

**PHYSICAL ACTIVITY AND MENTAL HEALTH -
THE ROLE OF EXERCISE IN THE PREVENTION
AND THE TREATMENT OF DEPRESSION
AND/OR ANXIETY SYMPTOMS, AS WELL AS IN
IMPROVING SLEEP QUALITY**

Abstract of PhD Thesis

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Introduction

The presence of a significant association between physical activity/exercise and mental health is not a new idea; it has been recognised for decades. In ancient Greece, the Athenians put a strong emphasis on physical education. At the same time, the intention was not to raise soldiers, but simply to develop a harmonic, aesthetic physique. Besides, they believed that gymnastics also contribute to improving one's character; and an increase in flexibility and rigidity of one's physical body contributes to an increase in one's will-power, and to gradually evolving altruism and self-sacrifice (Pukánszky & Németh 1996).

Socrates quotes by Xenophon: „I tell you, ... For in everything that men do the body is useful; and in all uses of the body it is of great importance to be in as high a state of physical efficiency as possible. Why, even in the process of thinking, in which the use of the body seems to be reduced to a minimum, it is matter of common knowledge that grave mistakes may often be traced to bad health. And because the body is in a bad condition, loss of memory, depression, discontent, insanity often assail the mind so violently as to drive whatever knowledge it contains clean out of it. But a sound and healthy body is a strong protection to a man, and at least there is no danger then of such a calamity happening to him through physical weakness: on the contrary, it is likely that his sound condition will serve to produce effects the opposite of those that arise from bad condition.”

In line with decades of research on exercise, even nowadays, it might be useful to consider Xenophon's advice, especially as we have seen a growing, pandemic trend in the prevalence of inactivity around the world in recent decades. Based on the recent population surveys, almost one-third of the adult population can be practically considered physically inactive both worldwide and in Hungary (WHO 2014, 2018; ELEF, KSH 2009). This contributes to the risk of developing somatic and mental disorders.

The relationship between exercise and somatic health and the physiological, somatic effects of exercise are now unquestionable. It has already been proven that the regular exercise in an adequate quantity is an effective tool in the prevention and treatment of many somatic, chronic disorders, including cardiovascular disorders, diabetes mellitus, certain cancers (breast and colon), obesity, hypertension, bone and joint disorders (Bouchard et al. 2007). At the same time, despite existing evidence, the effectiveness and

the proven role of exercise in the prevention and treatment of mental disorders is still undervalued. Health promotion and disease prevention strategies around the world focus on the prevention of mental disorders, whilst maintaining somatic and social health. Nevertheless, it seems to be considered much more obvious and often more valid that exercise has a positive effect on disorders of organ systems on which exercise has a direct effect, we tend to overlook the benefits of this simple, almost trivial, yet in many cases more effective and accessible treatment (and prevention) option, even though we are aware of the drastic decline in physical activity and exercise in the population. We believe that this neglect of the health-enhancing effects of exercise goes back to two reasons: on the one hand, the traditional view of body-mind dualism that still prevails today, and on the other hand, the multifaceted, complex, and still not fully explored relationship between exercise and mental health.

In my thesis, I examine the role of exercise on three interrelated mental health problems in the field of prevention and treatment. In the case of depression, research in recent decades has proven that exercise is associated with a lower incidence of depressive symptoms at a subclinical level (Rebar et al. 2015, 2017, Stubbs et al. 2016, Harvey et al. 2018). Moreover, lower levels of activity predict the development of major depressive disorder (Mammen & Faulkner 2013, Schuch et al. 2017, 2018, Schuch & Stubbs 2019), and these studies have proven the existence of unequivocally positive and preventive effects of higher levels of physical activity (Choi et al. 2019). Finally, based on the results of randomized controlled trials, a cause-effect association can be assumed between exercise and major depressive disorder. It is important to note that no studies have shown a statistically significant negative effect of exercise, i.e. an increase of depressive symptoms with an increase in activity levels.

Another one of the most prevalent mental disorders, which is also a public health issue, is the group of anxiety disorders. Although we have little knowledge on how exercise affects anxiety symptoms and disorders, compared to our knowledge on depressive symptoms or on major depressive disorder, recent studies suggest that there is a potential relationship between exercise and the decrease in the symptoms of subclinical anxiety, as well as of anxiety disorders (De Moor et al. 2006, De Mello et al. 2013). In the case of anxiety disorders, exercise can be a clinically useful and effective adjunctive therapeutic tool that also influences social and psychological processes (Stubbs et al. 2017, Aylett et

al. 2018). Exercise is a special psychological treatment that can be especially effective for patients with whom traditional interventions have failed (Salmon 2001). Although the studies are not fully comprehensive of the mental disorders classified as anxiety disorders, exercise can also be considered a transdiagnostic intervention, and it is an effective tool for treating many types of anxiety disorders (Kandola et al. 2018). However, the causal association remains questionable.

