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Review of studies on the impact of climbing as a complementary form of depression treatment and their evaluation according to the QUADAS-2 tool

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Summary

According to the World Health Organization (WHO), 4.3% of the global population exhibits symptoms of depression. In Poland, 1.5 million people suffer from this illness. Treatment of depression generates significant costs calculated in billions of zlotys. According to the International Statistical Classification of Diseases and Health Problems, depression is characterized by: reduced mood, reduced psychomotor drive, loss of interest (axial symptoms), as well as low self-esteem, pessimistic attitude, weakness of concentration, sleep disorders, and loss of appetite (additional symptoms). The aim of this research was to review and evaluate studies on the impact of sport climbing as a complementary form of treatment on reducing depressive symptoms. This is the first literature review undertaking a collective assessment of studies on this subject. The appropriate studies were selected in a three-stage process. PubMed, ResearchGate and Google Scholar databases were searched. Finally, 4 studies were qualified for the review and then assessed using the QUADAS-2 tool developed by Bristol Medical School: Population Health Sciences. Analysis of the research gives grounds to consider introducing an additional form of treatment for depression in the form of boulder climbing. The evaluation according to the QUADAS – 2 questionnaire indicates a low possibility of making mistakes in all assessed works.

Key words: depression, sports, psychology

Introduction

According to the World Health Organization, 350 million people around the world show symptoms of depression, and 4.3% of the global burden on all diseases is depressive disorder. Major depression epidemiology is estimated at 8–12% [1]. Women get depression twice as often as men [2]. Currently, it is estimated that in Poland this illness affects about 1.5 million people [3]. In 2016, according to IMS Poland statistics, about

20 million packages of antidepressants were sold in our country [4]. In 2019, according to the data of the Social Insurance Institution, due to depressive episodes, doctors issued 201,724 certificates for a total of 3,935,131 sick leaves days and 113,245 certificates associated with recurrent depressive disorders for 2,048,282 sick leaves days issued in total [5]. According to the report of the National Health Fund (NFZ) published in 2019, the value of reimbursement of benefits due to depression in 2018 amounted to PLN 250 million. This sum was 14% higher compared to 2013 [6].

According to the International Statistical Classification of Diseases and Related Health Problems (ICD-10), depression is characterized by: lowered mood, lowered psychomotor drive, loss of interest – axial symptoms, and low self-esteem, pessimistic attitude, weakness of concentration, sleep disorders, and loss of appetite – additional symptoms [7]. Determining the specific area of the brain responsible for depression causes many difficulties. Research suggests that the cause of the illness may be sought in several brain regions, including in the left dorsolateral and medial prefrontal cortex, amygdala, or in the limbic system [8, 9]. The latest publications (2017–2019) focus on the possible role of the cerebellum in depressive disorders [10–12], and imaging studies in patients with major depression state the presence of its noticeable changes [13, 14].

The cerebellum, which is the largest element of the posterior part of the brain, is located in the posterior part of the skull behind the fourth ventricle, pons and medulla oblongata. The cerebellum receives afferent information about any muscle movement from the cerebral cortex as well as muscles, tendons and joints. It also provides information about the balance of the vestibular nuclei. Each cerebellar hemisphere controls the same side of the body, so if they are damaged, symptoms will appear ipsilateral [15].

In the last three decades, knowledge about the role of the cerebellum in emotional processing has increased significantly [16]. According to the internal models of the cerebellum, in each of its functional unit (called microcomplex) there are connections between mossy fibers and granular cells and Purkinje cells. They provide a three-layer structure of the neural network [17]. The cerebellum consists of many microcomplexes, each of which is a unit of learning. In this model, Purkinje cells receive two different types of input information: strong signals from a single climbing fiber and weak signals from parallel granular cells. Climbing fiber serves as a 'teaching signal' and is induced by a change in the strength of the parallel fiber signals. Microcomplexes can be responsible for recognizing, transmitting and coding emotional information, and for regulating emotional states in relation to motor, cognitive and social behaviors [16, 18].

Climbing is becoming an increasingly popular form of spending free time [19]. According to the International Federation of Sport Climbing (IFSC), every day in the United States alone 1,000 people try climbing, while the number of people practicing it regularly is estimated at 25 million [20]. In Brazil, in Rio De Janeiro, at the 129th plenary session of the International Olympic Committee (IOC), it was officially announced that climbing was accepted as the official discipline of the Olympic Games in Tokyo in 2020 [21]. Sub-disciplines of sport climbing, which are most often practiced, are lead climbing and bouldering [22, 23]. Bouldering is cultivated relatively low above the ground, and on artificial climbing objects the routes do not exceed 5 meters in height. For belaying, a thick mattress is used, which is spread over the entire width of the climbing wall. When climbing in natural rock formations, a portable mattress is a belay. In bouldering, the athlete usually has a maximum of 10 moves to perform. He implements them with the help of grips, the size of which varies depending on the difficulty of the climbing route [24]. The climber usually starts climbing from a sitting position, where both legs and arms will be on the designated starting grips. Participant climbs the climbing path in specially adapted shoes, and the hands are dried with magnesium (magnesium carbonate, $MgCO_3$) to increase the ability to hold grips. Catching the last grip with both hands and static maintenance ends the climbing route [25, 26]. Climbing can take place both in a vertical and an inclined wall, even parallel to the ground.

