked to perform their individual warm up for all muscle and joint groups. Warm up was obligatory for all participants, in order to reduce the risk of injuries and to increase performance.

2.4.2 Safety requirements

Various safety measures had to be undertaken, in order to reduce the risk of injuries. The weather forecast was examined in advance to the measurement. Weather conditions had to be such, that reduced the chance of a highly wet ground, i.e. no precipitation or fog, in order to prevent the danger of slipping. Furthermore, all subjects were asked to wear sport clothes with accordance to the IAAF rules. Athletes were recommended to wear shoes, in order to have “a firm grip on the ground” and “to give protection to the feet”. Yet, shoes were not obligatory according to the IAAF rules.

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29 International Association of Athletics Federations: Competition rules 2018 – 2019, Monaco 2017, p. 84.
30 Safran, Marc R. et al. (1988): The role of warm up in muscular injury prevention, p. 125.
32 Simonson, Ernst et al. (1936): Einfluss von Vorübungen auf die Leistung beim 100m-Lauf, p. 154.
33 Ibid., p. 164.
35 Ibid., p. 69.
36 Ibid., p. 69.
37 Ibid., p. 69.
2.4.3 Performance assessment I

After the warm up, the subjects were asked to run the 100m sprint on a regular, 400m stadium track. The applied method for the performance assessment was the same for all 3 groups. The times of two individuals were measured in each run, this took place as followed: Participants were asked to take the low start position. 2 individuals (A and B) assessed the time for every participant: A was standing at the 60m mark while B was standing at the finish line. Both A and B were asked to keep a minimum distance of 5m from the outer lanes on each side\textsuperscript{38}. Then, A lifted his left arm into the air and commanded: “On your marks, set, go!”\textsuperscript{39} and dropped his arm. The drop of the arm combined with the “go”-shout served as signal for the runners to begin their sprint\textsuperscript{40}. At one of the assessments, a whistle was blown instead of the “go”-signal. The whistle was not blown during other assessments since the device was not available.

Stopwatches from mobile phones of the brand Apple, i.e. iPhones, were used to stop the times\textsuperscript{41}. A and B started their stopwatches at the same time. Yet, A, in contrast to B had to stop his device as soon as the runner had crossed the 60m mark and B at the finish line. (See Fig. 1).

\textsuperscript{39} Haugen, Thomas/ Buchheit, Martin (2011): Sprint running performance monitoring: methodological and practical considerations, p. 651.
\textsuperscript{40} International Association of Athletics Federations: Competition rules 2018 – 2019, Monaco 2017, p. 88.
\textsuperscript{41} Ibid., p. 99.
Such measurement technique was used in order to be able to calculate the time to complete the last 40m of the 100m sprint (L40m time) which was the study’s research subject. Marks were considered “crossed” once the torso, i.e. the upper body excluding the neck, arms and legs, had crossed the coloured lines. Time was measured in seconds, whereby the results containing two decimal points were rounded up to the “next longer 0.1 second”.

2.4.4. Performance assessment II

The second performance assessment took place after a two-week supplementation of a daily dose of 4g for the BA group and 5 capsules for the PL group. The procedure described in 2.4.1 and 2.4.3 was equally followed for the second performance assessment. BA and PL subjects were asked to complete a questionnaire regarding any general changes they had experienced throughout the supplementation period (see 7.1.2). The NO group did not complete this questionnaire since the latter did not supplement any substances used for the experiment. The answers for questions 3, 5, 6 and 7 of the post-supplementation questionnaires were not included into the study, since these could not usefully contribute to the study.

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42 Key: Start = Starting line; Finish line = Finish line; blue = 5m; green = 60m; yellow = 40m; orange = 100m.
44 Ibid., p. 100.
2.5 Data processing

2.5.1. Calculation of averages, standard deviations and L40m times

Since the focus of this study was to find out the effect of β-alanine supplementation on L40m time, the participants’ 60m times were subtracted from their 100m times. (See 7.3 for raw data times). Afterwards, averages and standard deviations of the L40m times were calculated for each of the 3 groups. Averages and standard deviations were calculated with Microsoft Excel 2016, by choosing the needed values and inserting them into the Excel STDEV or AVERAGE functions. Standard deviation and average were used in order to have more reliable results\textsuperscript{45, 46}. All time results, including the measurement precision time in 2.5.2, were rounded up to the “next longer 0.1 second”\textsuperscript{47}. Consequently, the averages and standard deviations were as well rounded up to the “next longer 0.1 second”\textsuperscript{48}.

