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The frequency of caffeine and caffeinated beverages consumption, health effects in children, adolescents and young adults and on physical performance

PhD Thesis

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1. Introduction

1.1. Personal background

The prevalence of Energy Drink (ED) consumption among children and young adults has increased in Hungary and all around the world in the recent years. These products are very fashionable these days, have a huge market and are accessible to anyone without restrictions. EDs affect mental and physical performance due to their composition, and the positive effects of EDs on cognition and physical performance depend on the combination of the different components (Scholey&Kennedy, 2004; Geiß et al, 1994). Their stimulating effect can be attributed to their high caffeine content, the doubled caffeine effect is created by caffeine and the caffeine content of guarana, causing therapeutic duplication (Grósz&Szatmári, 2008). Caffeine combined with other plant substrates have shown to increase alertness, concentration, mood and decreasing fatigue (Rashti et al, 2009; Hoffman et al., 2009; Scholey &Kennedy, 2004; Smith, 2002). The products can cause numerous adverse side effects and symptoms, depending on the dose and individual's sensitivity to caffeine, their consumption is a risk factor especially for the young, developing body. ED use may also be accompanied by seizures, anxiety, nervousness, hallucinations, migraines, gastrointestinal disease, metabolic acidosis, insomnia, arrhythmia, chest pain, and other cardiovascular complications (Higgins, 2015; Nordt et al., 2012; Seifert et al, 2011). Caffeine consumption in children and adolescents can cause unexpected side effects (Martos, 2010). As a teacher I see more and more school-aged children consuming ED, in many cases resulting from following the parental pattern/sample.

Location of the first study was Ormánság, I chose this location of my personal relationship and experience, since I work as a physical education teacher in the settlement here. Ormánság is one of the most disadvantaged areas of Hungary, featuring low schooling, early drop out of school, poor housing conditions, poor health, long-term unemployment, lack of motivation, living standards below the subsistence minimum, deep poverty, often resulting in the appearance of certain deviant behaviors - crime, alcoholism, drug use. As a result of these, the proportion of disadvantaged and cumulatively disadvantaged students is very high in public education institutions (Ragadics, 2015).

The subjects of the second study were high school and university students, ED consumption among them is also popular and has a high rate. 43.8% of Hungarian university students drunk ED mixed with alcohol (Dojcsákné&Kiss-Tóth, 2018).

In this age group the use of ED with alcohol (EDwA) is frequent. EDwA is popular among teenagers and college students (Verster et al, 2015; Higgins et al, 2015), bringing further high-risk behaviors such as excessive alcohol consumption smoking, and drug abuse (Bonar et al, 2015; Higgins et al, 2015; Trapp et al, 2014; McKetin et al, 2015).

I carried out a third examination based on the results of the two previous surveys. In the studied sample, the number of ED consumers who were noticing unpleasant symptoms after consumption of the product was high. The response to caffeine and the potential effects of caffeine seem to be multifaceted (Southward et al, 2018). After consumption of ED, responses vary in people ranging from positive, to neutral and negative effects on performance (Samoggia-Rezzaghi, 2021).

1.2.Aims of the Study

In the first part of my thesis I was studying two population of children and their families with different social backgrounds, concerning their health behavior and habits of ED consumption and I analysed the gathered results.

Aim of the study was, to get data of pupils and their family members in terms of health behaviour and ED consumption habits, in the schools of Ormánság, as one of the most disadvantageous area of Hungary, and in the schools of Pécs, as a county seat.

The of topic of the second survey was ED intake also, but in an older age group, high school and university students were examined. The aim of the research was to assess the prevalence of ED consumption and analyse their frequency, between high school and college students, motivations the effects and side effects of ED use as well. We looked for a correlation between the sense of coherence, depression, insomnia and ED consumption of young people. Based on these, we aimed to estimate the relative significance of the factors contributing to ED addiction.

In the third study the physical performance of young adults was tested and analysed following consumption of caffeine containing beverages. The aims of the study were measuring the changes of physiological parameters of young subjects after caffeine containing beverage consumption, like caffeine (Co), ED, EDwA, double dose of ED (DED).

Based on literature data I asked the following questions:

- what is the frequency of ED consumption in the examined sample and in different age-groups
- to what extent will the social background influence health behaviour and ED consumption habits of school-aged children and their family members
- how often will ED consumers notice unpleasant symptoms
- is there a connection between ED consumption and strength of sense of salutogenetic coherence, depression and sleep disorders in secondary school- and university students
- what are the acute effects of caffeinated beverages on physical performance, running performance, maximal oxygen capacity (VO_{2max}), on blood-lactate (BL) level measured before and after running and heart rate variability (HRV)
- what are the acute effects of caffeinated drinks on general physical strength, how do they affect balance and standing stability, reaction time and distributive attention

2. Hypothesis

According to our experience and the results of the previous studies and based on scientific literature data I suppose that schoolchildren and their family members drink ED in a higher proportion despite being in a worse social situation in Ormánság, being disadvantaged, than the pupils attending schools in Pécs and their family members. The location of the school (city or village) will influence ED consumption habits of students and their family members.