Historically, the name of the abovementioned sub-discipline is derived from mountaineers who, on rainy days when they could not climb mountains, trained on erratic boulders, called with the English word ‘boulder’ [25, 27]. Lead climbing (rope climbing) takes place on high walls (>10 meters), the routes consist of many movements, and the relative climbing time is longer compared to boulder routes [23, 27]. The size, shape and number of grips as well as the length of the route ultimately affect the valuation of its difficulties [28].

Climbing training is physical activity that not only affects the movement system but also stimulates the work of various structures and areas of the brain. Studies show that sport climbing affects the stimulation and enlargement of structures within the cerebellum [29, 30]. There are studies that confirm the therapeutic effects of climbing on mental problems such as ADHD, anxiety disorders and eating disorders [31, 32].

The aim of this study was to review and evaluate research on the impact of sport climbing as a complementary form to reducing depressive symptoms. This is the first literature review undertaking a collective assessment of studies on this subject.

Literature selection method

The relevant research was identified in a three-stage process by two independent persons. Data analysis began in December 2019 and ended in January 2020. In the first stage, PubMed, ResearchGate and Google Scholar databases were searched. The search was performed by entering key words separately and in combinations. Key words included terms such as depression, sport climbing, rope climbing, lead climbing, rock climbing, bouldering. At this stage, the publication titles were analyzed for thematic compatibility. 103 works were qualified to the second stage. Publications whose full text was in a language other than Polish or English, conference summaries, letters to the editor, and case studies were excluded from the analysis. At this stage, abstracts were analyzed and 21 works qualified for the next stage. At the third stage, the entire articles were analyzed, eventually including 4 papers in the author's review. In addition, bibliographic lists from selected works were analyzed in order to identify items that could be omitted. As a result of this analysis, no further publications have been included in this review.

Analysis of the evidential quality of the publication – QUADAS-2

QUADAS (Quality Assessment of Diagnostic Accuracy Studies) was developed in 2003 in cooperation with Bristol Medical School: Population Health Sciences. It was created by a team of nine diagnostic experts who evaluated 55 studies on the impact of researchers' bias on test quality. It was considered that the sources of bias in the assessment of research results were: clinical and demographic differentiation of the groups, prevalence and severity of the disease, partial verification error, clinical review error, and the variability of the observer or research instrument [33].

Initially, a list of 28 items was made, which was later reduced to 14 questions in the Likert scale format with three categories of answers. In 2011, a revised QUADAS-2 scale was proposed, which measured the extent to which individual test criteria correspond to the purpose of the review. QUADAS-2 includes 7 of the original 14 questions in the "bias and applicability" section and 3 questions in the "risk of use" category [34]. Answers to questions include the categories "low risk", "high risk" or "unclear". "Unclear" is used only when it is impossible to answer based on the data presented in the study. When in at least one question from the subsection (e.g., selection of patients) the answer was "high risk", it should be assumed that the entire subsection has high risk of bias error [35].

Each publication qualified for the review was assessed in accordance with the QUADAS-2 tool – Table 1. The assessment was made by two independent authors.

Table 1. **Evaluation process according to the QUADAS-2 tool [35]**

Bias and Applicability Section		Risk of bias		
Subsection	Support questions	low	unclear	high
Patient Selection	1. Could the selection of patients have introduced bias?	+	?	-
	2. Was a consecutive or random sample of patients enrolled?	+	?	-
	3. Was a case-control design avoided?	+	?	-
	4. Did the study avoid inappropriate exclusions?	+	?	-

table continued on the next page

Index Test	5. Could the conduct or interpretation of the index test have introduced bias?	+	?	-
	6. Were the index test results interpreted without knowledge of the results of the reference standard?	+	?	-
	7. If a threshold was used, was it pre-specified?	+	?	-
Reference Standard	8. Could the reference standard, its conduct, or its 9. interpretation have introduced bias?	+	?	-
	10. Is the reference standard likely to correctly classify the target condition?	+	?	-
	11. Were the reference standard results interpreted without knowledge of the results of the index test?	+	?	-
Flow and Timing	12. Could the patient flow have introduced bias?	+	?	-
	13. Was there an appropriate interval between index test(s) and reference standard??	+	?	-
	14. Did all patients receive the same reference standard?	+	?	-
	15. Were all patients included in the analysis?	+	?	-
Applicability Section		low	unclear	high
Patient Selection	1. Are there concerns that the included patients do not match the review question?	+	?	-
Index Test	2. Are there concerns that the index test, its conduct, or interpretation differ from the review question?	+	?	-
Reference Standard	3. Are there concerns that the target condition as defined by the reference standard does not match the review question?	+	?	-

Characteristics of results shown in qualified works

The work of Schwarz et al. [36] aimed to investigate the short – and long-term effects of boulder climbing as a form of supportive treatment for 97 people diagnosed with depression. The study group consisted of 48 randomly selected, sexually mixed participants (mean age of women: 57.7 years, mean age of men: 42.3 years). The Beck Depression Inventory – Second Edition (BDI-II) was used to analyze the indicator of the presence and severity of depressive symptoms. Climbing sessions were conducted for 8 weeks, once a week for 3 hours. In the results of the study, the authors indicate a decrease in the results of the severity of depression on the BDI-II by 7.21, which was maintained for 12 months of the control measurement [36].