2.5.2 Measurement precision

A measurement precision needs to be taken into consideration, when representing the participants’ L40m times. This study’s measurement precision was based on the time, which the sound from the “go”-signal of measurer A needed to travel to the participants’ ears at the start of the 100m lane. This time, termed measurement precision time ($t_{mp}$) was calculated with the following formula: $t_{mp} = (s-s_0)/v$\textsuperscript{49}. Thereby, “$v$” was the velocity of sound in air, i.e. “$v = 340 \text{ ms}^{-1}$”\textsuperscript{50}; “$s$” was the distance from measurer A to the start, i.e. $s = 60$ m;

\begin{itemize}
  \item Ibid., p. 34.
  \item International Association of Athletics Federations: Competition rules 2018 – 2019, Monaco 2017, p. 100.
  \item Ibid., p. 100.
  \item Biner, Paul et al.: Fundamentum Mathematik und Physik, Zurich 2015, p. 81.
\end{itemize}
“s₀” was the distance at t = 0, i.e. s₀ = 0m. Consequently, tₘₚ = (60m – 0m)/ 340m⁻¹; tₘₚ = 0.2s.

2.5.3. Calculations of the t-value

In order to find out, whether the differences between control groups were significant, the t-value was calculated with the formula in Fig. 2:

\[
 t = \frac{\bar{X}_T - \bar{X}_C}{\sqrt{\frac{\text{var}_T}{n_T} + \frac{\text{var}_C}{n_C}}}
\]

Fig. 2

Thereby, Xₜ and Xₖ represent the averages of any two examined groups, varₜ and varₖ are the groups’ variances and nₜ and nₖ are the number of samples per group. In this study, as described in 2.5.1, averages and variances were calculated using Microsoft Excel 2016, by choosing the desired values and inserting them into the average function (AVERAGE) or the variance function (VAR), depending on which statistical parameter had to be calculated. In 3.1, Xₜ was the groups’ average L40m time in the first assessment and Xₖ in the second one. In 3.2, Xₜ and Xₖ were the average time differences of two examined groups.

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51 Biner, Paul et al.: Fundamentum Mathematik und Physik, Zurich 2015, p. 81.
53 Ibid.
2.5.4 Application of t-test

Below, a t-table can be seen (see Fig. 3), which was used to interpret the calculated t-value. \( \alpha \) (significance level) of 0.05 was used\(^{54}\). This value means the following: If the sample were to be done 100 times, then the \( H_0 \), the null hypothesis\(^{55}\), would be rejected 95 times and accepted 5 times. Since no obvious prediction could be done about the direction of the difference of two examined samples, a two-tailed t-value was applied. Hence, the probability less than the critical value for this study’s t-test was: \( 1 - (\alpha/2) = 1 - (0.05/2) = 0.975\)^{56}. If the calculated results were greater than 0.975, \( H_0 \) would be rejected. In order to get the “\( \nu \)” value (degrees of freedom) the following formula was used: “\( \nu = n_1 + n_2 - 2 \)”\(^{57}\). Thereby, \( n_1 \) and \( n_2 \) were the number of samples per each of the two groups. For every calculation \( n_1 \) and \( n_2 \) were equal to 5. The “\( \nu \)” value was thus equal to 8.