The third most common group of mental health problems in the population is insomnia symptoms and insomnia disorder, which can also be associated with depressive and/or anxiety symptoms/disorders. The sleep-enhancing effects of exercise are a relatively new idea, no wonder it is still difficult to provide clear evidence for the sleep-enhancing effects of exercise based on the available literature. Recent studies have demonstrated a sleep-enhancing effect of acute/chronic exercise (Yang et al. 2012, Kredlow et al. 2015, Kelley & Kelley 2017), which increases total sleep time, slow-wave sleep stage, decreases sleep-onset latency and REM sleep, as well as the number and length of awakenings after falling asleep. Although exercise does not always have a direct and extensive effect on sleep, very often exercise improves sleep only slightly, its role should not be underestimated, especially in insomnia disorder, since participation in aerobic exercise can help break the “vicious circle” of insomnia.

My thesis seeks to present further evidence for the role of exercise in developing and maintaining mental health, by studying the role of exercise in the prevention and treatment of the most common and closely related mental problems (depression and / or anxiety symptoms, sleep problems). It aims to explore and present results and relationships that can help better understand the interrelationship between exercise and mental well-being/health and promote a more active lifestyle.

Purposes

1. To analyse the national representative survey data (Hungarostudy 2013) for a) determining the prevalence of physical inactivity in Hungary, and to identify possible confounding variables in this prevalence, and b) examining physical activity and exercise separately in relation to mental health.

2. To examine the relationship between exercise (active lifestyle) and mental health in young adults/adults to a) examine depression and anxiety symptoms, as well as sleep

problems together in relation to exercise, taking into account the effects of gender as an underrepresented influencing factor, and b) study the effects of the duration and type of exercise on mental health, as well as c) examine the interrelationship of mental health problems, and to explore the role of exercise in reducing comorbidity.

3. To examine the relationship between daily physical activity, subjective sleep quality, and mood in sedentary adults in a longitudinal within-subjects study. In this research design, the emphasis on between-subjects variability (as opposed to within-subjects variability) may help to determine the „optimal’ dose-response of exercise.

4. To design and conduct a short-term exercise programme for female adults with mild depression and sleep problems based on the result of the above objectives.

Materials and methods

Study 1: The prevalence of physical inactivity and its relationship with mental health in the Hungarian population (Hungarostudy 2013)

Hungarostudy 2013 representative population survey contains data on 2000 people. For my analysis, I excluded people who evaluated their overall health as poor/very poor. Thus, the sample used for the analysis contains data on 1713 subjects (839 males and 874 females), with a mean age of 44.28 yrs ($SD=17.50$).

In this study, I used the following questionnaires: the Hungarian version of the shortened Beck Depression Inventory (9 items; BDI), Athens Insomnia Scale (5 items, AIS-5). I also used some 'standard' questions related to mental health and physical activity: „Over the past one year, have you been hospitalized or treated as an outpatient with a psychiatric disorder such as depression, panic disorder or other anxiety disorder?; „How often do you do exercise, play sports, such as swimming, running, cycling, playing football, aerobics; „How many times a week do you exercise?; „How often do you do physical activity in addition to sports, such as gardening, working around the house, when you have a fast heartbeat, you warm up and sweat for at least 10 minutes?“. Body Mass Index was determined based on the reported body weight and height data.

Study 2: Relationships between exercise and depression, anxiety symptoms and sleep problems in young adults/adults

The survey included young adults/adults, aged 25–35 years (N = 1878), 45.2% males and 54.8% females. 1055 (56.2%) of the examined subjects do not exercise, and 823 (43.8%) do exercise. For samples used in examining the objectives and hypotheses of Study 2, see Figure 1.