In the work of Stelzer et al. [37], the aim of the study was to assess whether boulder climbing, as a complementary form of treatment, affects the severity of depressive symptoms and is independent of general physical activity. The study was conducted on a group of 27 people whose mean age was 45.44 years. The control group consisted of 29 people with a mean age of 44.41 years. Both groups were gender balanced. BDI-II and the Symptom Checklist-90-R questionnaire (SCL-90-R) were used to analyze the indicator of the presence and severity of depressive symptoms. 8 sessions were used, once a week, and the duration of the training was 3 hours. After the intervention, the test results dropped even by 6.74 points on the SCL-90-R scale and by 8.26 points on the BDI-II compared to the results collected before the start of training. The authors note in the conclusions that this study provides evidence that short-term bouldering psychotherapy (BPT) can effectively reduce the symptoms of depression, even when using other therapeutic forms, including antidepressants. The level of general physical fitness did not affect the results [37].

Kleinstäuber et al. [38] studied the relationship between rock climbing and the acute effects of emotion regulation in patients with major depression. The study involved 20 people in the study group and 20 in the control group, the mean age was 41 years, and the groups were sexually balanced. Criteria according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) were used to analyze the level of depression, and the Patient Health Questionnaire-9 (PHQ-9) was also used in the study. Subjects climbed for 7 months, once a week for 2.5 hours. The authors note that the results of the questionnaires decreased after the climbing session. In the conclusions we can read that climbing is combined with effects that regulate emotions. These findings should be repeated using a random project, and future research should pay attention to the potential mechanisms of climbing in relation to emotion regulation [38].

The work of Luttenberger et al. [28] has a dual purpose: firstly, developing guidelines for an eight-week psychotherapeutic program in the form of boulder climbing, and secondly, assessing the impact of boulder climbing on people with depression. 22 people were qualified to the study group and 25 people to the control group. Mean age of the group was 44 years, the group gender balanced. BDI-II and SCL-90-R were used to analyze the indicator of presence and severity of depressive symptoms. Climbing sessions were conducted for 8 weeks, once a week for 3 hours. After eight weeks of intervention, the results showed a positive effect of bouldering on the severity of depressive symptoms. The authors point out that this was the first study providing evidence that bouldering could offer effective treatment for depression [28].

Collective Conclusions

All four studies note the positive effect of climbing on depression treatment. Three out of four studies highlight the effectiveness of bouldering therapy. All studies were carried out on a similar time scale: 3 hours training, once a week for 8 weeks.

According to the mean age, people over 40 but before 60 years of age participated in the study. Three of the four studies used the same BDI-II questionnaire. Three of the analyzed studies included study groups whose population was less than 30 people, which indicates the low statistical power of the analyzes. The authors of 3 qualified papers indicate that the selection of samples for the study was random.

The studies showed significant similarities in terms of the studied groups and the used methodology. The unanimity of the results as well as the author's assessment according to the QUADAS-2 indicate the low possibility of bias in the evaluated publications – Table 2. It is suggested that climbing, and in particular subdiscipline in the form of bouldering, can be considered as complementary therapy in the treatment of depression.

Table 2. **Characteristics of qualitative assessment using the QUADAS-2**

Study	Bias and applicability section				Applicability section		
	patient selection	index test	reference standard	flow and time	patient selection	index test	reference standard
[36]	+	+	+	+	+	+	+
[37]	+	+	+	+	+	+	+
[38]	+	+	+	+	+	+	+
[28]	+	+	+	+	+	+	+
"+" low risk							

Discussion

This is the first literature review undertaking a collective assessment of climbing research as a complementary form of depression treatment. Evidence indicates the great effectiveness of sport climbing, and in particular its variation – bouldering, in the treatment of patients with depression. The mechanism of the influence of physical activity in the form of climbing on the reduction of depressive symptoms is complex and can be explained in different ways.

The effectiveness of depression therapy in the form of climbing can be explained by stimulation and changes in the cerebellum. This is indicated by the latest research on the role of the cerebellum in depressive disorders [10–12]. A review by Depping et al. notes features characterizing depression in the form of cerebellar neuroanatomic correlates that communicate with cortical networks supporting cognitive and autoreferential processing [11]. The work of Xu et al. notes that emotional memory and the severity of depressive symptoms are associated with structural changes in both the posterior and anterior regions of the gray matter in the cerebellum in patients with severe depressive disorders [10]. The discussed authors notice that changes in the cerebellum have been observed, among others, in the cerebellar vermis I–II, IV–V, VIII, and IX

[10]. Di Paola et al. showed in their study that climbers represent significantly larger volumes of the cerebellar vermis lobules I–V, with no significant difference in other cerebellar vermis lobules or hemispheres, compared to the control group. Cerebellar enlargement was associated with enlargement of the right medial-posterior parietal area [30]. There are reports in the literature that in addition to the motor function, the cerebellar vermis cooperates in the formation of emotional memory. This connection probably functions with the amygdala and is bi-directional [16]. Based on the above information, one can hypothetically explain the effectiveness of therapy for people with depression through the influence and stimulation of the cerebellum, its specific parts. Animal studies show that individuals whose environment requires learning new motor skills, as opposed to performing normal motor activity, show an increase in the size and number of synapses on Purkinje cells in the cerebellar cortex [39]. In turn, the decline in Purkinje cell function is associated with social and motor disorders [40].

