Influence of Long-term Fasting and Intermittent Fasting on the Cognitive Abilities

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Abstract

OBJECTIVE: *Fasting as skipping or abstaining from eating or drinking for a certain time is known mainly due to religion. In addition to religious reasons, we can also fast for weight loss or detoxication. We have decided to examine the impact of fasting on the human organism more closely, especially on cognitive functions.*

METHODS: *The research underwent and completed 16 participants (M + F; 25.8y ± 2.7; 179.5 cm ± 11.6; 74.6 kg ± 15.1). There were divided into 2 groups (long-term fasting /LTF/ and intermittent fasting /IF/). For measurement cognitive function we used Montreal Cognitive Assessment (MoCA), which has been filled out by all participants in the study before and after the fasting period.*

Results: *The total score of MoCA decreased in both group after the fasting period, more in the IF group (–1.1 points), but not statistically significant. Values for short-term memory evaluation decreased in both groups, also in the IF group more (–0.9 points), there was a large effect size. Word production values decreased in both group and these changes were statistically significant with small effect size.*

Conclusion: *Our results suggest that long-term fasting and intermittent fasting may reduce cognitive abilities. Especially short-term memory can be influenced by intermittent fasting. Both fasting methods decreased the level of word production.*

Keywords: *fasting methods, cognition, Montreal Cognitive Assessment, short-term memory, word production*

INTRODUCTION

Under the term "Fasting" we can imagine voluntary abstinence from food and drink lasting a certain period, from 12 hours to 3 weeks or more (Anton et al. 2018). Fasting is most often contrasted with ad libitum intake, which in modern societies is characterized by three or more meals a day, which, combined with a sedentary lifestyle, may increase the risk of developing the chronic neurological disease (Mattson et al. 2018), insulin resistance or obesity (Mattson, Longo, and Harvie 2017). Recent recommendations mention long-term calorie restriction for the treatment of obesity, but this leads to moderate weight loss, so more and more people are interested in alternative dietary approaches such as intermittent fasting or time-limited food intake (Rynders et al. 2019).

Concerning the effect of fasting on cognitive functions, the results are still ambiguous, and therefore new studies are exploring this issue. We can influence the level of cognition in several ways, such as memory training, exercise and diet (Vance et al. 2011; Vandewoude et al. 2016). Most studies examining the effect of fasting on cognitive functions are still conducted in animals, most commonly mice. Intermittent fasting, as opposed to caloric restriction, increases the tolerance of the hippocampal neuron to excitotoxic stress in mice, which may indicate the neuroprotective effects (Anson et al. 2003) and improves learning and memory in mice (Li, Wang, and Zuo 2013). Lieberman et al. (2017); Solianik et al. (2016, 2018) reached almost the same

conclusions: a two-day calorie restriction does not affect cognitive functions, but can negatively affect a person's mood, e.g. increasing aggression and rage. It further increases parasympathetic activity, reduces brain frontal lobe activity and improves cognitive functions associated with the prefrontal cortex, including mental flexibility and decision making. Since it is still a big question in this area of research whether fasting can affect brain function, especially cognitive function, we have decided to extend this knowledge.

METHODS

Research sample

Recruitment of participants for the study took place in the form of leaflets posted at the Faculty of Sports Studies and Social Networks (Facebook, Instagram). Inclusion criteria were: age range 20–35 y; at least secondary education with graduation; good health condition based on their judgment; no medication that could affect response to fasting; no evidence of any acute or chronic bodily or mental disease, eating disorders, and past trauma of the head. Exclusion criteria were: serious health problems that could be affected by fasting; any cognitive diseases. 16 Czech male and female participants took place in the study (25.8 y ± 2.7; 179.5 cm ± 11.6; 74.6 kg ± 15.1). Anthropometric data for each group are listed in Table 1. Written informed consent was obtained from all participants after the explanation of all details of the experimental procedures and after answering all the research questions from the participants.