<table>
<thead>
<tr>
<th>( \nu )</th>
<th>0.90</th>
<th>0.95</th>
<th>0.975</th>
<th>0.99</th>
<th>0.995</th>
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<td>31.821</td>
<td>63.657</td>
<td>318.313</td>
</tr>
<tr>
<td>2.</td>
<td>1.886</td>
<td>2.920</td>
<td>4.303</td>
<td>6.965</td>
<td>9.295</td>
<td>22.327</td>
</tr>
<tr>
<td>3.</td>
<td>1.638</td>
<td>2.353</td>
<td>3.182</td>
<td>4.541</td>
<td>5.841</td>
<td>10.215</td>
</tr>
<tr>
<td>4.</td>
<td>1.533</td>
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<td>2.776</td>
<td>3.747</td>
<td>4.032</td>
<td>7.173</td>
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<tr>
<td>5.</td>
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<td>2.015</td>
<td>2.571</td>
<td>3.365</td>
<td>3.707</td>
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<td>2.998</td>
<td>2.998</td>
<td>4.143</td>
</tr>
<tr>
<td>8.</td>
<td>1.397</td>
<td>1.860</td>
<td>2.201 (^{64})</td>
<td>2.896</td>
<td>2.571</td>
<td>4.090</td>
</tr>
<tr>
<td>9.</td>
<td>1.383</td>
<td>1.833</td>
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<td>2.821</td>
<td>2.457</td>
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<tr>
<td>10.</td>
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<td>1.812</td>
<td>2.052</td>
<td>2.764</td>
<td>2.360</td>
<td>3.707</td>
</tr>
</tbody>
</table>

Fig. 3\(^{59}\)

The t-test was applied in 4.1 to interpret the t-values in 3.1 and 3.2.


\(^{58}\) The critical value marked in yellow was used as a critical value for the study’s t-test.

3. Results

3.1 t-value second versus first assessment

All the participants’ L40m times are represented in Fig. 4. It should be noted that a higher orange graph means that more time was needed for a group to complete the last 40m of the 100m sprint in the second assessment. Consequently, the group’s velocity was lower and its performance worse in the second assessment than in the first one.

3.1.1 BA group

In the first assessment, the BA group’s average time to complete L40m was 5.3s ± 0.4s. In the second assessment, the average L40m time was 5.3s ± 0.5s. Hence the difference between the second and first assessment was 0.1s ± 0.3s. The calculated t-value for L40m time difference significance between the first and second assessment was 0.0. x₅ was not able to appear to the scheduled second measurement and had to be assessed two days later. He thus ingested a total dose of 64g of β-alanine. His L40m time did not differ significantly from the other β-alanine participants’ L40m times. x₄ reported slight symptoms of paraesthesia and x₁ and x₅ noticed other changes in their physical performance. x₅ reported having more energy and being able to lift heavier weights as well as having more visible muscles. x₁ reported that his upper body muscles got stronger. x₂ reported being less tired after 60m on the second assessment. All 4 participants who experienced any changes thought that these changes were β-alanine related.
3.1.2 PL group

In the first assessment, the PL group’s average time to complete L40 was 5.4 s ± 0.8 s respectively. In the second assessment, the PL group’s average L40 m time was 5.2 s ± 0.9 s respectively. As a result, the average difference from the PL groups’ second to first assessment was 0.3 s ± 0.2 s. The calculated $t$-value for L40 m time difference significance between the second and the first assessment was 0.4. None of the PL participants reported any symptoms of paraesthesia nor any other physical changes in their body or changes in their daily life.

3.1.3 NO group

The NO group’s average L40 m time was 5.8 s ± 1.4 s in the first assessment and 5.6 s ± 1.4 s in the second assessment. The average time difference from the NO participants’ first to their second assessment was -0.3 s ± 0.5 s. The calculated $t$-value for L40 m time difference significance between the first and second assessment was 0.3.

3.1.4 Summary & presentation of L40 m times of BA, PL and NO groups

All the participants’ L40 m times are represented in Fig. 4. It should be noted that a higher orange graph means that more time was needed for a group to complete the last 40 m of the 100 m sprint in the second assessment. Consequently, the group’s average velocity was lower and its performance worse at the second assessment than at the first one.
3.2 $t$-values: differences between groups

The average time difference between the first and the second assessment was calculated in advance for each group. The calculated $t$-value to test the difference significance between the BA and PL group was 1.3. The $t$-value for the difference between the BA group and NO group was 1.3. The $t$-value between the PL and NO group was 1.8. The average L40m time differences between the first and the second assessment of the BA, PL and NO groups are represented in Fig. 5. It should be noted that negative values mean a shorter L40m time in the second assessment than in the first one.