Another explanation may be the effect of dopamine on the limbic system. It is part of the cerebral cortex and subcortical structures. The main function of the limbic system is managing impulse and emotional behavior and processes related to cognition, including spatial memory, learning and motivation [41]. The above system includes: cortical centers, amygdala, forebrain centers, and brainstem centers. The last of these centers are involved in the functioning of the reward system. Ventral tegmental area, located in the brainstem, gives dopaminergic projections to all structures of the limbic system and receives feedback from them [42]. This field contains dopaminergic D_1 (D1-like) receptors that induce an increase in dopaminergic neuron activity and a large number of receptors from the D_2 (D2-like) subfamily which are associated with a decrease in dopaminergic neuron activity [43]. Dopamine is produced in dopaminergic neurons of the substantia nigra, in the ventral tegmental area and the hypothalamus. Dopamine system dysfunction is associated with many diseases and disorders of the nervous system, such as Parkinson's disease, schizophrenia, autism or attention deficit hyperactivity disorder [44]. Clinical studies show dopaminergic system deficits in depression [45], which may be associated with the fact that the processing of negative emotional stimuli may be greater when dopamine transmission is low [46]. It is suggested that the activity of dopaminergic neurons is a response to learning, meaning the possibility of making a mistake in anticipation of reward [47]. The switch hypothesis defined by Redgrave et al. indicates that the dopamine reaction appears as a response to significant and unexpected situations, e.g., unexpected sensory stimulation or new stimuli [48]. Confirmation of the concept of the effect of learning on dopamine stimulation was observed in a laboratory study in rats [49]. The result obtained in this review may be related to the learning of many movement patterns needed for climbing, e.g., how to catch individual grips of different size and shape, how to put fingers on them, or how to position limbs to make a move. Climbing involves gradation of difficulty of climbing routes, which allows learning new forms of movement [24, 50]. The study of Baláš et al. indicates that after climbing training there is a significant increase in dopamine and noradrenaline levels [51]. It is worth noting that other sports will also involve learning new motor functions [52], and this learning may be associated with dopamine activity. The view on stimulating dopamine reactions by learning new motor functions may explain the results of this review. However, this requires further research, because no work has analyzed the impact of climbing training.

Another explanation for the success of climbing in treating depressive disorders may be the impact of this activity on the human psyche. First of all, climbing is associated with strong emotions such as feelings of pride, fear and trust. In addition, this sport requires very high body control and concentration [28]. Considering the above aspects, Steimer and Weissert suggest that climbing seems to be a very useful means of preventing mental health disorders. According to the cited authors, climbing can lead to a balanced mood [53]. This can be explained by the insights of Buechter and Fechtelpeter, according to which sport climbing provides the opportunity to feel success, increase self-confidence and self-esteem, enabling the participant to set a clear goal and, by achieving it, arouse the feeling that he has mastered a difficult challenge [54]. The above studies highlight the aspect of emotional regulation, which has also been noticed in studies qualified for the review of Kleinstäuber et al. [38]. Emotional regulation is important in maintaining the effects of depression treatment [55]. This is also noticeable in the work of Schwarz et al. who note the persistence of the effects of a decrease in the severity of depression after 12 months [36].

The result obtained in this review may be related not only to the specific sport discipline in question but to physical activity itself. According to a meta-analysis conducted by Josefsson et al., intensive physical exercises in the treatment of depression have moderate to high efficacy. The discussed author notes that physical activity may be recommended in people with mild to moderate depression [56]. A meta-analysis conducted by Silveira et al. notes that physical exercise, especially aerobic training, improves response to treatment. However, the effectiveness of exercise in the treatment of depression was affected by age and severity of symptoms. The work of Silveira et al. describes that elderly patients and patients with mild depressive symptoms showed a better response to physical exercise therapy [57]. Although the effectiveness of physical activity in reducing depressive symptoms is well known [56–58], the mechanisms underlying its foundations are still the subject of research [58]. Sport affects changes in brain neurobiology, which may explain its positive effect in patients with depression. Slight to moderate physical activity reduces the concentration of proinflammatory cytokines [59]. The importance of these molecules in the process of depression is associated with their effect on the neurotransmitter system, especially on the metabolism of monoamines (e.g., serotonin, dopamine and noradrenaline). These neurotransmitters are involved in the regulation of mood in depressive behavior [58, 60, 61]. Cytokines are also involved in the endocrine system because they affect the level and release of:

cortisol, corticoliberin and adrenocorticotropic hormone, which occur in increased amounts in depression [62]. The discovery of irisin (Ir) in Purkinje cells in the rodent cerebellum has increased interest in the function of this myokine in the central nervous system. It has been shown to be a fragment of the extracellular protein FNDC5 (also referred to as PeP and FRCP2), and that it improves systemic metabolism by increasing energy consumption [63]. Studies link an increase in the level of Ir with physical activity [63–65]. The work of Wang and Pan shows that irisin plays a key role in antidepressant action by regulating energy metabolism in the prefrontal cortex of the brain [66]. The Wang and Pan research is consistent with the work by Tu et al. which combines low levels of Ir in the blood with the development of depression [67]. Craft and Perna note that exercise has a positive effect on depression due to the increased release of β-endorphins after exercise. Endorphins are associated with good mood and general well-being [58].