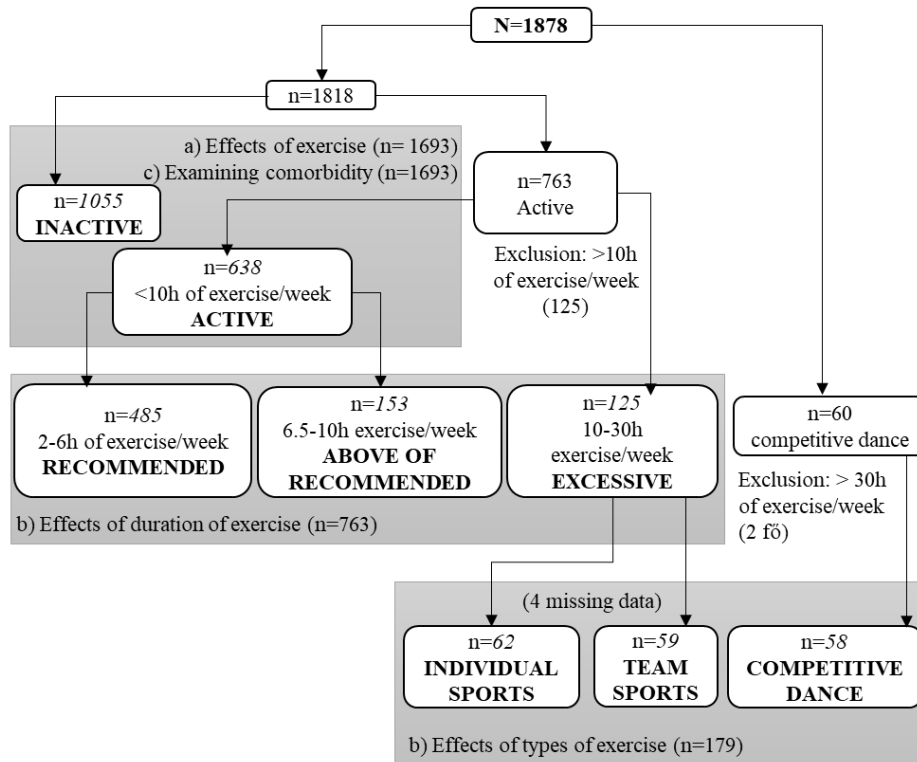


Figure 1: Samples used in Study 2

In my studies (Study 2-4), I measured depressive symptoms, anxiety levels, and sleep problems with the following tests: 13-Item Beck Depression Inventory (BDI₁₃), Epworth Sleepiness Scale (ESS), Spielberger State-Trait Anxiety Inventory (STAI-S, STAI-T), Pittsburgh Sleep Quality Index (PSQI). In Study 2, I used the following questions on exercise: „Do you do exercise, sports (e.g. swimming, running, cycling, football, aerobics, etc.)? If so, how long have you been exercising, training regularly? If so, how much time do you spend per week on exercise, sports, training? (how many times a week and for how long), What kind of sports do you do (with specifying the name of the sport) (TE-KEB/No25/2019).

Study 3: The relationship between daily physical activity, subjective sleep quality, and mood in sedentary adults: A longitudinal within-subjects study

The sample included 35 participants (18 females and 17 males). They were physically healthy office employees with a sedentary and inactive lifestyle, and they all worked 8 hr a day and earned the same salary. The mean age of participants was 34.6 years (SD = 2.9). Based on the PSQI-HUN, the sleep quality of participants indicated poor sleep, and participants showed small, non-disruptive daytime sleepiness based on ESS. All participants were in a normal mood state (based on the BDI and the STAI-T/S minimal depression and/or low/moderate state/trait anxiety) and by normal body mass (BMI = 18.5–24.9) (TE-KEB/No26/2019).

For assessments measuring depressive and anxiety-related symptoms as well as sleep problems, vid. Study 2. To register steps/day, a pedometer was used (OMRON HJ151). Furthermore, they kept a sleep diary for 7 days (Consensus Sleep Diary) and rated their level of happiness and stress at the end of each day on a 10-point Visual Analogue Scale (1 = not at all, 10 = very).

Study 4: The effect of the three-week exercise programme on sleep quality and depression symptoms in female adults

Thirty female adults, aged 30-35 years, participated in this study. Participants were physically healthy, sedentary females with normal body mass index, and they have not been under any medical or psychiatric treatments. Participants declared the state of health with a standard form about medical or psychiatric treatments, pregnancy, cardiovascular and/or respiratory disorders or any serious illnesses in the previous two years. They met criteria for mild depression on the Beck Depression Inventory ($6 \leq \text{BDI} \leq 11$) and showed sleep complaints on the Pittsburgh Sleep Quality Index ($\text{PSQI} \geq 5$).

For assessments measuring depressive and anxiety-related symptoms as well as sleep problems, vid. Study 2.

There were 15-15 participants randomly assigned to the experimental group (exercise programme) or the control group (waiting list condition). Participants in the control group could take part in the exercise programme after the experiment (TE-KEB/No24/2019). Each spinning lesson consists of three sections: warm-up (10 minutes), the main programme (30 minutes) and cool-down (10 minutes). The 10-minute warm-up section

consisted of spinning with low to medium resistance. The purpose of the main programme is to increase the intensity gradually. Intensity is increased throughout three weeks (from 60-70% maximal heart rate [endurance energy zone] to 70-80% HRmax [strength energy zone]). For the study design, see Figure 2.