Tab. 1: Anthropometric data for each group

	LTF group Mean (±SD)	IF group Mean (±SD)
Age	26.8 (±3.5)	24.9 (±1.1)
Weight	79.1 (±16.3)	70.0 (±13.2)
Height	179.1 (±10.7)	179.8 (±13.1)

Study design

The research took place in October 2018 and lasted for one week. Before the research began, the participants got the necessary information about experimental procedures and fasting period, e.g. how to eat before fasting, during fasting and after it, or what happens in the organism during the fasting period. We created two experimental groups: long-term fasting (LTF) and intermittent fasting (IF). The control group was not created. Grouping took place in the form of draws. We have only divided the drawing group by gender, thus achieving the same number of men and women in the group to preserve the homogeneity (5 men, 3 women in each group). LTF group practised a 5-day fast in which they could receive only clean water ad libitum. There were no other restrictions, they behaved according to their habits and feelings – they went to work, to train. IF group practised alternate fasting, so they fasted every other day. On fasting days, the same rules applied to them as to the LTF group. The detailed timeline is below in Figure 1.

The experiment itself consisted of two sessions, each morning at 8 o'clock. Before the session, the participants were instructed to sleep for ≥ 8 h the night before the experiment and to refrain from alcohol, caffeine, and from ≥ 24 h refrain heavy exercise. At the first session (Day 1), the participants arrived at the Faculty of Sports Studies to measure baseline values, witch there were

anthropometric data (age, weight, height, previous experience with fasting, level of physical activity, belief in alternative diets such as veganism, vegetarianism, etc. and motivation to enter the study), then the researcher completed the Montreal Cognitive Assessment with each participant separately. The participants rested the rest of the testing day before starting the fasting period (according to the group, detailed are described above) followed by the performance of experimental measurements in the same order as that used in the first sessions (i.e., before fasting).

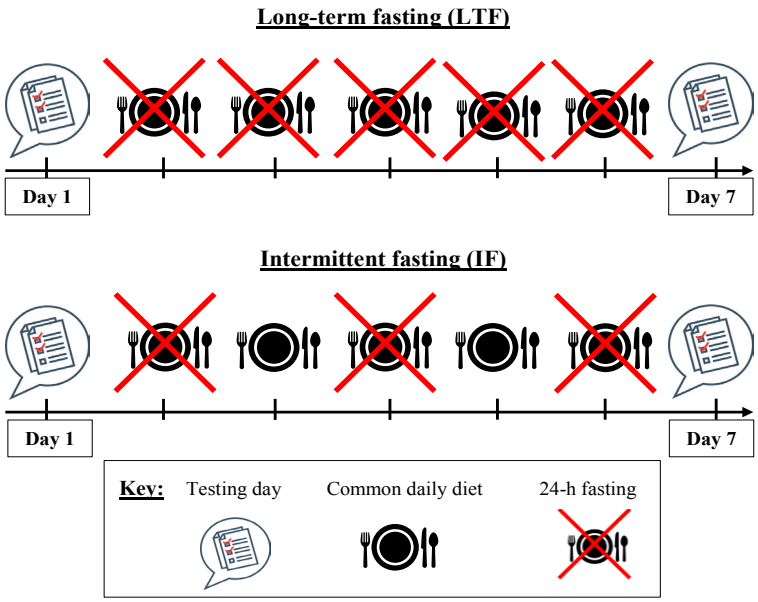

Fig. 1: Research timeline for each group separately

Research methods

We were used to determining the degree of cognitive abilities Czech standardized version of ***Montreal Cognitive Assessment (MoCA).*** This test is validated, with high repeatability, reliability, sensitivity and less time-consuming (Bartoš and Raisová 2015). The test is available free online at the Alzheimer's Centre for Research, Diagnosis and Treatment and has a high-quality Czech equivalent available in 3 variants. We used the MoCA-CZ1 variant for the pre-test and MoCA-CZ3 variant for the post-test, both variants are almost equivalent. One difference is in sequence no. 8, wherein MoCA-CZ1 variant, the participants had to recall as many words as possible to the letter K, invariant MoCA-CZ3 it was the letter N. Detailed description of the test is in Table 2. It takes approximately 10–15 minutes to complete the test. The maximum score is 30 points, "0" means worst performance and "30" means the best performance. The cut-off score is 26 points, for Alzheimer's disease is 23/24 points (Orlíková et al. 2014).

