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PRACA POGLĄDOWA
REVIEW

Exercise-induced hypoalgesia in response to different exercise types and intensities: A narrative review

Hipoalgezja wywołana wysiłkiem fizycznym w odpowiedzi na różne rodzaje i intensywność ćwiczeń – przegląd narracyjny

Barbara Boba[1], Sylwia Bryksy[1], Barbara Chojnacka[1], Patrycja Kolano[2], Jerzy Krzeszowiak[3], Agnieszka Przybyłowska[4], Julia Wątor[5], Alicja Podolska[6], Aleksandra Ożga[7]

[1]5th Military Clinical Hospital with Polyclinic SPZOZ in Krakow, Poland
[2]Centrum Medyczne w Łańcucie Sp. z o.o. / Medical Center in Łańcut, Poland
[3]Department of Medical Education, Jagiellonian University Medical College in Krakow, Poland
[4]Szpital św. Anny w Miechowie / St. Anne's Hospital in Miechów, Poland
[5]Samodzielny Publiczny Zakład Opieki Zdrowotnej MSWiA w Krakowie / Independent Public Healthcare Facility of the Ministry of Interior and Administration in Krakow, Poland
[6]The University Hospital in Krakow, Poland
[7]Warszawski Szpital Południowy Sp. z o.o. / Warsaw Southern Hospital, Poland

ABSTRACT

It has been documented in the literature that physical activity can lead to hypoalgesia. The aim of this review is to provide insight into the effects that different exercise programs have on the pain threshold of pain-free individuals. Two databases, PubMed and Google Scholar, were searched. A total of 13 studies were included in this review. The results indicate that, in most cases, exercise leads to an exercise-induced hypoalgesia (EIH) response of various type and intensity. The EIH effect can occur after stationary cycling, treadmill running, dancing, functional training, submaximal isometric exercises, and dynamic exercise programs. However, in some studies, the expected EIH effect was not achieved. This applies to upper limb aerobic exercise, resistance training, and cycling. The literature on the relationship between exercise intensity and the EIH response is ambiguous, with some studies revealing a positive correlation and others showing different results. Various exercise programs can result in EIH in healthy individuals. However, more research is needed to discover what type and intensity of exercise is most effective in inducing hypoalgesia.

KEYWORDS

exercise-induced hypoalgesia, pain pressure threshold, physical exercise, sport, pain tolerance

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Address for correspondence: lek. Barbara Boba, 5. Wojskowy Szpital Kliniczny z Polikliniką SPZOZ w Krakowie, ul. Wrocławska 1–3, 30-901 Kraków, tel. +48 515 544 315, e-mail: bboba@su.krakow.pl

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STRESZCZENIE

W literaturze udokumentowano, że aktywność fizyczna może prowadzić do hipoalgezji. Celem niniejszego przeglądu jest przedstawienie wpływu różnych programów ćwiczeń na próg bólu u osób niedoświadczających bólu przewlekłego. Przeanalizowano dwie bazy danych – PubMed i Google Scholar. Uwzględniono łącznie trzynaście badań. Wyniki wskazują, że w większości przypadków wysiłek fizyczny, niezależnie od jego rodzaju i intensywności, prowadzi do hipoalgezji indukowanej wysiłkiem (*exercise-induced hypoalgesia* – EIH). Efekt EIH może wystąpić po jeździe na ergometrze rowerowym, bieganiu na bieżni, tańcu, treningu funkcjonalnym, submaksymalnych programach ćwiczeń izometrycznych i dynamicznych. Jednak w niektórych badaniach nie osiągnięto oczekiwanego efektu EIH. Dotyczy to ćwiczeń aerobowych kończyn górnych, treningu oporowego i jazdy na rowerze. Literatura dotycząca związku między intensywnością ćwiczeń a reakcją EIH jest niejednoznaczna – niektóre badania wykazują dodatnią korelację, inne zaś odmienne wyniki. Różne programy ćwiczeń mogą prowadzić do EIH u zdrowych osób. Potrzebne są jednak dalsze badania, aby ustalić, jaki rodzaj ćwiczeń i ich intensywność jest najskuteczniejsza w wywoływaniu hipoalgezji.