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Key: blue = L40m time at first assessment; orange = L40m time at second assessment; dark lines with caps at top and bottom represent the standard deviations of the respective means.
Comparison of calculated average L40m time differences between the first and the second assessment of BA, PL and NO groups including standard deviations of the respective means.

Fig. 5

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Key: dark lines with caps represent standard deviations of the respective means.
4. Discussion

4.1 t-values and t-tests: Interpretation

The calculated $t$-values in 3.1 for the L40m time difference significance between the first and the second assessment were 0.0 for the BA group, 0.4 for the PL group and 0.3 for the NO group. The calculated $t$-values in 3.2 for the L40m time difference significance between the groups were: 1.3 between BA and PL, 1.7 between BA and NO and 1.8 between PL and NO.

All of the $t$-values that were lower than the critical value of 2.306 needed a rejection of the study’s $H_0$. Thus there was neither a statistically significant difference between the first and the second assessment for all 3 groups, nor did any two of each of the 3 groups’ differences between the first and the second assessments differ significantly from each other.
4.2 Discussion I: Null hypothesis’ acceptance and random event

Several reasons can be the cause of the conclusions drawn about the t-values in 4.1. Firstly, all of the results may occur due to a random event, i.e. purely by chance. This hypothesis corresponds with the applied t-tests of the study. Beta-alanine probably operated in 4 of the 5 BA individuals, since those reported changes which are most likely to be β-alanine related. However, the results of those were worse than in their first assessment, which questions the hypothesis about the action of Beta-alanine. It could also be that the participants did not perform at their best during the second assessment, due to several reasons. All participants were in their final school year, thus their workload might have been high and could have increased during the supplementation period. Consequently, participants might have experienced emotional stress. The second of the two reasons might have affected the second assessment results of the BA group. It should be noted that the following claim is only a hypothesis.\(^62\)

4.3 Discussion II: Limitations and their possible improvements

4.3.1 Imprecise timing method

Imprecise timing method might be another reason for the results. Since 60m and 100m times were manually stopped, they had to be rounded up to the “next longer 0.1 second”. To improve the measurement precision of 60m and 100m, electronic timing devices such as those that have to be used at IAAF competitions should be used.\(^63\) An example of such a device would be the FinishLynx Fully Automatic Timing.\(^64\) These devices have a measurement precision of 0.001s or less which is more precise than the

---
study’s 0.2s measurement precision. However, results would only be recorded to the nearest hundredth with accordance to the IAAF competition rules\textsuperscript{65}. This improvement in measurement precision would ultimately contribute to a more precise L40m times’ calculation.

### 4.3.2 Supplementation strategy and blood pH measurement

Another limitation could be that the β-alanine supplementation period was too short and hence not long enough for the amino acid to accumulate in the body to provide an increase in L40m performance\textsuperscript{66}. This hypothesis is however controversial, since 4 of the BA participants experienced β-alanine related changes within the supplementation period. The described limitation could be improved by increasing the daily supplementation dose to 6g, which according to Eric T. Trexler et al. would contribute to a larger increase in muscle carnosine content\textsuperscript{67}. This larger increase would contribute to more lactic acid production buffering and would thus positively affect L40m performance.

To determine whether β-alanine was operating, a measurement of blood pH would be useful, since the blood plasma H\textsuperscript{+} concentration would decrease and the blood pH would thus increase, if more carnosine was to be synthesized\textsuperscript{68}. A possible method to measure blood pH would be the use of a glass electrode. A sample of blood serum would then be taken from a participant’s vein or finger and its pH measured with the respective apparatus\textsuperscript{69}.