Statistical analysis

Data were collected in the program Statistica 13.2. To evaluate data, we used descriptive (mean, maximum and minimum, standard deviation) and analytical statistics (normality test, non-parametric t-test) and Cohen's d (Effect size). The level of statistical significance was set at $p < 0.05$.

Tab. 2: Content structure and scores of the Montreal Cognitive Assessment (Orlíková et al. 2014)

Sequence	Subtest	What is investigating	Scale	Points
1.	Short path test (from number to letters)	Structural executive function	Executive function	1
2.	Drawing a cube	Drawing a three-dimensional shape	Visual and spatial functions	1
3.	Clock drawing test	Visual and spatial functions		3
		Structural and imaginative executive function		
4.	Naming 3 animals in the picture	Naming	Language	3
5.	Repetition of 5 words	Implantation	Short-term memory	0
		Focus of attention		
6. A	Repeating numbers (front and back)	Working memory	Attention, concentration and working memory	2
6. B	Typing the letter "A"	Wakefulness		1
6. C	Subtraction of number 7	Working memory		3
7.	Repetition of 2 sentences	Repetition	Language	2
8.	Word production per minute	Phonemic word production	Language	1
9.	Abstraction – understanding the similarities between 2 words	Understanding	Executive function	2
10.	Remote recall of 5 words	Spontaneous recall without help	Short-term memory	5
		Recall with help of category		0
		Recognition (choice of 3 options)		0
11.	Time and place orientation	Orientation	Orientation	6
Total score				30

RESULTS

This study sought to determine how fasting has an impact on cognitive function. Research completed 16 participants. They were divided into 2 groups (long-term fasting /LTF/, intermittent fasting /IF/), each with 8 people (3 F, 5 M). Essential anthropometric data are above in Table 1. We used the Montreal Cognitive Assessment to test cognitive abilities, where the maximum possible number of points is 30, the cut-off score is 26 points. First, we examined the differences in the total score (before and after fasting period) for each group separately, then we focused on short-term memory and word production, because they were the most demanding for the participants and at the same time, these sub-tests have undergone the biggest changes. More detailed results for a total score from MoCA are below in Table 3.

Tab. 3: Results for a total score from MoCA

Group	Before fasting Mean ± SD (min–max)	After fasting Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	27.6 ± 2.3 (23–30)	27.2 ± 1.3 (26–30)	0.50	0.02
IF	28.1 ± 1.6 (25–30)	27.0 ± 2.7 (21–30)	0.23	0.05

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

The minimum points in LTF group were 23 points before and 26 points after fasting. In IF group in was 25 points before and 21 points after. These differences were not statistically significant relative to a significance level of $p < 0.05$. According to the effect size, the effect is insignificant. But, the SD changed in every group a different way. In the LTF group, the SD decreased, but in the LF group, SD increased.

One part of MoCA deals with short-term memory. It is tested in two phases. First, the test person tries to instil 5 words. After a while (at least 5 minutes), during which the test person performs other tasks, the test person should recall these 5 words, no matter which order. The maximum possible score is 5 and the minimum is 0. Detailed results for short-term memory are below in Table 4.

Tab. 4: Results of a MoCA sub-test focused on short-term memory

Group	Before fasting Mean ± SD (min–max)	After fasting Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	4.1 ± 1.4 (2 – 5)	4.0 ± 1.2 (2 – 5)	0,79	0.10
IF	4.8 ± 0.5 (4 – 5)	3.9 ± 1.4 (2 – 5)	0,17	0.86

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

The difference in mean values in the LTF group was –0.1, in IF group it was –0,9. Both changes were not statistically significant relative to a significance level of $p < 0.05$. The effect size was less than small in LTF group and large in the LF group. The SD values slightly decreased in LTF group against the LF group, where the value of SD distinctly increased.

Word production is one of the areas tested by MoCA. This task consisted of telling the participants a letter to make up as many words as possible for one minute. The condition was that the words should not be repeated, not even their root and also not allowed proper names. The maximum score is not given. Detailed results for word production are below in Table 5.