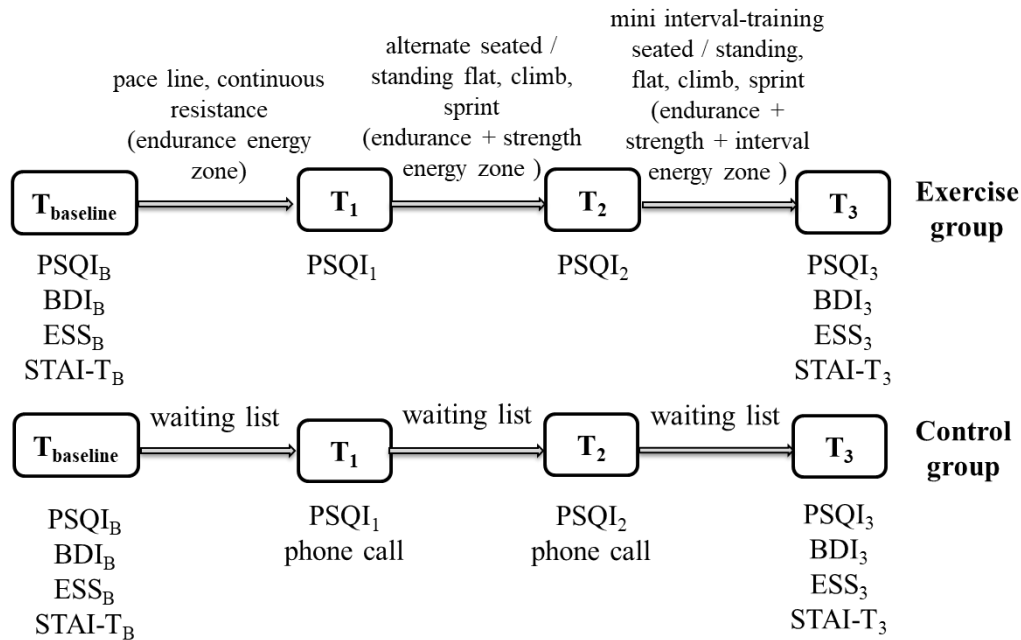


Figure 2: Study design of the three-week exercise programme

PSQI_B: sleep quality at baseline, BDI_B: depression at baseline, ESS_B: daytime sleepiness at baseline, STAI-T_B: trait-anxiety at baseline, PSQI_{1,2,3}: sleep quality at first, second, the third week, BDI₃: depression at the third week, ESS₃: daytime sleepiness at the third week, STAI-T₃: trait-anxiety at the third week

Results

Study 1: The prevalence of physical inactivity and its relationship with mental health in the Hungarian population (Hungarostudy 2013)

Physical inactivity and mental health

Based on the results, one third of the Hungarian population maintains an inactive lifestyle, i.e. do exercise or other physical activities less than once a week or never do them at all. Another third only maintains a certain level of activity, which is typically physical activity once/several times a week, that is, doing unplanned, non-regular, unstructured activity. Finally, the last third maintains an active lifestyle; these people play sports, do exercise once or more times a week. Overall, the prevalence of total inactivity (the frequency of those who never do exercise and/or never do physical activity) was

15.3% in the Hungarian population. For people who do exercise, the frequency of exercise was 4.81 days per week (SD = 2.10).

In addition to determining the prevalence of inactivity in the Hungarian population, this study also identified some confounding factors influencing inactivity, and showed significant differences in age, gender, and body mass index. It means that the elderly, females, and underweight or obese (based on body mass index) people show a higher prevalence of inactivity. These differences were also found to be present in mental health: a higher rate of females reported depressive symptoms and had undergone psychiatric treatments in the past year compared to males. There was a slight increase in the frequency of depressive symptoms and sleep problems with age. Underweight or obese people showed a higher prevalence of depressive symptoms; furthermore, they also reported a higher prevalence of significant/severe early awakening problems. Moreover, underweight people also had problems with falling asleep.

The role of physical activity and exercise in mental health

In examining the relationships between activity and mental health, I also had to take into account the above described gender, age, and body mass index differences. Consequently, I calculated the odds ratio controlling for gender, age and body mass index, which shows how many times an inactive person is more likely to have depressive symptoms and significant/severe sleep problems, and to be under psychiatric treatments compared to those who do physical activity or exercise.

Based on my results, inactive people are nearly twice as likely (OR: 2.25) to develop depressive symptoms as active people (doing exercise). Furthermore, inactive people are nearly four times as likely (OR: 3.72) to be under psychiatric treatments as active people. Finally, inactive people are nearly twice as likely (OR: 1.76) to have significant/severe sleep problems as active people. For both depressive, anxiety symptoms and sleep problems, there was no difference in the likelihood of symptoms/problems occurring between inactive people and people who do physical activity (but do not do exercise).

Study 2a: Relationships between exercise and depression, anxiety symptoms and sleep problems in young adults/adults

In Study 1, when analysing the Hungarian population survey, I identified significant differences in gender in mental health problems, which affected the relationship between activity and mental health. Thus, I also examined gender differences in depressive, anxiety symptoms, and sleep problems in the sample of young adults/adults. Based on my results, males showed better mental health than females. I examined the role of exercise, taking into account gender differences, assuming that exercise may show a different association with the studied mental health variables among males and females.

