# EFFECT OF THE PROBLEM-BASED LEARNING METHOD ON STUDENT ELECTROENCEPHALOGRAMS AND MICROCIRCULATORY BLOOD PERFUSION IN THE TEACHING OF SPORTS PHYSIOLOGY

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*EFEITO DO MÉTODO DE APRENDIZAGEM BASEADA EM PROBLEMAS EM ELETROENCEFALOGRAMAS E PERFUSÃO SANGUÍNEA MICROCIRCULATÓRIA DE ESTUDANTES NO ENSINO DE FISIOLOGIA DO ESPORTE*

*EFECTO DEL MÉTODO DE APRENDIZAJE BASADO EN PROBLEMAS EN ELECTROENCEFALOGRAMAS Y PERFUSIÓN SANGUÍNEA MICROCIRCULATORIA DE ESTUDIANTES EN LA ENSEÑANZA DE LA FISIOLOGÍA DEL DEPORTE*

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## ABSTRACT

Introduction: Applying the problem-based learning (PBL) method to the teaching of sports physiology. Objective: This study explored the mechanism of the PBL method to improve the interest and learning effectiveness of students. Methods: Twenty male students at the Physical Education College of Hubei Minzu University were randomly divided into a PBL group (10) and a traditional teaching method group (TTM). During the test, the subjects in the TTM group sat quietly listening to the experienced teacher, while the subjects in PBL group sat quietly and participated in a 20-minute group discussion under the guidance of the experienced teacher. Transcutaneous partial pressure of oxygen (TcPO2), microcirculatory blood perfusion (MBP), and alpha- and beta-band power were monitored at the beginning of and during the test. Results: The mean of the PBL-group quiz score was significantly higher than that of the TTM group. In the PBL group, the alpha power of the students decreased statistically in the F3, T3, P3, and O1 channels and the beta power of the students increased statistically in the F7, F3, T3, C3, P3, and O1 as compared to the baseline values. Conclusion: PBL can be an effective learning mechanism, since the students are actively engaged in the teaching of sports physiology. ***Level of Evidence I; Therapeutic studies - Investigating treatment results.***

**Keywords:** Teaching method; Electroencephalogram; Microcirculation.

## *RESUMO*

*Introdução: Aplicação do método de aprendizagem baseada em problemas (PBL) ao ensino da fisiologia do esporte. Objetivos: Este estudo explorou o mecanismo do método PBL para ampliar o interesse e a eficácia da aprendizagem dos estudantes. Métodos: Vinte estudantes do sexo masculino da Faculdade de Educação Física da Universidade Hubei Minzu foram divididos randomicamente em um grupo PBL (10) e um grupo de método de ensino tradicional (TTM). Durante o teste, os participantes do grupo TTM ficaram sentados e em silêncio ouvindo o professor experiente, enquanto os do grupo PBL ficaram sentados e participaram de uma discussão em grupo de 20 minutos de acordo com a orientação do mesmo professor. A pressão parcial do oxigênio transcutâneo (TcPO2), a perfusão sanguínea microcirculatória (MPB) e a potência das bandas alfa e beta foram monitoradas no início e durante o teste. Resultados: A média do escore do questionário do grupo PBL foi significativamente maior do que a do grupo TTM. No grupo PBL, o poder alfa dos estudantes diminuiu em termos estatísticos nos canais F3, T3, P3 e O1 e o poder beta dos estudantes aumentou nos canais F7, F3, T3, C3, P3 e O1 em comparação com os valores basais. Conclusão: O PBL pode ser um mecanismo eficaz de aprendizagem, uma vez que os estudantes ficam ativamente engajados no ensino da fisiologia do esporte.* ***Nível de Evidência I; Estudos terapêuticos - Investigação dos resultados do tratamento.***

***Descritores:*** *Método de ensino; Eletroencefalograma; Microcirculação.*

## *RESUMEN*

*Introducción: Aplicación del método de Aprendizaje Basado en Problemas (PBL), a la enseñanza de la fisiología del deporte. Objetivos: Este estudio exploró el mecanismo del* método *PBL para ampliar el interés y la eficacia del aprendizaje de los estudiantes.* Métodos*: Veinte estudiantes varones de la Facultad de Educación Física de la Universidad de Hubei Minzu fueron divididos aleatoriamente en el grupo PBL (10) y en un grupo de método de enseñanza tradicional (TTM). Durante la prueba, los participantes del grupo TTM permanecieron sentados y escuchando en silencio al profesor experimentado, mientras que los del grupo PBL permanecieron sentados y participaron en un debate de grupo de 20 minutos de acuerdo con la orientación del mismo profesor. La presión parcial de oxígeno transcutáneo*