SŁOWA KLUCZOWE

hipoalgezja indukowana wysiłkiem, próg bólu ciśnieniowego, ćwiczenia fizyczne, sport, tolerancja bólu

INTRODUCTION

Pain is often a chief complaint of patients visiting doctors [1] and in some cases there are still no effective means to treat it. Therefore, it is a subject of interest for scientists to find the factors that determine pain sensitivity in humans. Over the past few decades, researchers have investigated the influence of physical exercise on pain perception [2]. Many studies have been conducted to determine the effect it has on both healthy individuals and patients experiencing chronic pain. Exercise has already been proven to increase pain threshold in healthy adults [3]. This phenomenon is commonly known as exercise-induced hypoalgesia (EIH).

The mechanism of EIH has been frequently studied in the hope of explaining the phenomenon, as it is still not fully understood. Animal research on rats suggests that the analgesic effect of stress coming from swimming can be mediated by endogenous opioid pathways, although when combined with more severe stress, analgesia seems to be induced by non-opioid substances [4]. However, the results from research on humans are inconsistent. There is evidence supporting the involvement of opioid and endocannabinoid systems in the phenomenon [5], but this was not confirmed by another study, which proposed non-opioid pathways to be responsible for EIH [6]. Moreover, research on mice reveals that EIH can result from changes in the mesocorticolimbic system of the brain – more specifically, in the amygdala, which is responsible for emotional regulation [7]. Conditioned pain modulation (CPM) is another potential factor that may contribute to EIH. CPM refers to the net effect of descending pain pathways in which the central nervous system is involved [8]. In practice, CPM can result in endogenous hypoalgesia when another painful stimulus, such as contact with heat or cold, is applied ("pain inhibits pain") [9]. Some studies have found a correlation between the EIH response and CPM, suggesting that these pathways can be at least partially responsible for EIH [10].

There might be some differences in the effect of exercise on pain threshold and pain perception in patients already experiencing pain; research on this topic remains ambiguous. Some findings suggest that EIH cannot be achieved through isometric exercise in this population [11]. In patients suffering from reumathoid arthritis, health-enhancing physical activity (strength training and aerobic exercise) did reduce global pain, but did not reduce pressure pain sensitivity [12]. In patients with lower back pain, EIH might be achieved through core stabilization exercises [13], but not through repeated lifting [14]. In the case of knee osteoarthritis, exercise has been found to cause hyperalgesia in some patients, but the EIH response in other patients was associated with better treatment outcomes [15]. Patients suffering from patellofemoral tendinopathy reported EIH after isometric and dynamic resistance exercise, but the effect was temporary and minimal [16]. Whiplash-associated disorder has also been found to negatively influence EIH in one study [17], with only a partial response during exercise. However, other research shows that EIH can be achieved through isometric – but not aerobic – exercise in this population [18]. Another study on healthy subjects found that there was no difference in the EIH response in muscles free of pain versus muscles subjected to painful injections [19].

This review investigates the effect of different types of exercise on the pain threshold of healthy adults. It examines a variety of exercise types and intensities that have been studied to better understand EIH. Discovering what exactly should be done to achieve EIH in the most efficient way can facilitate further research on the topic.

METHODS

The literature on the subject was analyzed by searching for the keywords "exercise-induced hypoalgesia" in two databases: PubMed and Google Scholar. The inclusion criteria were healthy, pain-free subjects, randomization in the study design, and pressure pain tolerance (PPTol) as an outcome measure. All included studies were published within the last 10 years. Studies investigating the effect of blood flow restriction on EIH were excluded. As a result, 13 studies were selected for this review.

RESULTS

Cycling

Four of the studies examined the EIH effect after cycling. A randomized controlled crossover trial investigated different cycling intensities [20]. In it, 25 healthy men aged 18–30 conducted four exercise sessions on a stationary bicycle equipped with an ergometer at 60%, 80%, 100%, or 110% of their individual anaerobic threshold (IAT). Each cycling session lasted 30 min and they were performed in a randomized order. IAT was based on blood lactate level measured during baseline tests. Pressure pain threshold (PPT) and CPM were measured 5 min prior to and 5 and 45 min after exercising. To measure PPT, pressure was applied to the forehead, sternum, elbows, knees, and ankles. After the exercise session, a statistically significant increase in PPT was observed at all sites apart from the forehead. Based on the results of this study, no specific relationship between the intensity of cycling and EIH can be established. Nonetheless, post hoc analysis showed that higher intensity exercise (100% and 110% of IAT) can induce a greater EIH response.