\textsuperscript{66} Saunders, B. et al. (2017). β-alanine supplementation to improve exercise capacity and performance: a systematic review and meta-analysis, p. 3.
\textsuperscript{67} Ibid., p. 3.
4.3.3 Sample size

A small sample size could also be a reason for the t-tests’ results, since only 5 participants per group, BA, PL and NO were tested. A larger sample size would be needed to get a more precise measurement, since “a larger sample size is better than a smaller one”70. A possibility to increase the sample size would be to let every individual participating in the study to undergo all 3 supplementation strategies, i.e. the ones of BA, PL and NO groups. Like this, the sample size would grow to 15 people per group and the large spread of data due to the large standard deviation71 in the NO group could thus be avoided.

70 Lantz, Björn (2012): The large sample size fallacy, p. 488.
5. Conclusion

In general, it can be said that supplementing 16-19 year-old *Homo sapiens* male individuals with a daily dose of 4g of β-alanine for 2 weeks will have an insignificant negative effect on the second phase of the 100m sprint performance. Thus, β-alanine should not be used to improve L40m results of 16-19-year-old *Homo sapiens* males. Hence, the study’s hypothesis stated in the introduction was wrong. Due to the limitations of the study, the results contain a degree of uncertainty. Further research needs to be done, taking into consideration all of the study’s mentioned limitations and eliminating those the best way possible.
6. Bibliography

6.1 Print sources

- Décombaz, Jacques et al. (2012). Effect of slow-release β-alanine tablets on absorption kinetics and paresthesia. In: Medicine & Science in Sports & Exercise; Vol. 43, Iss. 5
- Derave, Wim et al. (2007). β-Alanine supplementation augments muscle carnosine content and attenuates fatigue during repeated isokinetic contraction bouts in trained sprinters. In: Journal of Applied Physiology; Vol. 103, Iss. 5
- Giannini Artioli, Guilherme et al. (2010). Role of β-alanine supplementation on muscle carnosine and exercise performance. In: Medicine & Science in Sports & Exercise; Vol. 42, Iss. 6
- Lantz, Björn (2012). The large sample size fallacy. In: Scandinavian journal of Caring Sciences; Vol. 27, Iss. 2

• Simonson, Ernst et al. (1936). Einfluss von Vorübungen auf die Leistung beim 100m-Lauf. In: Arbeitsphysiologie; Vol. 9, Iss. 2

• Stellingwerff, Trent et al. (2012). Optimizing human in vivo dosing and delivery of ß-alanine supplements for muscle carnosine synthesis. In: Amino Acids; Vol. 43, Iss. 1


6.2 Electronic sources


• Smeco, Arlene: Beta-alanine: A beginner’s guide (2016). 

6.3. Other sources

• Personal communication. Professor of medicine Vladimir Chekhonin; Russian scientist; Specialization: Immunochemistry and biochemistry of the nervous system; Vice-president of the Russian Academy of Science.
7. Appendix

7.1 Questionnaires

7.1.1 Questionnaire prior to supplementation

First Name/Last Name: ........................................... Date of birth (dd/mm/yyyy): ......................

Weight (in kg): .................... Height (in m): .................... BMI: ....................

For each of the questions below, circle the respective answer and write additional information at the dotted lines if asked to do so.

1) Do you regularly do any sports, excluding the sports lessons at school? Yes/ No

   If you do, please write which type of sport (-s) you do and how many hours of the respective sport (-s) per week you do on the lines below:

   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………………………
   ……………………………………………………………………………

2) Do you have any chronic conditions? Yes/ No

   If you do, please write the name (-s) of the condition (-s) on the lines below:

   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………

3) Do you think β-alanine supplementation will improve your general fitness? Yes/ No

4) Do you think -alanine supplementation will improve your 100m sprint performance? Yes/ No

Note: The participation in the following experiment is done voluntarily. The participant has the right to withdraw from the study any time he wants, regardless of the reason for withdrawal.

Should you want to withdraw from the experiment or have any questions regarding the experiment, please either contact me directly at school or per following phone number: 079 260 89 72

Herewith, I agree to participate in the experiment:

Signature: ………………………………. Date (dd/mm/yyyy): ………………………
7.1.2 Questionnaire after the supplementation

First name/ Last name : ……………………………… Date of birth (dd/mm/yy): …………………

For each of the questions below, please circle the respective answer and write additional information if asked to do so onto the dotted lines.