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*(TcpO2), la perfusión sanguínea microcirculatoria (MBP) y la potencia de las bandas alfa y beta se monitorizaron al inicio y durante la prueba. Resultados: La puntuación media del cuestionario del grupo PBL fue significativamente mayor que la del grupo TTM. En el grupo PBL, la potencia alfa de los estudiantes disminuyó estadísticamente en los canales F3, T3, P3 y O1 y la potencia beta de los estudiantes aumentó en los canales F7, F3, T3, C3, P3 y O1 en comparación con los valores de referencia. Conclusión: El PBL puede ser un mecanismo de aprendizaje eficaz, ya que los estudiantes participan activamente en la enseñanza de la fisiología del deporte.* ***Nivel de evidencia I; Estudios terapéuticos - Investigación de los resultados del tratamiento.***

***Descriptores:*** *Método de enseñanza; Electroencefalografía; Microcirculación.*

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## INTRODUCTION

Sports physiology, a branch of physiology, plays a bridge role between sports and medical knowledge. Students, major in physical education, need to acquire physiology knowledge and improve their understanding of sports medicine through their learning in this course. However, sports physiology teaching faces some unique difficulties compared with other PE theory classes or PE skilles. For instance, Sports majors have no medical background, so it is too difficult for them to understand. Problem-Based Learning (PBL) is defined as the "learning that results from the process of working toward the understanding or resolution of a problem" under the guidance of an experienced tutor.[1] Compared to typical of traditional teaching methods and passive information transmission, this approach stimulates students to play an active role in the learning process, which may improve the student's ability to explain physiological phenomena in sports field.

Numerous studies have found that in physiology teaching, the PBL mode presents certain advantages in improving students' learning effect.[2,3] A study by Durand et al., suggested that PBL has a positive impact on students' learning and motivates them toward self-study in practical classes.[2] Bhattacharya demonstrated that PBL was feasible even in a traditional set-up despite limited resources, rigid time schedules and little interaction among various disciplines in undergraduate classes.[3] Furthermore, Carvalho et al found active learning can strengthen students' lifelong learning goals.[4] So PBL is an effective teaching method in physiology field.

Many evaluation methods were used to evaluate the effects of PBL teaching. Summative assessment as multiple-choice exams has become the most common way to measure the educator's effective teaching ability and assess students' performance.[5] As an evaluation strategy, programmatic assessment and progress test have gained a definite place in the context of PBL.[6] At the same time, questionnaire survey was used to evaluate the feedback of the teaching effects.[7] However, all the evaluation methods focus on educational outcomes or students' subjective feelings. We still didn't know the mechanisms why students are more active in PBL. In this study, we evaluated the learning outcome through a small quiz, and test students' electroencephalogram (EEG) and brain perfusion during the class in PBL to find the change of neural electrophysiology and the energy consumption.

## MATERIAL AND METHODS

### Participant

Twenty healthy male students (20.2±0.4 ys), whose final exam score of sports anatomy was 90 or above, voluntarily participated in the study in PE department at Hubei Minzu University. Prior to enrolment, the volunteers attended a screening meeting and signed consent to take part in the trial which was reviewed and approved by the ethical committee at Hubei Minzu University (No. 2020035). Participants were screened for any contraindications to the trial with the use of an exclusion questionnaire. The participant exclusion criteria included: over-the-counter or prescribed drugs; a diagnosis of any physical or mental illness; the use of dietary supplements, use of recreational and/or tobacco products (including vaping).