It is also worth noting that the studies qualified for the review showed similar intensity and duration of climbing sessions (8-week cycle, once a week, for 3 hours). A series of exercises of the same intensity was observed in the works of Rawson et al. and Cecchini-Estrada et al. examining the impact of physical activity on changes related to depression [68, 69]. These two papers note the effectiveness of sports cycle and training in reducing depressive symptoms. Rawson et al. explain their results by the fact that an organized exercise program is an effective form of therapy aimed at improving the symptoms of depression and anxiety [68]. Craft and Perna note that the mechanisms underlying the antidepressant effects of exercise can be associated with the frequency of activity [58].

In most of the works included in the literature review, the authors note that another advantage of including climbing in supportive treatment of depression is its relative safety. Although climbing is often referred to as extreme sport and is considered dangerous in the public opinion, statistics suggest that the risk of an accident on an artificial wall is 0.02–1.66 injury per 1,000 hours of climbing [26, 70]. In comparison, in running the injury index is from 2.5 to 33 injuries per 1,000 hours of running [71].

It is worth noting, however, that bouldering, as a therapy supporting the treatment of depressive disorders, may also carry risks. Any desire to start climbing with depression should be consulted with a psychiatrist and a doctor specializing in sports medicine. Contraindications for climbing are, for example, suicidal thoughts, psychosis, cardiovascular problems, fear of heights, and frequent dizziness [28, 72]. A person who wants to start training in sport climbing must be aware that the most common injuries are related to fingers, shoulder girdle and elbows [73].

Another aspect to consider when undertaking sports training is the possibility of experiencing traumatic brain injury (TBI). A large number of patients after TBI suffer from cognitive, anxiety and depressive disorders. Persistence of these symptoms may suggest that brain injury has permanently affected neurotransmission [74]. It is estimated that every year in the United States TBI affects 1.7 to 3.8 million people; approximately 10% of cases are caused by sport and recreation [75]. There is no current literature on the subject of TBI in climbers who practice bouldering on artificial climbing walls. However, it cannot be excluded that this type of injury does not occur in this sub-discipline.

Recapitulation

The evaluation according to the QUADAS-2 indicates a low possibility of bias in all evaluated studies. In Poland, depression generates significant healthcare costs, which are estimated in millions, and indirect costs in billions of zlotys a year [3]. There is therefore a need to reduce the cost of treating the illness in question. The results of previous studies provide the basis for considering the introduction of additional forms of depression treatment based on physical activity in the form of boulder climbing. However, it is important to use this method carefully because of the different physical and mental condition of depressed patients. A small number of papers on this topic, in particular in relation to the Polish population, suggests the need for further research. Both future scientific works and the therapy of depression using boulder climbing should be conducted after taking into account the opinions of specialists in the field of psychiatry and sports medicine. Patients included in the boulder training program should be informed about its contraindications and about the type and location of the most common injuries.

References

1. Gałecki P, Talarowska M. *Inflammatory theory of depression.* Psychiatr. Pol. 2018; 52(3): 437–447.
2. Kuehner C. *Why is depression more common among women than among men*? Lancet Psychiatry 2017; 4(2): 146–158.
3. Gałecki P, Bliźniewska-Kowalska K. *Treatment-resistant depression – recommendations of the National Consultant in the field of psychiatry*. Psychiatr. Pol. 2021; 55 (1): 1–15.
4. Gałecki P. *Zalecenia konsultanta krajowego w dziedzinie psychiatrii dotyczące leczenia epizodu depresji i zaburzeń depresyjnych nawracających*. Farmakoterapia w Psychiatrii i Neurologii 2018; 34(3): 157–199.
5. *Absencja chorobowa z tytułu choroby własnej osób ubezpieczonych w ZUS* – Absencja chorobowa – Portal Statystyczny ZUS [Internet]. [cited 22 May 2020]. Available from: https://psz.zus.pl/kategorie/absencja-chorobowa/absencja-chorobowa-z-tytulu-choroby-wlasnej-osob-ubezpieczonych-w-zus
6. *NFZ o Zdrowiu*. Depresja [Internet]. Warsaw: Center of the National Health Fund, Department of Analysis and Innovation; 2019. Available from: https://zdrowedane.nfz.gov.pl/pluginfile.php/266/mod_resource/content/1/nfz_o_zdrowiu_depresja.pdf