1) Did you feel symptoms of paresthesia, i.e. itching of skin anywhere on your body? Yes/ No

If you have, please circle the number, representing the degree of the itching you felt from 1 to 5, (1 = very slight symptoms; 5 = totally unbearable)

1 2 3 4 5

2) Did you feel any other symptoms, which are abnormal to you/your body? Yes/ No

If you did, please write what you felt below and rank the respective symptoms from 1 to 5, same as in Question Nr. 1.

……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………

3) Are you surprised with the results of the experiment? Yes/ No

Please briefly write the reason for your answer below.

……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………

4) Did you feel any changes in your general fitness abilities throughout the supplementation period? Yes/ No

If you did, please briefly summarize the changes you felt below.

……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………
……………………………………………………………………………………………………………

5) Do you think the changes are related to β-alanine supplementation or not? Yes/ No

6) Will you continue taking β-alanine after the experiment? Yes/ No

7) Are there any other changes concerning diet, sleep rhythm, work schedule, general well-being that happened during the supplementation period? Yes/ No

If there are, please briefly summarize what you felt below.

……………………………………………………………………………………………………………
### 7.2 Participants data

#### 7.2.1 Ages, weights, heights and BMIs of participants including averages and standard deviations of the 4 criteria for every group (BA, PL and NO\(^{72}\)) and supplement type of each participant

<table>
<thead>
<tr>
<th>Participant number</th>
<th>Supplement</th>
<th>Age [y (±1y)]</th>
<th>Weight [kg (±1kg)]</th>
<th>Height [m (±0.01m)]</th>
<th>BMI (±0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1</td>
<td>BA</td>
<td>18</td>
<td>79</td>
<td>1.82</td>
<td>23.85</td>
</tr>
<tr>
<td>x2</td>
<td>BA</td>
<td>16</td>
<td>80</td>
<td>1.87</td>
<td>22.88</td>
</tr>
<tr>
<td>x3</td>
<td>BA</td>
<td>18</td>
<td>65</td>
<td>1.80</td>
<td>20.06</td>
</tr>
<tr>
<td>x4</td>
<td>BA</td>
<td>17</td>
<td>60</td>
<td>1.80</td>
<td>18.52</td>
</tr>
<tr>
<td>x5</td>
<td>BA</td>
<td>16</td>
<td>60</td>
<td>1.70</td>
<td>20.76</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>17</td>
<td>69</td>
<td>1.80</td>
<td>21.21</td>
</tr>
<tr>
<td>St Dev.</td>
<td>-</td>
<td>1</td>
<td>10</td>
<td>0.06</td>
<td>2.15</td>
</tr>
<tr>
<td>x6</td>
<td>PL</td>
<td>17</td>
<td>74</td>
<td>1.80</td>
<td>22.84</td>
</tr>
<tr>
<td>x7</td>
<td>PL</td>
<td>17</td>
<td>62</td>
<td>1.87</td>
<td>17.73</td>
</tr>
<tr>
<td>x8</td>
<td>PL</td>
<td>18</td>
<td>67</td>
<td>1.80</td>
<td>20.68</td>
</tr>
<tr>
<td>x9</td>
<td>PL</td>
<td>19</td>
<td>85</td>
<td>1.94</td>
<td>22.58</td>
</tr>
<tr>
<td>x10</td>
<td>PL</td>
<td>16</td>
<td>79</td>
<td>1.80</td>
<td>24.38</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>17</td>
<td>73</td>
<td>1.84</td>
<td>21.64</td>
</tr>
<tr>
<td>St Dev.</td>
<td>-</td>
<td>1</td>
<td>9</td>
<td>0.06</td>
<td>2.55</td>
</tr>
<tr>
<td>x11</td>
<td>NO</td>
<td>17</td>
<td>85</td>
<td>1.74</td>
<td>28.08</td>
</tr>
<tr>
<td>x12</td>
<td>NO</td>
<td>17</td>
<td>75</td>
<td>1.92</td>
<td>20.35</td>
</tr>
<tr>
<td>x13</td>
<td>NO</td>
<td>16</td>
<td>69</td>
<td>1.76</td>
<td>22.28</td>
</tr>
<tr>
<td>x14</td>
<td>NO</td>
<td>17</td>
<td>65</td>
<td>1.90</td>
<td>18.00</td>
</tr>
<tr>
<td>x15</td>
<td>NO</td>
<td>16</td>
<td>60</td>
<td>1.76</td>
<td>19.37</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>17</td>
<td>71</td>
<td>1.82</td>
<td>21.62</td>
</tr>
<tr>
<td>St Dev.</td>
<td>-</td>
<td>1</td>
<td>10</td>
<td>0.09</td>
<td>3.94</td>
</tr>
</tbody>
</table>