Tab. 5: Results of a MoCA sub-test focused on word production

Group	**Before fasting** Mean ± SD (min–max)	**After fasting** Mean ± SD (min–max)	p-value	Effect size (Cohen's d)
LTF	16.8 ± 4.2 (12–24)	12.1 ± 3.3 (7–16)	0,04	0.12
IF	16.1 ± 3.9 (12–24)	11.1 ± 3.2 (7–17)	0,02	0.14

Note LTF-long term fasting; IF-intermittent fasting; SD-standard derivation; min-minimum points earned; max-maximum points earned; P value for non-parametric t-test comparing changes in the LTF group and IF group before and after fasting period.

For LTF participants, the average number of words decreased by 4.7. Statistically, this is a significant difference. The effect size was small. If participants, the average number of words decreased to, but more than in the LTF group, by 5. There is statistical significance and also a small effect size. In both tested groups decreased the values of SD, more in LTF group.

DISCUSSION

The presented study evaluated the influence of two different fasting methods on cognitive abilities. The first testing fasting method was long-term fasting lasting 5 days when participants could receive only clear water *ad libitum*. The second testing fasting method was the type of intermittent fasting, where participants fast every other day, they receive only clean water *ad libitum*. The other days they eat *ad libitum*. The test period lasted one week and we used the Montreal Cognitive Assessment (MoCA) to determine the state of cognitive abilities. During data processing, we realized that it is not appropriate to look only at the total score from the MoCA, but also to focus on the sub-tests. For this reason, we focused on the two areas (short-term memory and word production) that were the most affected by fasting and which were also the most challenging for the research participants.

Based on several studies (Li et al. 2013; Lieberman et al. 2017; Solianik et al. 2016, 2018), we hypothesized that both fasting methods will not adversely affect the level of cognitive abilities. Whereas, our results demonstrated that the total score from the Montreal Cognitive Assessment decreased in both groups, more in the intermittent fasting group. As we mentioned earlier, the most affected areas were short-term memory and word production. However, the changes were not statistically significant with a negligible effect size.

Short-term memory also decreased in both groups, more in the intermittent fasting group. Even these changes did not have statistical significance, however, a large effect size was demonstrated in the intermittent fasting group. Tian et al. (2011) conducted a difference effect of fasting on short-term memory concerning the time of day. While in the afternoon (4 p.m.) the results of short-term memory tests were worse, in the morning (9 a.m.) there was no impairment. Unfortunately, this theory does not support our results. On the other hand, the results of other studies mention that accuracy of recall in verbal short term memory was not impacted by fasting, but subjects needed a little more time to respond (Benton and Parker 1998; Owen et al. 2012; Sünram-Lea et al. 2001). Statistically significant changes with a small effect size were recorded in the Montreal Cognitive Assessment sub-test focused on word production, where participants had to say as many words as possible on a particular letter. This sub-test is useful for examining mainly psychomotor pace, executive functions and semantic and working memory (Bartoš and Raisová 2015).

After evaluating our results, we must agree with the statement by (Tian et al. 2011) that the effect of fasting on cognition is heterogeneous and domain-specific. The individual results of our tested group are really important because they are visible differences, so we should consider the different impact of different fasting methods. On the other hand, individual components, such as short-term memory, word production or attention, show different results than the overall cognitive function test score.

We realize that our results may be influenced by several limiting factors, such as a low number of participants, short experiment time, missing control group, different motivation to participate in research, previous experience with any type of fasting. The level of cognitive abilities could be affected by countless stressful situations for example in the job, in the family, by problems with a partner or friends. Furthermore, the participants' lifestyle and training in between test sessions were not controlled. Other potential confounders include the duration of the previous night's sleep and daytime naps, as well as the time of awakening, which was not regulated in this study. For these reasons, we would like to do more research that could help us better understand the relationship between fasting and cognition in humans.

CONCLUSION

The present study shows, that long-term fasting and intermittent fasting harms the cognitive functions as a whole. On the other side, intermittent fasting can negatively influence short-term memory. And both fasting methods harmed the word production of the participants. We consider the conclusions of our work to be very interesting and beneficial, but some of the changes we are watching are so insignificant that we need further research to confirm our results. For example, it would be interesting to see if fasting can delay ageing and its symptoms, such as degenerative changes in the brain associated with the loss of short-term memory.

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