Another randomized controlled crossover study assessed the potential of short isokinetic cycling to induce EIH [21]. The subjects – healthy, physically active men aged 18–35 years – were asked to participate in three intervention sessions: 90 or 15 seconds of isokinetic cycling and a control session. Exercise was performed after a 15-min warm-up at 50% of IAT. PPT was measured pre-intervention, post-warm-up, and post-intervention, at the forehead, sternum, elbows, knees, and ankles as with the previous study. The results indicate that both 90 and 15 s of isokinetic cycling induced the EIH response. A higher increase in PPT was observed after the 90-s exercise protocol, but this difference was only noted at the ankles and knees. It was also the only intervention in which EIH was greater at the sites being exercised than the other locations.

The third study investigated the influence of exercise duration on EIH response. Healthy men aged 18–35 who were not highly active were recruited [22]. They conducted three cycling sessions at sub-maximal intensity on a stationary bicycle with an ergometer for 30, 45, or 60 min in a randomized order. The control session was a 30-min rest period 30 min prior to the exercise session. PPT measurements were taken before and after each exercise session at the same sites as in the previous studies. In this study, no EIH response was observed after any exercise protocol based on PPT changes.

The fourth study also examined the effect of aerobic cycling at different intensities on EIH [23]. Pain-free individuals aged 18–25 years took part in four sessions in a randomized order: three stationary cycling sessions at 30%, 50%, and 70% of heart rate reserve (HRR) and one rest session. PPT and temporal summation of pain (TSP) were measured before and after each session in the quadriceps, biceps, and trapezius muscles. An EIH response based on changes in PPT occurred after all exercise sessions at both the exercised and distant locations. Furthermore, a weak positive correlation between cycling intensity and EIH magnitude was observed in the exercised muscles. There was no such correlation with the distant locations. No relationship between exercise intensity and TSP changes was observed.

Running

Running is another type of exercise that has been studied in terms of inducing EIH. In one, the effects of different intensities of treadmill running on EIH were investigated [24]. All participants were women aged 18–30 years, randomly assigned to three groups of exercise intensities: 40%, 55%, and 70% of HRR. Each exercise session lasted 35 min and consisted of running for five intervals every 5 min. No control group was created. Measurements of PPT (in the arm and leg) and PPTol were taken before the exercise, during every interval, and after exercising, as a follow-up. CPM was tested before and 24 h after the session. To check for a possible long-lasting EIH, all measurements were taken 24 h post-exercise. The study found that moderate- and low-intensity exercise induced a significantly greater EIH effect than high-intensity exercise, although all protocols resulted in an EIH response. There was no significant difference between the 40% and 55% HRR groups. PPTol was also higher in the moderate-intensity group than the high-intensity one, indicating that some central mechanisms influenced by exercise may play a role in generating the EIH response. In a preprint of another study, the effect of 4 weeks of treadmill running at different intensities on EIH magnitude was investigated [25]. A group of healthy students aged 18–30 was asked to perform 12 running sessions lasting 30 min within a 4-week period. The intensities were set based on target heart rate at 40%, 55%, or 70% of HRR. The participants were randomly assigned to these groups; there was no control group. The primary outcome was a change in PPT at the leg, as a local EIH response, and PPT in the arm, as a global EIH response. Other outcome measures included CPM, TSP, and mechanical pain threshold (MPT). Measurements were taken before the intervention, before and after the running session, and 24 h afterwards. The results indicate that high- and low-intensity running can only cause short-term EIH. Moreover, an acute EIH response increased with exercise duration during low- and moderate-intensity exercise, but decreased after high-intensity running. The EIH response measured by changes in MPT decreased over time during high-intensity running and remained unaltered during low- and moderate-intensity running.

Upper limb exercise

One study investigated the relationship between different protocols of upper limb exercise and EIH [26]. Healthy subjects aged 18–55 years were randomly divided into two groups. Each group was first asked to rest in a sitting position for 20 min; control measurements were taken before and after this session. Next, they underwent two protocols consisting of 20 min of aerobic exercise in a randomized order. The intensity was targeted to either 60% of HRR or a rate of perceived exertion of 7/10 on the Borg scale. To assess EIH response, PPT, heat pain threshold (HPT), and tonic heat pain (THP) were measured. The results revealed that moderate-intensity upper-limb exercise did not lead to an EIH response, as there was no significant difference in PPT, HPT and THP between the exercise and control conditions.