\(^{72}\) BA: group being subject to a 2 week \(\beta\)-alanine supplementation of daily dosage of 4 g; PL: group being subject to a 2 week placebo (cellulose) supplementation of daily dosage of 5 capsules of 0.35g – 0.40g; NO: group not taking any nutritional supplements.
### 7.2.2 Diseases/ Health issues of participants; Sports done by participants outside of school; Participants’ belief in the improvement of general fitness after the β-alanine supplementation period; BA and PL participants’ belief in the improvement of 100m sprint results after the β-alanine supplementation period

<table>
<thead>
<tr>
<th>Participant number</th>
<th>Diseases/ Health issues</th>
<th>Sports outside of school</th>
<th>Belief in the improvement of general fitness</th>
<th>Belief in the improvement of 100m sprint results</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1</td>
<td>No</td>
<td>Boxing: 2h/ week</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x2</td>
<td>No</td>
<td>tennis: 3h/ week; fitness 2.5h/ per week</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x3</td>
<td>asthma</td>
<td>Gym: 3-4/week; handball: 2/week + games</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x4</td>
<td>No</td>
<td>Jogging: 3 h/week</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>x5</td>
<td>No</td>
<td>tennis: 4h/week; fitness: 2h/week</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>x6</td>
<td>No</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x7</td>
<td>Hay fever</td>
<td>None</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x8</td>
<td>No</td>
<td>Swim ca. 2h/ week</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>x9</td>
<td>No</td>
<td>Fitness and Running: 3-4 h/week</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>x10</td>
<td>No</td>
<td>Ice hockey: 8-9 h/week</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>x11</td>
<td>No</td>
<td>None</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>x12</td>
<td>No</td>
<td>None</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>x13</td>
<td>No</td>
<td>Soccer (approx. 5-6 h/week); skiing in winter (ca. 2 times of 8h per month)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>x14</td>
<td>No</td>
<td>Basketball: 2h/ week</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>x15</td>
<td>No</td>
<td>Squash: 1.5-2.5 h/ week; golf: 1h/week; general exercises: 1.5h/week</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
7.2.3 Experience of paraesthesia symptoms and other abnormal symptoms during the supplementation period in BA and PL individuals, including symptom degree; changes in general fitness ability and other changes to daily life schedule during the supplementation period in BA and PL individuals

<table>
<thead>
<tr>
<th>Participant number</th>
<th>Symptoms of paraesthesia &amp; symptom degree</th>
<th>Other abnormal symptoms &amp; symptom degree</th>
<th>Changes in general fitness ability</th>
<th>Other changes to daily life schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>x₁</td>
<td>No</td>
<td>No</td>
<td>Upper body muscles got stronger throughout the supplementation period</td>
<td>No</td>
</tr>
<tr>
<td>x₂</td>
<td>No</td>
<td>No</td>
<td>Feeling of being less tired after 60m at the second assessment</td>
<td>No</td>
</tr>
<tr>
<td>x₃</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₄</td>
<td>Yes; 1 (= very slight)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₅</td>
<td>No</td>
<td>No</td>
<td>Feeling of having more energy; ability to lift more weight; muscles became more visible during supplementation period</td>
<td>No</td>
</tr>
<tr>
<td>x₆</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₇</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₈</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₉</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x₁₀</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
7.3 Participants’ 60m, 100m and L40m times

