frontiers FOR YOUNG MINDS

HEALTH
Published: 24 May 2017
doi:10.3389/frym.2017.00022

MOVE!—BECAUSE EXERCISE CAN BOOST YOUR BRAINPOWER

Valentin Benzing and Mirko Schmidt*

Institute of Sport Science, University of Bern, Bern, Switzerland

REVIEWED BY:

PETERHEAD ACADEMY
11–15 YEARS OLD

Have you ever considered preparing for an exam by doing physical exercise? Would it not be great to go outside and play capture the flag or double Dutch with your friends instead of doing math? Of course, you already know that this is wishful thinking. Everyone has to prepare carefully and learn attentively if they want to do better on their exams. However, it is also true that physical activity can boost your brainpower. In the following article, we are going to talk about when and to what extent physical activity is beneficial to your brain and under what circumstances positive effects can occur.

INTRODUCTION

Most people know that **physical activity** is important for their physical health. People who are more physically active have a smaller risk of getting ill (for example, developing heart disease), they tend to live longer and they have a higher quality of life [1]. Because of this, an average of at least 60 min of physical activity per day is recommended for children and teenagers. Unfortunately, fewer and fewer children and teens are getting the recommended amount of exercise—sedentary (seated or inactive) behavior is increasing, especially in developed countries (http://www.activehealthykids.org).

PHYSICAL ACTIVITY

Any movement of the body that is produced by muscles and uses up energy. In other words, any movement we do using our muscles. It therefore includes running to catch a train, for example [3].

PHYSICAL EXERCISE

Includes at least four factors: (1) Planning: you have to plan the exercise; for example, my plan is to go to soccer training. (2) Structured: you need to follow a certain structure; for example, I start with a warm-up before I start practicing corners. (3) Repetitive: doing it on a regular basis is important; for example, my soccer training takes place every Monday. (4) Objective: a purpose, such as staying fit/getting fitter, becoming better at sports or winning a sports contest [3].

Lack of exercise is not just a cause for concern because **physical exercise** is good for physical health, but because there is a connection between physical activity and the human brain. You may have heard the saying "be smart, exercise your heart"? [2] Well, a large amount of research has been conducted that shows that physical exercise has positive effects on the brain [3]. This research indicates that exercise can boost your brainpower under certain circumstances. More specifically, this means that physical activity can help the brain to work better and more efficiently. These effects can occur right away after a single session of physical activity, or they can be noticeable after multiple sessions of regular physical exercise. For this reason, the effects can be categorized as being either immediate (after a single session of physical activity) or long-term effects (after multiple sessions of physical exercise).

A LITTLE PHYSICAL ACTIVITY CAN BOOST BRAINPOWER IMMEDIATELY

Research has been done to examine the question of whether physical activity can immediately improve brainpower. *Imagine you are at school, and you know that you will have to take an exam right after recess. You are wondering how you should spend your recess. Should you go to the school yard and play tag, or should you watch YouTube videos on your phone? What would help you to do better on the exam?*

Many studies show that a short period of physical activity (e.g., 10–20 min) can help you to perform better on a variety of cognitive tasks immediately after the activity [3]. These effects have been seen in children [4], teens [5], and adults and are therefore important at every age. With regard to the question of how to spend your recess, it is possible that playing tag will help you to get a better grade on your exam.

REGULAR PHYSICAL EXERCISE BOOST BRAINPOWER, TOO

Research into the long-term effects of physical activity on the brain tries to answer the question of whether taking part in physical exercise on a regular basis can improve brainpower. In other words, here the question would be: *Should I go to a sports club and do some regular physical exercise (for example, three or four times a week for 45 min each time)? Can this physical exercise also help my brain to become more efficient?*

So far, studies have shown that physical exercise also has positive long-term effects on the brain (e.g., Ref. [6]). These studies show that even 6 weeks of regular exercise can make the brain function more efficiently. Furthermore, it has been shown that these positive effects can also improve school performance.

As you see, immediate and long-term effects are both highly important for performance at school, since physical activity can have positive effects on the functioning of the brain.

HOW DOES BEING ACTIVE HELP THE BRAIN?

Now, the exciting question is: how can we explain the positive effects of physical activity on brainpower? There is no simple answer—instead, there are multiple possible explanations, each of which is supported by its own research.