Based on the results of this study, there were no statistically significant differences in the frequencies of sleep problems (PSQI, ESS) and depressive, as well as anxiety symptoms (BDI13, STAI-T) between active and inactive males. Among females, however, there were significant differences between active and inactive groups: active females were characterized by better sleep quality, i.e. they reported better subjective sleep quality, shorter time to fall asleep, more optimal total sleep time, higher sleep efficacy and less use of medication. Furthermore, active females also showed better mood status compared to their inactive counterparts. It is also important to note that females, regardless of the level of activity, showed poorer mental health than males, i.e., active females consistently have poorer mental health variables than active males.

Study 2b: The relationship between the duration and type of exercise and depression, anxiety symptoms and sleep problems in young adults/adults

Duration of exercise

The duration of exercise showed a significant association with sleep quality, independently from age, i.e. the *excessive* group (> 10.5 hrs/week) showed worse sleep quality than in the *recommended* group (2-6 hrs/week; $p < .001$) and in the *above the recommended* group (6.5-10 hrs/week; $p = .023$). Furthermore, females reported worse sleep quality than males, independently from age and the duration of exercise.

It is important to highlight that one of the components of sleep quality, namely, sleep duration showed different kinds of differences in the duration of exercise groups in the two genders. Among males, sleep duration did not show a significant difference between the duration of exercise groups, while among females, the *excessive* group showed shorter

sleep duration (less than 6-7 hours) than the *recommended/above the recommended* groups ($p < .001$). Finally, independently from gender and age, the *excessive* group showed a higher level of sleepiness than the *recommended* ($p < .001$) or the *above the recommended* groups ($p = .002$).

The relationship between the duration of exercise and depressive symptoms was significantly different in females than in males. The *excessive* group showed a higher rate of depressive symptoms than the *recommended/above the recommended* groups in males ($p < .001$), while in females, already the *above the recommended* group reported more depressive symptoms than the *recommended* group ($p < .001$).

Types of exercise

Competitive dancers reported worse sleep quality independently from gender than individual ($p < .001$) and team sport players ($p < .001$). Total sleep quality showed a non-significant difference between the individual and team sport groups ($p = .0629$). Among the components of sleep quality, subjective sleep quality, sleep one-set latency, total sleep time and daytime dysfunction showed a similar relationship with the type of exercise to total sleep quality (only the type of exercise has a significant main effect), and in all components, competitive dancers showed worse values than individual ($p < .001$) and team sports players ($p < .013$). Daytime sleepiness showed a non-significant relationship with the type of exercise. Independently from the type of exercise, females reported more depressive symptoms ($p = .007$) than males; and independently from gender, a higher rate of competitive dancers showed depressive symptoms than individual ($p = .005$) and team sports players ($p = .003$). Finally, as for anxiety, females showed higher trait-anxiety than males, independently from the type and duration of exercise (gender only has a significant main effect).

Study 2(c): The interrelationship between depression, anxiety symptoms and sleep quality, and the role of exercise in decreasing comorbidity

I also examined the interrelationship between sleep quality, depressive and anxiety symptoms using partial correlation controlling age and gender. Based on my results, there is an interrelationship between sleep quality, depressive and anxiety symptoms, and this interrelationship is not affected by confounding variables such as age and gender.

Although comorbidity is typically low in the studied sample, a significant difference was found in the comorbidity of each “disorder” between inactive and active individuals, except for the co-occurrence of the three “disorders”. Significantly lower incidences can be observed among active individuals, which implies that exercise has a comorbidity-reducing effect.

Study 3: The relationship between daily physical activity, subjective sleep quality, and mood in sedentary adults: A longitudinal within-subjects study

The mean of steps/week was 8526.7 steps/day (SD =7780.9). There was no statistically significant difference between males and females in steps/day over a week ($t(33) = -0.432, p = .667, d = .15$). When studying the relationship between steps/day and the variables of sleep and mood, 245 steps/day scores were examined (the number of participants was 35, the procedure was continued for 7 days; therefore, the number of cases $35 \times 7 = 245$ steps/day scores).

Results of sleep variables

The relationship between steps/day and *sleep duration, feelings after waking up („fatigued-refreshed”) and sleep quality* can be described with an inverted U-shaped curve. The *below-the-usual* and the *above-the-usual* steps/day scores were associated with shorter sleep duration, less refreshed feelings after waking up, and worse sleep quality than the *usual* steps/day scores.

There was a significant, positive, weak monotonous relationship between sleep efficiency and steps/day ($\rho(243) = .394, p = .006$). This means that if a person reported a high number of steps a day, they evaluated their sleep that night as more restful, than after a lower number of steps a day, and vice versa. There was a significant, negative, moderate monotonous relationship between daytime sleepiness and steps/day ($\rho(245) = -.517, p < .001$). This means that increasing the number of daily steps decreases daytime sleepiness and vice versa.