7.3.1 Participants’ measured 60m times and 100m times and the calculated L40m times

in the first assessment including averages and standard deviations of the 3 times for

each of the 3 groups (BA, PL and NO)

<table>
<thead>
<tr>
<th>Participant number</th>
<th>60m [s (±0.2s)] in the first assessment</th>
<th>100m [s (±0.2s)] in the first assessment</th>
<th>L40m [s (±0.2s)] in the first assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>8.1</td>
<td>13.7</td>
<td>5.6</td>
</tr>
<tr>
<td>X2</td>
<td>8.0</td>
<td>12.7</td>
<td>4.7</td>
</tr>
<tr>
<td>X3</td>
<td>7.3</td>
<td>12.8</td>
<td>5.5</td>
</tr>
<tr>
<td>X4</td>
<td>7.8</td>
<td>13.2</td>
<td>5.4</td>
</tr>
<tr>
<td>X5</td>
<td>8.0</td>
<td>13.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Average</td>
<td>7.9</td>
<td>13.1</td>
<td>5.3</td>
</tr>
<tr>
<td>St Dev.</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>X6</td>
<td>8.9</td>
<td>14.5</td>
<td>5.6</td>
</tr>
<tr>
<td>X7</td>
<td>8.5</td>
<td>13.7</td>
<td>5.2</td>
</tr>
<tr>
<td>X8</td>
<td>9.4</td>
<td>15.9</td>
<td>6.5</td>
</tr>
<tr>
<td>X9</td>
<td>8.3</td>
<td>12.9</td>
<td>4.6</td>
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<td>X10</td>
<td>8.1</td>
<td>13.1</td>
<td>5.0</td>
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<tr>
<td>Average</td>
<td>8.7</td>
<td>14.1</td>
<td>5.4</td>
</tr>
<tr>
<td>St Dev.</td>
<td>0.6</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>X11</td>
<td>11.1</td>
<td>19.2</td>
<td>8.1</td>
</tr>
<tr>
<td>X12</td>
<td>8.8</td>
<td>14.1</td>
<td>5.3</td>
</tr>
<tr>
<td>X13</td>
<td>8.1</td>
<td>13.4</td>
<td>5.3</td>
</tr>
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<td>X14</td>
<td>8.2</td>
<td>13.0</td>
<td>4.8</td>
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<tr>
<td>X15</td>
<td>8.4</td>
<td>13.6</td>
<td>5.2</td>
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<tr>
<td>Average</td>
<td>9.0</td>
<td>14.7</td>
<td>5.8</td>
</tr>
<tr>
<td>St Dev.</td>
<td>1.3</td>
<td>2.6</td>
<td>1.4</td>
</tr>
</tbody>
</table>

73 L40m time refers to the time needed to complete the last 40m of the 100m sprint.
7.3.2 Participants’ measured 60m times and 100m times and the calculated L40m times in the second assessment including averages and standard deviations of the 3 times for each of the 3 groups (BA, PL and NO).

<table>
<thead>
<tr>
<th>Participant number</th>
<th>60m</th>
<th>100m</th>
<th>L40m</th>
</tr>
</thead>
<tbody>
<tr>
<td>x₁</td>
<td>8.9</td>
<td>14.5</td>
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7.3.3 Calculated 60m, 100m and the L40 time differences between second and first assessments, including averages and standard deviations for each of the 3 times

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8. Acknowledgements

First of all, I would like to express my gratitude and appreciation to my Biology teacher and my Extended Essay supervisor, Valentin Grob, who has given me useful criticism of my work throughout the writing process of my Extended Essay. Secondly, I would like to thank all the people who participated in the study. I want to thank those for their commitment to the study and for showing their best performance they could show during the assessments. Additionally, I want to thank my Sports teacher, Pierre Gattiker, for helping me during the time measurement and also giving me some useful ideas for my research at the beginning.

Thank you, all!
9. Declaration of Authenticity

Herewith, I, Maxim Vovk, confirm, that I wrote the following essay independently and without the use of any prohibited aid.

Date: .......................................................

Signature: ..............................................

Signature of Supervisor: .........................