I suppose that gender differences can be measured in consumption habits and effects of caffeine as well.

I hypothesize that in rest and during physical activity some fitness and physiological parameters change significantly after ED consumption.

3. Methods

Energy drink consumption habits of school-aged children among disadvantaged and in better social environment

Sampling was carried out regardless of gender and sports habits in the primary schools of the settlements of Ormánság, as one of the most disadvantaged areas of Hungary, and in the

"advantageous" primary schools of Pécs, as a city with county rights. Four primary schools of Ormánság were investigated, having a very wide enrolment area, the sample can be considered representative in the given environment (Ethics: 6456-PTE 2019).

In the research 752 students of seven primary schools participated. The number of evaluable questionnaires were 724. From the four schools of Ormánság (OI) 366 pupils responded, while from the chosen three schools of Pécs (PI) 358 pupils responded to our survey. The number of disadvantaged (HH) and cumulatively disadvantaged (HHH) students in OI was 249 (68%), in PI 12 (3.4%), there is a significant difference between the proportions ($p < 0.001$).

For data collection a questionnaire method was used (self-completion). The questionnaire included 14 questions, 13 closed and one ended, one open ended question taking into account age characteristics. In the questionnaire mostly closed questions were used, the answers to the questions were compiled to be informative, clear and easy to evaluate.

Energy Drink consumption, depression and salutogenic sense of coherence among high school and university students

The examined sample was chosen randomly from among high school and university students of Baranya County. Considering the content of the questionnaire, the lowest age limit was set at 16 years. Gender, sport activities and social environment were not relevant (Ethics: 6456-PTE 2019).

The number of the evaluable questionnaires in the survey were 631, 284 boys (45%) and 347 girls (55%) participated. The ratio of genders do not differ significantly in the two samples ($p = 0.358$). 45.3% of respondents were high school students, 54.7% were university students.

Sampling was using an anonymous questionnaire method. Besides questions of the gender, age, type of school and of the use of ED and other mood-enhancing and performance-enhancing drugs and sports, the questionnaire contained three tests AIS (8 item), Beck's Depression Scale (13 item), SOC-13 validated in Hungarian also.

The effects of caffeinated beverages on human performance during exercise

Measured volunteer healthy young adults aged 18-35 years in the study (Ethics: 6456).

The examined sample of N=30, 14 females (46.7%), 16 males (53.3%). The 20 m shuttle run test was completed by 24 subjects, therefore, other results of this measurement such as VO_{2max} , BL level and HRV data, were obtained with N=24.

The questionnaires were completed after detailed verbal and written information and the signing of the consent form. The questionnaires were: the use of ED, SOC13 test, ATHEN insomnia test, Beck's Depression Scale. During the study, following establishing the basal physiological and anthropometric parameters, measurements were done for 5 weeks, twice a week. After drinking various caffeinated beverages (20-30 minutes), aerobic endurance was measured using a 20m shuttle run test, before and after that BL concentrations were measured. During the running test, heart rate was monitored with the aid of Polar Team System®. In the study hand grip strength, reaction time, distributive attention and stability balance were also measured.

4. Results

- The ratio of ED consumption among school children and teenagers (N=724) is high (65.8%). There is a significant difference between genders, boys (71.8%) drank ED more often and in higher quantities than girls (59.8%).
- The living environment, social background influenced the rate of ED consumption. Schoolchildren living in HH (with cumulative disadvantages) settlements (78.7%) and their family members (67.5%) also consuming these products to a greater extent than their peers in a better social environment (53.4%) and family members (32.5%). The possibility of ED consumption is three times higher in this environment, than of peers in the city. The quantity of ED consumption among family members of consumer children in OI is twice as much as among PI family members.
- In families of worse social background the possibility that at least one family member is a consumer is 3.4 higher, than in the environment of the city. Family, parental pattern is a strong influence, in case of a family member consuming ED, children are six times more likely to consume it than in families not drinking such beverages.
- In the homes of HH families, children have 30.2% access rate to ED, while in homes with better social backgrounds it is 12%. In HH families there is a 17-fold chance that children will also become consumers.