- *Explanation A (for immediate effects)*: Some researchers are focusing on the effects that physical activity might have on the body (e.g., Ref. [7]). In other words, if somebody engages in a physical activity, the body has to adapt to it. This adaptation can be characterized by different responses of the body. When you do a single session of physical activity, for example, the response by your body could be for your heart to beat faster. This faster heart beat might be related to the release of **hormones** into your blood stream. One example of a hormone that appears to be released during physical activity is called **cortisol** [8]. Cortisol has many functions, but one of them may be to make you more awake, and being more awake may affect the functioning of the brain immediately after the activity. This means that your brain will be able to perform better at a task when you do this task immediately after doing a physical activity.
- *Explanation B (for long-term effects)* [3, 6]: If you do physical exercise on a regular basis, your body has to adapt in the same way again and again. The heart has to pump faster and harder to move more blood around the body to supply the oxygen needed by the exercising muscles. As more blood is moved around your body, there may also be an increase in the amount of blood flowing to your brain. This increased blood flow to the brain carries more oxygen to the brain. When the brain gets more oxygen, it may function better because the brain needs oxygen to work properly. In this explanation, the key player is the heart, which drives the body's oxygen delivery system (blood). When the heart pumps faster, more fuel (oxygen) can be transported to the brain. This tells us that the brain can be trained by *any* kind of exercise that makes the heart pump faster, including things like running, jumping, and swimming.
- *Explanation C (for both immediate and long-term effects)* [6]: A different explanation is that you can actually train your brain *while* doing physical activities. That is because some elements of physical activities are also demanding for the brain. An example of this is copying complicated movements that require coordination, such as dance moves. During these movements, the brain has to (a) coordinate the eyes and follow the movements that are being demonstrated by the teacher; (b) remember the sequence of movements; (c) initiate the body's own movement; (d) coordinate the way all the muscles work together; and much more on top of this. So, it is clear that some forms of physical activities can also make demands on

HORMONES

Hormones are chemicals in the body that help the body to do certain things—for example, they help the body to grow, or to be awake. Usually, hormones are stored in the body, in which case they are not at work. When somebody speaks of hormone release, they mean that these hormones are now starting to work.

CORTISOL

Cortisol is a hormone that is released after physical exercise or stress. It helps the body to regulate itself and it is linked to brain function. Cortisol makes energy quickly available, which might be experienced as a state of being more awake.

your brain and therefore might train your brain as you are performing the activity. In this explanation, the key player is the brain, which is stimulated by the physical activity itself. This brain training might help the brain both immediately, right after the activity, and long-term, after regular periods of brain-challenging exercise. This research tells us physical activity and exercise should be challenging for the brain in order to achieve better brainpower afterward.

When you look at these explanations, you might find that they all make sense. This is not surprising, because there is research to support each of them and they do not necessarily contradict each other. Imagine some children were to do a short dance exercise several times a week, with the result that their brainpower was increased afterward. This might be explained by the bodily response to physical activity (explanation A), which leads to an increase in brainpower after each single session. This bodily response to single sessions might also occur after multiple sessions (explanation B), by bringing more oxygen into the brain and resulting in increased brainpower after long-term physical exercise. Since the children would have to copy new dance moves, which is a challenging exercise for the brain (explanation C), they would also be training their brains while being physically active.

By now, it should be clear to you that physical activity is good for the brain. But, exactly what kind of activity should we do to increase brainpower? The three explanations above seem to give us different pictures of what the physical activity should look like in order to produce the best effects. Explanations A and B tell us that no matter what type of activity is done, it needs to be strenuous enough to make the heart beat faster, while C tells us that the activity needs to be demanding for the brain as well. This is where our research comes in!

WHAT KIND OF PHYSICAL ACTIVITY IS BEST FOR BOOSTING BRAINPOWER?

The purpose of our research was to examine which type of physical activity (physically challenging vs. challenging for the brain) produces the best immediate and long-term effects on brainpower. We performed three different studies on a total of 344 children and teens.

In all three studies, participants were randomly assigned to at least one of three groups: the *control group*: a group which did not do any specifically challenging or non-challenging activity; the *bodyfit group*, which did physically challenging activity that *did not* specifically challenge the brain; and the *brainfit group,* which did an activity that was physically challenging *and* challenging for the brain.

FIGURE 1

The obstacle course of the bodyfit group in our study of how exercise affects brainpower. In this example of a playful form of exercise, children had to run, to the rhythm of the music, over the "hurdles" placed on the floor.

FIGURE 1

FIGURE 2

In **A.** and **B.**, two activities of the brainfit group are shown. **A.** Children had to lay down on the floor and react as fast as possible to either a red or a yellow ball, the color of the ball indicates, which child has to chase the other and which has to run away. **B.** Children played normal streetball. The teacher would blow a whistle suddenly, to tell the players that some rules of the game were changing immediately. Players then had to react appropriately.