Results of mood variables

There was a non-significant correlation between happiness and steps/day ($\rho(243) = -.194, p = .187$). There was a significant, negative, strong correlation between stress and steps/day ($\rho(243) = -0.717, p < .001$); consequently, increasing the number of steps/day decreases the level of stress, and vice versa.

Study 4: The effect of the three-week exercise programme on sleep quality and depression symptoms in female adults

There were significant differences between the exercise and the control group on sleep quality ($t(28) = -5.095, p < .001, d = 1.86$) and depression ($t(28) = -4.254, p < .001, d = 1.55$) at T₃. Participants in the exercise group showed significantly lower depression scores ($M = 4.60, SD = 1.06$) than those who participated in the control group ($M = 7.27, SD = 2.19$). The exercise group also reported better sleep quality (lower PSQI scores) ($M = 3.20, SD = 1.27$) than the control group ($M = 6.20, SD = 1.90$). Daytime sleepiness ($t(28) = -1.128, p = .230$) and trait-anxiety ($t(28) = -1.278, p = .212$) did not show significant differences between the exercise and the control group at T₃ (Table 2).

Within the exercise group there were significant differences between baseline and T₃ on sleep quality ($t(14) = 7.557, p < .001, d = 2.56$), depression ($t(14) = 6.507, p < .001, d = 2.19$), daytime sleepiness ($t(14) = 2.485, p = .026, d = 0.73$) and trait-anxiety ($t(14) = 4.525, p < .001, d = 1.46$). Participants of the exercise programme reported better sleep quality, fewer symptoms of depression and anxiety, as well as lower daytime sleepiness at the end of program than at baseline. In the control group non-significant differences were revealed between baseline and T₃ on sleep quality ($t(14) = 1.715, p = .108$), depression ($t(14) = 1.702, p = .111$), daytime sleepiness ($t(14) = .521, p = .610$), as well as trait-anxiety ($t(14) = -.695, p = .499$).

To measure the effects of exercise on sleep quality at baseline and Time (T₁, T₂, T₃) between the control and the exercise groups, repeated measures of ANOVA were performed with between-subject factor (Group: control vs. exercise). There was a significant Time main effect on sleep quality ($F(3,84) = 15.831, p < .001, \eta^2_{partial} = .361$). The Group main effect was also found significant ($F(1,28) = 11.506, p = .002, \eta^2_{partial} = .291$). The Time x Group interaction also showed a significant effect ($F(3,84) = 6.842, p < .001, \eta^2_{partial} = .196$) (see Figure 3).

PSQI-HUN scores significantly decreased which means improving sleep quality in the exercise group, and this decrease already occurred after one week of exercise. Furthermore, sleep quality was significantly lower in the exercise group than in the control group at the end of the second week. In the control group, sleep quality remained statistically unchanged during the three-week exercise programme.

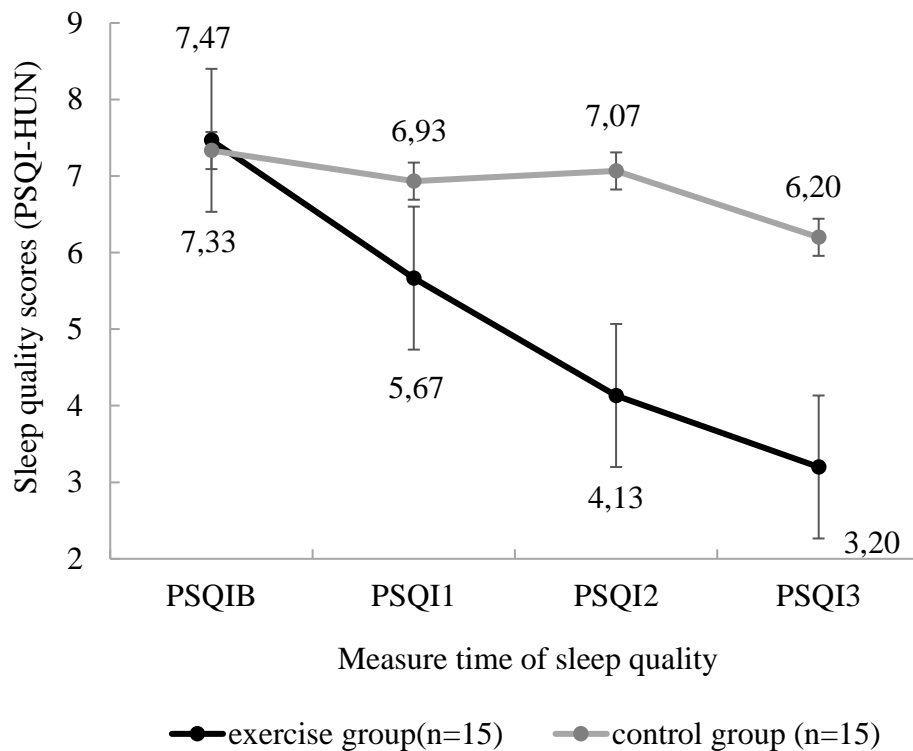


Figure 3: The effects of the three-week exercise programme on sleep quality in the exercise and control group

PSQIB: sleep quality at baseline, PSQI₁: sleep quality at the end of the first week, PSQI₂: sleep quality at second week, PSQI₃: sleep quality at the end of the third week, error bar: standard error

Conclusions

In my PhD thesis, I presented four studies which examine the prevalence of physical inactivity and the role of exercise in the prevention and treatment of depression and/or anxiety symptoms, as well as in improving sleep quality. Based on the results of my studies, the following findings and conclusions can be outlined.