Dance therapy

One study examined the EIH response after dance movement therapy (DMT) [27]. Healthy adult participants were randomly assigned to three groups: single DMT, double DMT, and a control group. In the single DMT group, the subjects underwent an individual intervention, whereas the double DMT subjects exercised together with an instructor. The exercise type was moderate-intensity aerobics. PPT was used to assess pain threshold; functional near-infrared spectroscopy (fNIRS) while performing the Color-Word Stroop Task reflected changes in prefrontal cortex function; and a Self-Assessment Manikin was used to measure the dimensions of pleasure and arousal. The results showed significantly greater changes in PPT in the DMT groups compared to the control group, which confirms the presence of an EIH response. The effect can last up to 1 hour after the exercise. Moreover, compared with the control conditions, DMT significantly activated the ventrolateral (left) and dorsolateral (bilateral) prefrontal cortex on fNIRS. These regions are believed to be responsible for some cognitive functions. The DMT group also showed improvement in cognitive task execution and positive emotional activity. Finally, based on the results, the study hypothesized that dorsolateral prefrontal cortex activation may play a role in inducing the EIH response after DMT.

Resistance exercise

One randomized control trial investigated the relationship between dynamic resistance exercise intensity and EIH [28]. Subjects aged 18–60 were divided into three groups and each of them participated in one of three procedures: high-intensity exercise (75% of the subject's one-repetition maximum), low-intensity exercise (30% of the subject's one-repetition maximum), or rest. One exercise session included ten repetitions of three sets of exercises. Measurements of PPT, HPT, TSP, and CPM were taken before the intervention. PPT was then measured after each set and CPM was tested after the whole intervention. There was no significant difference in PPT or CPM changes between groups, which indicated that dynamic resistance exercise did not cause EIH, regardless of intensity.

Submaximal isometric exercise

Two studies aimed to examine the effect of submaximal isometric exercise on EIH. One of them [29] included healthy subjects aged 18–30 years, participating in three sessions. The control session (15 min of rest) was performed followed by two sessions of 12 min of rest plus 3 min of isometric knee extensions of the dominant lower leg at 30% of maximal voluntary contraction (MVC). Before and after each exercise session, measurements of either PPT and PPTol or HPT were taken. All measurements were also taken before and after the rest sessions. PPT and PPTol were assessed using computer-controlled cuff-algometry, whereas HPT was measured by a computer-controlled surface thermode. The results revealed that this type of exercise only affected pain tolerance, but not pressure or heat pain threshold in healthy young men. Moreover, contrary to HPT, PPT was not significantly affected by rest, which makes this measure more reliable for assessing EIH. The second study investigated the EIH response after different intensities of submaximal isometric exercise [30]. Healthy young women were included in this study and randomly assigned to one of three study protocols: elbow flexions at 20% or 40% of MVC and a control. There were two phases in each protocol, separated by a 48-h wash-out period. In the first one, PPT and pressure pain ratings (PPR) were assessed; the second one included HPT measurements and electroencephalography (EEG) recording. Heat-evoked potentials (HEPs), specifically N2 and P2 waves, were included to reflect the processing of pain information in the brain. PPT and HPT were measured locally in the hand and arm of the exercised limb. PPR was assessed by applying force to the index finger of the unexercised limb. The study found a significant increase in PPT and HPT in the exercised limb, as well as lower PPR in the other limb after both low- and moderate-intensity isometric exercise, indicating the presence of a local and global EIH response. However, there was no significant change in heat pain rating (HPR) in the unexercised limb, which showed that the EIH response could vary depending on the pain modality under study. Moreover, there was a positive correlation between exercise intensity and the magnitude of the local EIH effect. EEG recordings supported this evidence, since the HEPs were significantly correlated with subjective pain sensitivity, which suggests that the EIH effect could depend on central pain modulation mechanisms.

Isometric vs. dynamic exercise

One of the studies compared the effects of isometric and dynamic exercise on the EIH response [31]. It enrolled healthy students aged 18–23 years and randomly divided them into two groups. They performed either a submaximal isometric exercise session or a short-duration dynamic exercise session. The isometric exercise protocol included squeezing a handheld dynamometer, whereas the dynamic exercise group was asked to squeeze and then release the device. PPT was measured in both forearms during the first resting session and after the training. The study found that both isometric and dynamic exercises induced an EIH response, with no significant difference in magnitude between the groups.