FIGURE 2

In the study on long-term effects, children in the control group took part in regular physical education lessons. Children in the bodyfit group participated in an obstacle course. While listening to music, they had to run in a circuit (Figure 1). Children in the brainfit group played team games such as floorball (Figure 2A) and basketball (Figure 2B), which were specifically designed to be challenging for the brain because they require a lot of coordination.

The brain's performance was measured before and after each type of exercise. This was done using different tasks, such as the fish flanker task (Figure 3A) and the d2 test of attention (Figure 3B). These tasks are described in the figure legend. To measure the immediate effects, performance was measured right away after doing the physical activity and for long-term effects, performance measured before the exercise and after 6 weeks of training (two times a week, 45 min each time).

AND THE WINNER IS...?

In all three studies, we observed a similar pattern regardless of whether we were looking at immediate or long-term effects. The children and teens in the *brainfit* group performed the best in the brain performance tasks.

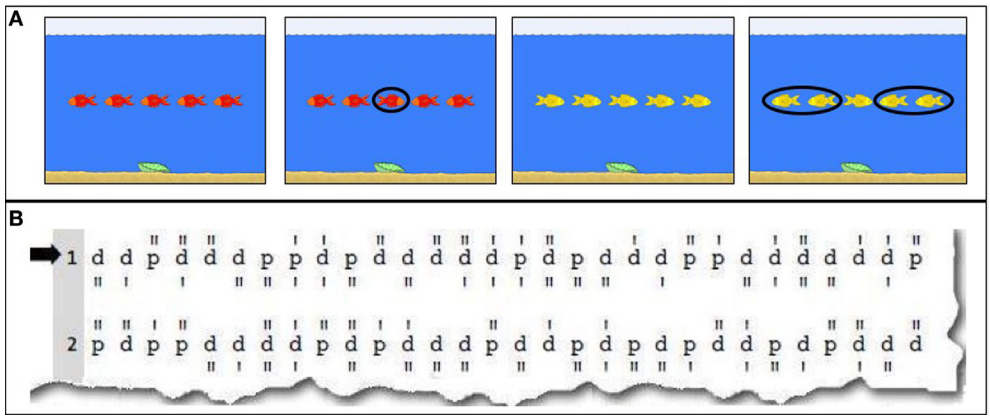

FIGURE 3

A. Fish flanker task: in this computerized task, children had to feed the fish. Therefore, two buttons were attached to a computer, one on the left and one on the right side. On the computer screen, fish were depicted. If all fish are swimming in the same direction (pictures 1 and 3), the task was quite easy and children had to press the button on the side the fish were swimming toward. However, if the fish were looking in different directions, the children had to press the respective button, dependent on the color of the fish and dependent on where the fish were swimming toward. For the red fish, they had to feed the fish in the middle (picture 2). So they had to check, where the fish in the middle is swimming toward and press this button. However, for the yellow fish the goal was to feed the fishes around the middle (picture 4), so they had to check were these fish are swimming toward and press this button. Red and yellow fish appeared in random order and children had to indicate which button to press case by case. **B.** The d2 Test of Attention (Brickenkamp et al., [9]; copyright by Hogrefe) was also used to test brainpower after exercise. You can try this yourself here on the paper! Cross out any letter "d" with two marks around it. Only cross out the ones with two marks and only the letter "d." Start now! You have a maximum of 20 s per line.

It therefore seems that an activity that is challenging for the brain *and* the body has a greater effect on brainpower. Our results therefore tell us that the *type* of physical activity can be important for increasing brainpower.

Of course, many other related factors could play a role in the effect of physical activity on brainpower as well, and attention should be paid to these, too. For example, a physical activity can vary in *intensity* (how hard it is)—from low to very high intensity. Imagine you are doing a very intense physical activity right before a math test. You might be tired during the test, which may not be the best state for your brain to be in. Similar to intensity, the *duration* (length of time it is done for) of a physical activity also seems to matter—in the sense that every activity becomes tiring after long durations. For immediate effects, short duration activities (10–20 min) of moderate intensity seem to be most effective with regard to brainpower; when it comes to long-term effects, at least half an hour per training session seems to be the necessary duration. Both the intensity and the duration also depend on the *age* of the children. The same physical activity may not be suitable for every child, because an activity may be too difficult for young children, whereas older children might not find it difficult enough. Therefore, an activity should be *optimally challenging* for the body and brain, meaning it should be the right level for the age and ability of the child. An optimal challenge is helpful in order to achieve one of the most important factors: children need to *enjoy* what they are doing. But do not worry, sometimes it takes a while to get used to a physical activity or to find the right one. So just keep trying out different activities and do not give up!

In summary, in our studies a physical activity that was demanding for the brain *and* physically challenging had the best effects on brainpower. We therefore conclude that the brain can be trained by performing physical activities and that the type of physical activity is a crucial factor. So spread the news: "move!—because exercise can boost your brainpower." If you want to train your body and your brain, just start doing exercise that you enjoy and that challenges your body and your brain!