In Hungary, 6 out of 10 people either have a passive lifestyle or have a level of activity that does not reach the recommended level necessary for maintaining somatic and mental health, that is, doing exercise at least 3 times a week. The prevalence of inactivity is higher in females, in the elderly, and in underweight and obese people.

There are only few surveys that examine the relationships between activity and mental health in the population, while a great number of studies explore the relationship between activity and somatic health. Furthermore, to my knowledge, there are no population surveys that distinctively examine physical activity and exercise in the relationship between activity and mental health.

Thus, my findings on the role of activity in mental health draw attention to new and significant relationships/associations. Based on my research, we can conclude that inactive people are more than twice as likely to be depressed, nearly four times more likely to be under psychiatric treatments, and nearly twice as likely to have sleep problems as active people, regardless of gender, age, or body mass index. At the same time, these differences in odds ratios occur only in the case of those who do exercise.

In sum, we can conclude that in order to maintain mental health, at least in mood and sleep problems, it is not enough to have a low level of activity, that is, doing ‘only’ physical activity, but people should do exercise, i.e. planned, structured, repetitive physical activity. My results confirm and provide further evidence for the fact that exercise should definitely play a more central role in the prevention and treatment of mental disorders in Hungarian psychological/psychiatric practice.

Based on my research among young adults/adults, we can conclude that females can expect greater “benefits” from maintaining an active lifestyle. In the female population, there is a lower incidence of poor sleep, depression, and anxiety in active individuals than in inactive one who maintains a passive lifestyle. By contrast, in the male population, maintaining an active lifestyle does not cause a significant difference in the incidences of mental problems. All this highlights the importance of examining the under-represented variable of gender in this research area.

My findings are particularly important as they concern the population of young adults/adults, while the vast majority of research on the relationship between exercise and mental health/illness has been conducted in children/adolescents or in the elderly population (in the main age groups of prevention and intervention). Another novelty of my research is that it examines three areas of mental health together, which are interrelated with each other and presumably with exercise as well.

Finally, it is important to highlight that international population surveys examining the relationship between exercise and mental health provide relatively little information on the characteristics of exercise itself. According to population surveys, people are considered active if they exercise several times a week; however, they do not provide information on how long a person has been maintaining an active lifestyle or how long they have been doing exercise. In my research, I considered people active if they have performed planned, structured and repetitive physical activity (exercise) for 2–10 hours a

week since childhood/adolescence, i.e. they have been maintaining an active life for several years.

To the best of my knowledge, one of the studies presented here on young adults/adults is the first to analyse the relationships of the duration (recommended, above-recommended, excessive) and type (individual, team, dance) of exercise to depressive, anxiety symptoms and sleep problems among people maintaining an active lifestyle.

Based on my results, we can conclude that the prevalence of poor sleep and depression symptoms may be higher in people who do exercise more than 10.5 hrs a week. Based on the simultaneous examination of the duration and type of exercise, we can conclude that the effects of excessive exercise on mental health are dependent on the type of exercise. Finally, it seems that the type and duration of exercise have no significant influence on the level of anxiety. Only gender differences can be observed in the level of anxiety, like in the previous studies, i.e. females showed a higher level of anxiety than males.

We can also conclude that exercise with a duration of minimum 2 and maximum 10.5 hrs (6.5 hrs for females) is associated with a lower prevalence of depressive symptoms and poor sleep. A recent study by Chekroud et al. (2018) conducting a population survey on the relationship between exercise and mental health, proved a U-shaped association between duration and frequency of exercise and mental health. They also found that this association existed independently from the type and intensity of exercise. The same U-shaped association has been revealed in my studies. A novel result of my research is the gender differences observed in relation to the maximum duration of exercise. In addition, my studies also examined the types of exercise in people who do excessive exercise, which was a simultaneous examination of the duration and types of exercise.

Depression, anxiety symptoms and poor sleep quality are interrelated; and exercise also shows a significant association not only with depressive, anxiety symptoms and poor sleep quality, but also with a lower incidence of comorbidity of mental disorders.

My study is the first to examine the associations between the fluctuation of daily activity and sleep and mood in a Hungarian sample. My results suggest that there is an inverse U-shaped relationship between sleep duration, sleep quality, feelings after awaking and the number of steps taken per day. Furthermore, as the number of steps per day goes up, the efficiency of sleep increases and the feeling of tension during the day decreases.