High-intensity functional training

One study examined the effect of high-intensity functional training (HIFT) on the EIH response [32]. The subjects were physically active, healthy, and aged 18 to 35 years. Since the study was designed as a randomized controlled crossover trial, they all performed a session of 12 min of HIFT and a supervised deep breathing session, in random order. HIFT is a new training method based on high-intensity interval training that incorporates both strength-building and aerobic exercise with little or no equipment and a relatively short duration. Measurements of PPT were taken from elbows, knees, ankles, and forehead before and after each session. The study found that HIFT induced global hypoalgesia, though there was a difference between the male and female groups: the effect was only present among the male participants. Changes of PPT were greater in the lower limbs than the forehead, indicating that the EIH effect is more likely in exercised locations than in distant ones.

DISCUSSION

The aim of this review was to investigate the effect of different exercise types and intensities on the EIH effect. The results turned out to be ambiguous. In three of the studies, the subjects did not present any EIH response after exercise. These studies focused on resistance training [28], cycling [22], and upper limb exercise [26]. One study investigating submaximal isometric exercise revealed increased pain tolerance, but not pain threshold in the participants [29]. HIFT was found to cause hypoalgesia, but only in male subjects [32]. According to the remaining three studies examining cycling [20,21,23], two other studies investigating submaximal isometric exercise [30,31], and those which assessed running [24,25], dance therapy [27], and dynamic exercise [31], physical exercise did cause hypoalgesia.

Among the studies selected for the review – one investigating cycling [23] and the other submaximal isometric exercise [30] – two found a positive correlation between exercise intensity and magnitude of the EIH response. This applied only to a local EIH effect. In one study, post hoc analysis showed that cycling at higher intensities resulted in a greater EIH response; however, at first the results did not reveal such correlation [20]. Contrary to these results, one study on running found that moderate- and low-intensity exercise induced greater hypoalgesia [24]. The second study showed a more long-lasting effect after these intensities, with an acute EIH response after high- and low-intensity running [25].

These results seem to be consistent with the literature in most aspects. A meta-analysis showed that isometric, dynamic resistance, and aerobic exercise can induce hypoalgesia. The effect size for isometric and dynamic resistance exercise was large, while for aerobic exercise it was moderate [3]. Although the studies included in this review confirmed the effect of aerobic and isometric exercise on hypoalgesia, they did not indicate resistance exercise as a contributing factor. There is evidence in the literature that EIH can occur consistently after high-intensity exercise, where intensity was measured by either workload or percentage of maximal oxygen uptake. The results were less consistent when the intensity was self-selected or measured by heart rate reserve [33]. The studies included in this review did not reveal a positive correlation between exercise intensity and the EIH response, when measuring exercise intensity by HRR [24,25]. One study measuring the intensity based on HRR did find a weak positive correlation [23]. The study on isometric exercise, which also found higher intensities of exercise to cause a greater EIH effect, based its assessment of exercise intensity on the percentage of MVC [30].

Furthermore, the systematic review assessing the reliability of EIH in pain-free subjects found it to be insufficient, but with a very low level of certainty. It also highlights that no minimal important change has been established while assessing EIH using the most common measurement tools [34].

CONCLUSIONS

This review provides insight into the current state of knowledge about how different types of exercise affect pain threshold in humans. Stationary cycling, treadmill running, dance therapy, HIFT, and isometric and dynamic exercise can result in an EIH response in healthy individuals. However, there are studies showing no effect of exercise on pain threshold. Exercise intensity can impact the EIH response, but the research results are inconsistent and vary depending on the type of exercise and the measurement tools for assessing intensity. Further research is needed to discover factors that determine EIH in healthy humans. More studies need to be done on other exercise types and different exercise intensities and durations to discover the most optimal way of inducing EIH.

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Conflict of interest

The authors declare no conflict of interest.

Authors' contribution

Study design – B. Boba, A. Podolska, A. Ożga

Data collection – B. Chojnacka, P. Kolano

Manuscript preparation – B. Boba, S. Bryksy

Literature research – J. Krzeszowiak, A. Przybyłowska, J. Wątor

Final approval of the version to be published – B. Boba, S. Bryksy, B. Chojnacka, P. Kolano, J. Krzeszowiak, A. Przybyłowska, J. Wątor, A. Podolska, A. Ożga

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