ACKNOWLEDGMENTS

Our warmest thanks to all the children and teachers who participated in our studies. They did a great job! Thanks to everyone else who helped us to carry out these three studies. A special thanks to those who funded the three studies: The Federal Office of Sport (FOSPO), Magglingen, Switzerland; the Fondation Gaydoul; and the Swiss Cancer Research Foundation.

ORIGINAL ARTICLE REFERENCE

Schmidt, M., Jäger, K., Egger, F., Roebers, C. M., Conzelmann, A. 2015. Cognitively engaging chronic physical activity, but not aerobic exercise, affects executive functions in primary school children: a group-randomized controlled trial. *J. Sport. Exerc. Psychol.* 37(6):575–91. doi:10.1123/jsep.2015-0069

REFERENCES

1. Penedo, F. J., Dahn, J. R. 2005. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Curr. Opin. Psychiatry* 18(2):189–93. doi:10.1097/00001504-200503000-00013
2. Hillman, C. H., Erickson, K. I., Kramer, A. F. 2008. Be smart, exercise your heart: exercise effects on brain and cognition. *Nat. Rev. Neurosci.* (1):58–65. doi:10.1038/nrn2298
3. Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., et al. 2016. Physical activity, fitness, cognitive function, and academic achievement in children. *Med. Sci. Sport. Exerc.* 48(6):1197–222. doi:10.1249/MSS.0000000000000901
4. Schmidt, M., Benzing, V., Kamer, M. 2016. Classroom-based physical activity breaks and children's attention: cognitive engagement works! *Front. Psychol.* 7:1–13. doi:10.3389/fpsyg.2016.01474
5. Benzing, V., Heinks, T., Eggenberger, N., Schmidt, M. 2016. Acute cognitively engaging exergame-based physical activity enhances executive functions in adolescents. *PLoS ONE* 11(12):e0167501. doi:10.1371/journal.pone.0167501
6. Schmidt, M., Jäger, K., Egger, F., Roebers, C. M., Conzelmann, A. 2015. Cognitively engaging chronic physical activity, but not aerobic exercise, affects executive functions in primary school children: a group-randomized controlled trial. *J. Sport. Exerc. Psychol.* 37(6):575–91. doi:10.1123/jsep.2015-0069
7. McMorris, T. (ed.). 2016. Exercise–cognition interaction: state of the art and future research. *Exercise-Cognition Interaction*. Amsterdam: Elsevier Inc. p. 459–81.
8. Jäger, K., Schmidt, M., Conzelmann, A., Roebers, C. M. 2014. Cognitive and physiological effects of an acute physical activity intervention in elementary school children. *Front. Psychol.* 18(5):1473. doi:10.3389/fpsyg.2014.01473
9. Brickenkamp, R., Schmidt-Atzert, L., and Liepmann, D. 2010. *Test d2-Revision: Aufmerksamkeits-und Konzentrationstest.* Göttingen: Hogrefe.

SUBMITTED: 16 December 2016; **ACCEPTED:** 02 May 2017;
PUBLISHED ONLINE: 24 May 2017.

EDITED BY: Fulvio D'Acquisto, Queen Mary University of London, UK

CITATION: Benzing V and Schmidt M (2017) Move!—Because Exercise Can Boost Your Brainpower. Front. Young Minds 5:22. doi:10.3389/frym.2017.00022

CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REVIEWED BY

PETERHEAD ACADEMY, 11–15 YEARS OLD

We are three young reviewers from our class at Peterhead Academy. We completed the review with the help of our science mentor, Dr. Suleman Sabir.

AUTHORS

VALENTIN BENZING

I am currently a PhD student at the Institute of Sport Science of the University of Bern, Switzerland. I came to work at the Institute of Sport Science because I am passionate about sports, but before that I studied psychology to find out more about how the human brain works. Now, I am glad that I can combine both my interests in my research: I am investigating the effects of physical activity on the human brain. For example, we are looking into whether physical activity can enhance brainpower or serve as a "remedy" for certain illnesses. *valentin.benzing@ispw.unibe.ch

MIRKO SCHMIDT

As an Assistant Professor at the Institute of Sport Science of the University of Bern, I am particularly interested in how physical activities ought to be designed if they are to have a positive effect on children's and adolescents' physical and mental health. Having conducted several studies to investigate the role which physical activity plays in affecting the development of children's personality, my current research looks at how brainpower can be boosted by cognitively engaging physical activities. When I am not at work, I love to play in the garden with my two kids or to snowboard in the Alps with my wife.