7. Pużyński S, Wciórka J, Brykczyńska C. *Klasyfikacja zaburzeń psychicznych i zaburzeń zachowania w ICD-10: opisy kliniczne i wskazówki diagnostyczne*. Krakow, Warsaw: University Medical Publishing House "Vesalius"; Institute of Psychiatry and Neurology; 2007.
8. Pandya M, Altinay M, Malone DA, Anand A. *Where in the brain is depression?* Curr. Psychiatry Rep. 2012; 14(6): 634–642.
9. Zyss T. *TMS in therapy of depressions – the problem of determining the area to be stimulated, i.e., a few words about the anatomy of depressive disorders*. Psychiatr Pol. 2013; 47(1): 75–87.
10. Xu L, Xu F, Liu C, Ji Y, Wu J, Wang Y et al. *Relationship between cerebellar structure and emotional memory in depression*. Brain Behav. [Internet]. 2017 [cited 29 January 2020]; 7(7). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5516611/
11. Depping MS, Schmitgen MM, Kubera KM, Wolf RC. *Cerebellar contributions to major depression*. Front Psychiatry [Internet]. 2018 [cited 29 January 2020]; 9. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6281716/
12. Clausi S, Lupo M, Olivito G, Siciliano L, Contento MP, Aloise F et al. *Depression disorder in patients with cerebellar damage: Awareness of the mood state*. J. Affect. Disord. 2019; 245: 386–393.
13. Liu L. *Analytic solutions of a second-order functional differential equation*. In: Wu Y, editor. *Software engineering and knowledge engineering: theory and practice*. Berlin, Heidelberg: Springer; 2012, P. 1–8. (Advances in Intelligent and Soft Computing).
14. Peng J, Liu J, Nie B, Li Y, Shan B, Wang G et al. *Cerebral and cerebellar gray matter reduction in first-episode patients with major depressive disorder: A voxel-based morphometry study*. Europ. J. Radiol. 2011; 80(2): 395–399.
15. Jimsheleishvili S, Dididze M. *Neuroanatomy, cerebellum*. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020 [cited 29 January 2020]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK538167/
16. Adamaszek M, D'Agata F, Ferrucci R, Habas C, Keulen S, Kirkby KC et al. *Consensuspaper: cerebellum and emotion*. Cerebellum 2017; 16(2): 552–576.
17. Ito M. *Control of mental activities by internal models in the cerebellum*. Nat. Rev. Neurosci. 2008; 9(4): 304–313.
18. Mak M, Tyburski E, Madany Ł, Sokołowski A, Samochowiec A. *Executive function deficits in patients after cerebellar neurosurgery*. J. Int. Neuropsychol. Soc. 2016; 22(1): 47–57.
19. Sanchez X, Torregrossa M, Woodman T, Jones G, Llewellyn DJ. *Identification of parameters that predict sport climbing performance*. Front Psychol. 2019; 10:1294.
20. Saul D, Steinmetz G, Lehmann W, Schilling AF. *Determinants for success in climbing: A systematic review*. J. Exerc. Sci. Fit. 2019; 17(3): 91–100.
21. Li L, Ru A, Liao T, Zou S, Niu Xh, Wang Yt. E*ffects of rock climbing exercise on physical fitness among college students: a review article and meta-analysis*. Iran J. Public Health 2018; 47(10):1440–1452.
22. Lutter C, El-Sheikh Y, Schöffl I, Schöffl V. *Sport climbing: medical considerations for this new Olympic discipline*. Br. J. Sports. Med. 2017; 51(1): 2–3.
23. Fanchini M, Violette F, Impellizzeri FM, Maffiuletti NA. *Differences in climbing-specific strength between boulder and lead rock climbers*. J. Strength Cond. Res. 2013; 27(2): 310–314.

24. Draper N, Giles D, Schöffl V, Fuss FK, Watts P, Wolf P et al. *Comparative grading scales, statistical analyses, climber descriptors and ability grouping: International Rock Climbing Research Association position statement*. Sports Technology 2015; 8(3–4): 88–94.

25. Eng RC. *Góry wolność i przygoda. Od alpinizmu do trekingu*. Lodz: Galaktyka; 2014.

26. Zieliński G, Zięba E, Ginszt M. *Determining the index of injuries requiring specialist treatment during boulder climbing on an artificial climbing wall*. J. Educ. Health Sport 2019; 9(9): 90–93.

27. Stien N, Saeterbakken AH, Hermans E, Vereide VA, Olsen E, Andersen V. *Comparison of climbing-specific strength and endurance between lead and boulder climbers*. PLoS One [Internet]. 2019 [cited 9 December 2019]; 14(9). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6752829/

28. Luttenberger K, Stelzer E-M, Först S, Schopper M, Kornhuber J, Book S. *Indoor rock climbing (bouldering) as a new treatment for depression: study design of a waitlist-controlled randomized group pilot study and the first results*. BMC Psychiatry 2015; 15: 201.

29. Lin C-Y, Kuo S-H. *The role of the cerebellum in rock climbing*. J. Neurol. Sci. 2017; 383:158–160.

30. Di Paola M, Caltagirone C, Petrosini L. *Prolonged rock climbing activity induces structural changes in cerebellum and parietal lobe*. Hum. Brain Map. 2013; 34(10): 2707–2714.

31. Hs L, Cs S. *Effects of therapeutic climbing activities wearing a weighted vest on a child with attention deficit hyperactivity disorder: a case study*. J. Phys. Ther. Sci. 2015; 27(10): 3337–3339.