- The primary motivations of ED consumption of school-aged children in both groups are the taste, overcoming fatigue and revving up, the ratio of motivations significantly depended on the location of the school. Boys in HH region were drinking ED in significantly higher ratio because of party/fun, while girls in HH regions were consuming ED in higher ratio because it was fashionable, compared to non HH peers.
- More than half of pupils in urban and rural schools also reported unpleasant side effects caused by EDs. The symptoms most often caused by these beverages were tachycardia, insomnia and headaches.
- In rural schools, 61.7% of pupils were informed of the harmful effects of EDs by teachers, and in urban schools a significantly higher proportion of pupils obtained information through reading (38%).
- ED consumption among the high school and university students is very high, 80.3% of the examined sample (N=631) had consumed ED at least once, with a significantly higher proportion of males (84.2%) than females (77.2%). Primary motivations of ED consumption were overcoming fatigue (women: 64%; men: 33.1%), taste (women: 56%; men: 43.8%) and revving up (women: 21.3%; men: 17.4%). Men are more likely to use these products for fun or before exercise than women. In terms of addiction among every day ED consuming subjects the primary motivational factor was the taste and quenching thirst more often than among rare ED consumers.
- High school and university youngsters consume ED mixed with alcohol and with other stimulant also. 24% of young adults consumed ED mixed with alcohol, and 21.2% consumed them in combination with other stimulants. ED consumers use other stimulants more often also, than non-consumers.
- Unpleasant symptoms were experienced in 71.4% of ED consumers, which were tachycardia, insomnia and tremors. With the increasing frequency of ED consumption, the number and severity of sleep disorders increased. The most significant correlation with habituation to ED consumption was the shortening of sleep duration and daytime sleepiness.
- The likelihood of ED consumption was significantly influenced by gender, age, sense of coherence, and depression. There is a strong correlation between the tendency to depression and a lower sense of coherence. Young people with a strong sense of coherence were less likely to consume ED than those with a weaker sense of coherence. Both a weak sense of

coherence and a tendency to depression increase the chances of addiction, while participation in sports reduced the chance of ED addiction by about fifty percent.

- Different caffeinated beverages had different ergogenic effects during and after exercise. In the studied sample Coff ($p=0.020$) and ED (0.037) significantly increased VO_{2max} during the 20m shuttle run test. Aerobic endurance of females was significantly increased by Coff ($p=0.026$) and of males by DED ($p=0.026$). Individuals having a higher VO_{2max} than the average, tolerated exercise load, and caffeine, taurine and alcohol caused stress better than others, because of the increased parasympathetic tone of the body. Individuals with above-average VO_{2max} had a significant reduction in VLF% (Coff $p=0.017$; DED $p=0.045$) and increased HF% (Coff $p=0.017$; DED $p=0.012$).
- In women, ED, EDwA and DED significantly increased resting BL levels.
- Physical activity and caffeine, taurin and alcohol containing products affect the sympathetic and parasympathetic balance of a person. These parameters, physical activity and caffeine, taurin and alcohol containing products also affect HRV values. HRV frequency ranges and parameters were significantly higher in males than in females (VLF $p=0.027$; HF $p=0.002$; HF% $p=0.007$) after consuming EDwA.
- The combined effect of load and EDwA is caused by the opposite mechanism of action of alcohol and ED, the different location and speed of absorption.
- Different caffeinated beverages cause unpleasant symptoms during load. During the 20m shuttle run test women experienced unpleasant symptoms and felt unwell in a significantly higher proportion, 100% ($p=0.046$) than men (62.5%) after DED. The rate of bad feelings was higher if the products consumed contained higher amount of caffeine, taurine and/or alcohol. Regular Coff and ED consumption does not change the combined negative effects of exercise load, caffeine, taurine and alcohol containing beverages, neither regular sport activity.
- EDwA ($p=0.006$) and DED ($p=0.017$) improved hand grip strength in the entire sample, however, caffeinated beverages did not improve the handgrip strength of females. In case of righthand dominance, handgrip strength increased after ED, EDwA and DED consumption.
- During measurement of distributed attention caffeinated beverages increased the number of correct answers, but did not influence the number of incorrect answers. Coff ($p<0.001$), ED ($p<0.001$), EDwA ($p<0.001$), DED ($p<0.001$) significantly improved distributive attention.

- Caffeinated beverages reduced the reaction time and the number of incorrect answers. Coff significantly improved reaction time ($p < 0.001$), reduced the number of errors in responses ($p = 0.001$), ED improved reaction time ($p < 0.001$) and reduced the number of errors. ($p = 0.003$). EDwA significantly reduced reaction time ($p < 0.001$) and the numbers of errors ($p = 0.001$), after DED consumption reaction time ($p < 0.001$) and the number of errors in responses ($p < 0.001$) were also reduced.
- Caffeinated beverages improve standing stability, but do not affect performance of females.

5. Summary

In summary, similarly to literature data, we found that, ED consumption among school-aged children, adolescence and young adults is very high, they caused numerous unpleasant side effects and symptoms.

The different caffeinated beverages showed different ergogenic effects during physical load, but unpleasant symptoms are also caused, which differed depending on gender and fitness level.

Our research also provided new results, showing that the social status is an influencing factor of ED consumption, in families with worse social background the ratio of the consumption of these beverages is higher, than in families with better social status.

The likelihood of ED consumption was significantly influenced by the sense of coherence, and tendency of depression. Young people with a strong sense of coherence were less likely to consume ED than those with a weaker sense of coherence. Both the weak sense of coherence and a tendency to depression increase the chances of addiction, participation in sports reduced the chance of ED addiction by about fifty percent.

The proportion of unpleasant symptoms caused by the combination of caffeinated beverages and physical load is higher when the products have a higher caffeine content and contain taurin and/or alcohol.

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7. List of publications

7.1. Articles underlying the thesis

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7.3.Articles related to the thesis

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