These results of my study, which used pedometers when examining the relationship between daily physical activity and sleep and mood, are particularly important from two aspects. First, in the relationship between exercise and health, a special emphasis is put worldwide on the definition of an accurate “dose-response” of health-enhancing exercise. Second, the most commonly performed and widely available health-enhancing exercise is walking (Tudor-Locke et al. 2014, Arem et al. 2015, Matthews et al. 2016). Thus, besides determining how many steps/days are needed to obtain the health-improving effects of exercise, it is also necessary to know what the results are if the daily number of steps (activity) is suddenly increased.

Although the currently well-known guidelines and recommendations emphasize the regularity of exercise and the development of an active lifestyle (WHO 2018), they do not provide sufficient information on the principle of graduality of exercise and on how to achieve and maintain an active lifestyle (dose-response effect).

My results highlight the fact that if we want to achieve our exercise goals too quickly (active lifestyle), we could overload ourselves. In this case, we may presumably experience the stress-reducing and sleep-improving effects of exercise; however, we may be more tired and sleepy the next day, which will also reduce motivation for doing further exercise.

The results of my study are the first to confirm the antidepressant and sleep-enhancing effects of exercise in a Hungarian sample of physically healthy individuals not under psychiatric treatments and showing depressive symptoms and sleep problems.

The exercise programme introduced in my study has two novelties: First, the use of gradually increasing intensity of exercise as opposed to long-term, moderate-intensity exercise programmes, and, second, the consideration of the individual's initial activity/fitness level when determining the intensity of planned exercise. The importance of intensity in the antidepressant effects of exercise has been demonstrated in previous studies as well, which, however, do not necessarily require strenuous, high-intensity exercise (Gerber et al. 2016, Chan 2019).

I conclude that a three-week exercise programme significantly improves sleep quality and reduces depressive symptoms. However, an important condition for that is to take into account the initial activity/fitness level, and to ensure a gradually increasing intensity (up to 80% of the maximum load). Nevertheless, how to become physically active

remains a question to be answered. A special challenge is how to increase the activity of psychiatric patients, most of whom are physically inactive, have low levels of training, and are ambivalent about changing their behaviour and habits.

Most people are aware that exercise is important and useful in maintaining good health. Knowing this, however, will not necessarily make them start doing exercise and maintain an active lifestyle. In the field of exercise, the most well-known model of behaviour change is the transtheoretical model (Prochaska & DiClemente 1983, Prochaska et al. 1992). According to that, behaviour change is a process that could take a long time and involves a series of specific stages. This model can be used to determine where we are in the process of change, and what principles and changes may be most effective to reduce resistance, facilitate progress and prevent relapses, which are inevitable since behaviour change is not a linear process (Prochaska & Prochaska 2011). However, as time goes by gradually, and as this behaviour (exercise) is repeated, people gain more and more positive experiences on the long-term positive effects of exercise (Matsumoto & Takenaka 2004). These experiences will cumulate in the motivation to continue doing exercise and will eventually result in maintaining an intrinsic-motivated active lifestyle. “Motivation is what gets you started; habit is what keeps you going” (Jim Ryun).

In sum, based on my studies, doing exercise and active living have proven to be important tools for developing and maintaining mental health (prevention and intervention) and are accessible to everyone. This statement is also supported by the assumption that there is a reciprocal relationship between exercise and depressive, anxiety symptoms (da Silva et al. 2012, Stavrakakis et al. 2011, de Mello et al. 2013) as well as sleep problems (Kline 2014, Dzierzewski et al. 2014, Lambiase et al. 2013). Furthermore, based on Hill’s (1965) criteria for causality (strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experimental evidence, analogy), although the relationship between depression and exercise does not meet only one criterion, which is specificity, overall, there is a causal relationship between inactivity and depression (Choi et al. 2019).

When it comes to research on exercise and mental health, we cannot forget Hill’s words: *„All scientific work is incomplete – whether it be observational or experimental. All scientific work is liable to be upset or modified by advancing knowledge. That does not confer upon us a freedom to ignore the knowledge we already have, or to postpone*

the action that it appears to demand at a given time.” (Sir Austin Bradford Hill 1965). Thus, although the relationship between exercise and mental health is not fully acknowledged, this does not prevent many mental health professionals from continuing to encourage people to lead a more physically active lifestyle. Fundamentally, the best thing that can come out of this is the symptoms of mental disorders being alleviated and stabilized, and the worst that might happen is that we experience the positive effects of exercise in other areas of life. Consequently, we cannot lose, because exercise, “exercise-medicine”, will necessarily result in a „winning scenario” (Biddle & Mutrie 2008), if the ‘pill’ is properly dosed, even if the ‘pill’ is small at first (Hallgren et al. 2016, Gerber et al. 2016).

List of publications

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