32. Wallner S. *Psychologisches Klettern: Klettern als Mittel klinisch – undgesundheitspsychologischen Handelns*. Psychol. Öster. 2010; 5(30): 396–403.

33. Venazzi A, Swardfager W, Lam B, Siqueira J de O, Herrmann N, Cogo-Moreira H. *Validity of the QUADAS-2 in assessing risk of bias in Alzheimer's disease diagnostic accuracy studies*. Front Psychiatry [Internet]. 25 May 2018 [cited 27 January 2020]; 9. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5982207/

34. Cook C, Cleland J, Hegedus E, Wright A, Hancock M. *The creation of the diagnostic accuracy quality scale (DAQS)*. J. Man. Manip. Ther. 2014; 22(2): 90–96.

35. Bristol U of. QUADAS-2 | Bristol Medical School: Population Health Sciences | University of Bristol [Internet]. University of Bristol; [cited 24 May 2020]. Available from: https://www.bristol.ac.uk/population-health-sciences/projects/quadas/quadas-2/

36. Schwarz L, Dorscht L, Book S, Stelzer E-M, Kornhuber J, Luttenberger K. *Long-term effects of bouldering psychotherapy on depression: benefits can be maintained across a 12-month follow-up*. Heliyon 2019; 5(12): e02929.

37. Stelzer E-M, Book S, Graessel E, Hofner B, Kornhuber J, Luttenberger K. *Bouldering psychotherapy reduces depressive symptoms even when general physical activity is controlled for: A randomized controlled trial*. Heliyon [Internet]. 23 March 2018 [cited 9 December 2019]; 4(3). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5968135/

38. Kleinstäuber M, Reuter M, Doll N, Fallgatter AJ. *Rock climbing and acute emotion regulation in patients with major depressive disorder in the context of a psychological inpatient treatment: a controlled pilot trial*. Psychol. Res. Behav. Manag. 2017; 10: 277–281.

39. Black JE, Isaacs KR, Anderson BJ, Alcantara AA, Greenough WT. *Learning causes synaptogenesis, whereas motor activity causes angiogenesis, in cerebellar cortex of adult rats*. Proc. Natl. Acad. Sci. USA. 1990; 87(14): 5568–5572.

40. Phillips JR, Hewedi DH, Eissa AM, Moustafa AA. *The cerebellum and psychiatric disorders*. Front Public Health [Internet]. 5 May 2015 [cited 29 January 2020]; 3. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4419550/
41. Torrico TJ, Abdijadid S. *Neuroanatomy, limbic system*. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2020 [cited 19 May 2020]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK538491/
42. Suchanecka A. *Rola dopaminy w procesach motywacyjnych i powstawaniu uzależnień*. In: Neurokognitywistyka w patologii i zdrowiu, 2011–2013. Szczecin: Pomeranian Medical University 2013. P. 158–161.
43. Gryz M, Lehner M, Wisłowska-Stanek A, Płaźnik A. *Dopaminergic system activity under stress condition – seeking individual differences, preclinical studies*. Psychiatr Pol. 2018; 52(3): 459–470.
44. Juárez Olguín H, Calderón Guzmán D, Hernández García E, Barragán Mejía G. *The role of dopamine and its dysfunction as a consequence of oxidative stress*. Oxid Med Cell Longev [Internet]. 2016 [cited 10 January 2020]; 2016. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4684895/
45. Belujon P, Grace AA. *Dopamine system dysregulation in major depressive disorders*. Int. J. Neuropsychopharmacol. 2017; 20(12): 1036–1046.
46. Cawley E, Tippler M, Coupland NJ, Benkelfat C, Boivin DB, Aan Het Rot M et al. *Dopamine and light: effects on facial emotion recognition.* J. Psychopharmacol. (Oxford) 2017; 31(9): 1225–1233.
47. Zwierzyńska E, Pietrzak B. *Patogeneza uzależnień – problem wciąż aktualny*. Alcohol. Drug Add. 2014; 27(2):163–175.
48. Redgrave P, Prescott TJ, Gurney K. *Is the short-latency dopamine response too short to signal reward error?* Trends Neurosci. 1999; 22(4): 146–151.
49. Young AM, Ahier RG, Upton RL, Joseph MH, Gray JA. *Increased extracellular dopamine in the nucleus accumbens of the rat during associative learning of neutral stimuli*. Neuroscience 1998; 83(4): 1175–1183.
50. Saul D, Steinmetz G, Lehmann W, Schilling AF. *Determinants for success in climbing: A systematic review.* J. Exerc. Sci. Fit. 2019; 17(3): 91–100.
51. Baláš J, Giles D, Chrastinová L, Kárníková K, Kodejška J, Hlaváčková A et al. *The effect of potential fall distance on hormonal response in rock climbing*. J. Sports. Sci. 2017; 35(10): 989–994.
52. Clark D, Ivry RB. *Multiple systems for motor skill learning*. Wiley Interdiscip Rev Cogn Sci. 2010; 1(4): 461–467.
53. Steimer J, Weissert R. *Effects of sport climbing on multiple sclerosis*. Front Physiol [Internet]. 19 December 2017 [cited 10 January 2020]; 8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5742106/
54. Buechter RB, Fechtelpeter D. *Climbing for preventing and treating health problems: a systematic review of randomized controlled trials*. Ger. Med. Sci. 2011; 9: Doc. 19.
55. Visted E, Vøllestad J, Nielsen MB, Schanche E. *Emotion regulation in current and remitted depression: a systematic review and meta-analysis*. Front Psychol [Internet]. 2018 [cited 10 January 2020]; 9. Available from: https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00756/full

56. Josefsson T, Lindwall M, Archer T. *Physical exercise intervention in depressive disorders: meta-analysis and systematic review*. Scand. J. Med. Sci. Sports 2014; 24(2): 259–272.

57. Silveira H, Moraes H, Oliveira N, Coutinho ESF, Laks J, Deslandes A. *Physical exercise and clinically depressed patients: a systematic review and meta-analysis*. Neuropsychobiol. 2013; 67(2): 61–68.

58. Craft LL, Perna FM. *The benefits of exercise for the clinically depressed.* Prim. Care Companion. J. Clin. Psychiatry 2004; 6(3): 104–111.

59. Pedersen BK, Hoffman-Goetz L. *Exercise and the immune system: regulation, integration, and adaptation*. Physiol Rev. 2000; 80(3): 1055–1081.

60. Miller AH, Timmie WP. *Mechanisms of cytokine-induced behavioral changes: psychoneuroimmunology at the translational interface Norman cousins lecture*. Brain Behav. Immun. 2009; 23(2): 149–158.

61. Haroon E, Raison CL, Miller AH. *Psychoneuroimmunology meets neuropsychopharmacology: translational implications of the impact of inflammation on behavior*. Neuropsychopharmacology 2012; 37(1):137–162.

62. Gałecki P. *Teoria zapalna depresji — podstawowe fakty.* Psychiatria 2012; 9(2): 68–75.

63. Pukajło K, Kolackov K, Łaczmański Ł, Daroszewski J. *Irisin – a new mediator of energy homeostasis*. Postępy Hig. Med. Dośw. (Online). 21 luty 2015; 69: 233–242.

64. Benedini S, Dozio E, Invernizzi PL, Vianello E, Banfi G, Terruzzi I et al. *Irisin: a potential link between physical exercise and metabolism—an observational study in differently trained subjects, from elite athletes to sedentary people.* J. Diabetes Res. [Internet]. 2017 [cited 21 May 2020]; 2017. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5366762/

65. Chen N, Li Q, Liu J, Jia S. *Irisin, an exercise-induced myokine as a metabolic regulator: an updated narrative review.* Diab. Metab. Res. Rev. 2016; 32(1): 51–59.

66. Wang S, Pan J. *Irisin ameliorates depressive-like behaviors in rats by regulating energy metabolism*. Biochem. Biophys. Res. Commun. 2016; 474(1): 22–28.

67. Tu W-J, Qiu H-C, Liu Q, Li X, Zhao J-Z, Zeng X. *Decreased level of irisin, a skeletal muscle cell-derived myokine, is associated with post-stroke depression in the ischemic stroke population*. J. Neuroinflam. [Internet]. 2 maja 2018 [cited 21 May 2020]; 15. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5932807/.

68. Rawson RA, Chudzynski J, Gonzales R, Mooney L, Dickerson D, Ang A et al. *The impact of exercise on depression and anxiety symptoms among abstinent methamphetamine-dependent individuals in a residential treatment setting*. J. Subst. Abuse Treat. 2015; 57: 36–40.

69. Cecchini-Estrada J-A, Méndez-Giménez A, Cecchini C, Moulton M, Rodríguez C. *Exercise and Epstein's TARGET for treatment of depressive symptoms: A randomized study*. Int. J. Clin. Health Psychol. 2015; 15(3): 191–199.

70. Schöffl VR, Hoffmann G, Küpper T. *Acute injury risk and severity in indoor climbing – a prospective analysis of 515,337 indoor climbing wall visits in 5 years*. Wilderness Environ. Med. 2013; 24(3): 187–194.

71. Videbæk S, Bueno AM, Nielsen RO, Rasmussen S. *Incidence of running-related injuries per 1000 h of running in different types of runners: a systematic review and meta-analysis*. Sports Med. 2015; 45(7):1017–1026.

72. Birrer RB, O'Connor FG, Kane SF, editors. *Musculoskeletal and sports medicine for the primary care practitioner*. 4th ed. Boca Raton: CRC Press, Taylor & Francis Group; 2016, 842.

73. Grønhaug G. *Self-reported chronic injuries in climbing: who gets injured when?* BMJ Open Sport Exerc. Med. [Internet]. 17 lipca 2018 [cited 3 April 2019]; 4(1). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6059297/
74. McGuire JL, Ngwenya LB, McCullumsmith RE. *Neurotransmitter changes after traumatic brain injury: an update for new treatment strategies*. Mol. Psychiatry 2019; 24(7): 995–1012.
75. Sahler CS, Greenwald BD. *Traumatic brain injury in sports: a review*. Rehab. Res. Pract. [Internet]. 2012 [cited 22 May 2020]; 2012. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3400421/

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