## METHODS

20 participants were randomly divided into the PBL group (10) and the traditional teaching method group (TTM). All experimental tests were performed approximately 25 minutes from 0900 to 1100 or from 1400 to 1600 on Saturday and Sunday. Participants from TTM group received traditional teaching method. Before class, students in TTM group were allocated compulsory readings for 20 minutes according to the course content, and participants from PBL group watched the micro-course video of the corresponding course. During the test, the subjects in TTM group sat quietly listening to the experienced teacher, while the subjects in PBL group also sat quietly and participated in the group discussion under the guidance of the experienced teacher for 20 minutes. Transcutaneous oxygen partial pressure (TcpO2) and microcirculatory blood perfusion (MBP) were continuously monitored from the subjects' prefrontal cortex by sensors (The sixth-generation dual-channel laser Doppler blood flow monitor, PF6000, Sweden). MBP and TcpO2 values recorded for 15 seconds from the 15 seconds before the test were extracted as baseline values, and from the 17 minutes after the test were extracted as test values. EEG was monitored noninvasively by EEG cap (Neuracle, China). After the test, a quiz was used to test the learning effects.

### EEG recording and analysis

EEG signals were recorded with the NeuSen. Uamp, system (Neuracle, China) at a sampling frequency of 1000Hz. Sixteen electrodes were arranged according to the international 10-20 system (F3/4, F7/8, C3/4, T3/4, P3/4, T5/6, O1/2, Pz, Oz, with reference at REF and a forehead ground at GND. Electrode impedances were kept below 10 kΩ for all electrodes.

From the 5th second before the test and from the 17th minutes after the test, the EEG signal of 5 seconds was extracted as the baseline value and the test values.[8] The alpha and beta band power of F7, P2, F3, T3, C3, P3, Pz and O1 channels of EEG signal were used as the characteristics of the learning effect evaluation of the subjects.[9]

The recorded EEG data were first notch filtered to remove the 50 Hz powerline noise, bandpass filtered to 0.05 - 50 Hz. Then the EEG signal was decomposed by wavelet analysis with the Morlet wavelet base. This method corresponds to a windowed Fourier transform with adaptive window size depending on the respective frequency. The wavelet scales corresponded to Fourier frequencies from 2 to 60 Hz in steps of 0.5 Hz. The resulting wavelet spectrum was squared to obtain a power spectrum and averaged over the alpha frequency range of 8–13 Hz, and beta frequency range of 14–24 Hz.[10]

### Statistics Analysis

Outcomes following teaching approaches interventions between the two groups were analyzed by univariate analysis to evaluate the significance of the group factor (i.e., TTM group vs. PBL group) and the time factor (i.e., baseline vs. during the test). If the results were significant, more statistical analysis would be done. Data at baseline and during the test within the group were analyzed using paired *t*-test. Data at baseline or during the test between the groups were compared using *t*-test for two independent groups. The statistical analysis was performed using SPSS 25.0 software. All continuous variable data were reported as group mean ± standard deviation (SD) of the mean. *P* value<0.05 was considered statistically significant.

## RESULTS

### Comparison of students' performance in the quiz of the two types of methods

Comparison of students' quiz marks on the two methods was done using independent t-test (Table 1). The mean score of PBL group was higher than that of TTM group, and the difference was significant (P = 0.026).

### The changes of alpha and beta band power in two groups

There was no interaction between group and time about alpha power. Alpha power in F3, T3, P3 and O1 channels decreased significantly during the test than that in baseline in PBL group (Table 2). At baseline, alpha power in F7 and Pz channels in PBL group was significant higher than that in TTM group, but there was no significant difference during the test.

There was an interaction of beta power in F3 and C3 channels. Beta power in F7, F3, T3, C3, P3 and O1 channels increased significantly during the test in PBL group (Table 3). However, beta power just in T3 and O1 channels increased significantly during the test in TTM group. In baseline, beta power in T3 channel in PBL group was significantly lower than that in TTM group.

### The changes of TcpO2 and MBP in two groups

(Table 4) lists the changes of TcpO2 and MBP in two groups. During the test, MBP in PBL group was significantly higher than that at baseline (8.2 PU *vs* 11.0 PU), and the MBP value was significant higher in PBL group than that in TTM group during the test. There was no significant difference in TcpO2 between the two groups.

**Table 1.** Comparison of students' performance in the quiz of the two types of methods.

| Teaching method | Students' marks | t-Test | P |
|---|---|---|---|
| PBL | 90.3 ± 3.9 | 2.419 | 0.026 |
| TTM | 85.0 ± 5.7 | | |

## DISCUSSION

Results from the current trial provided evidences of increasing of students' beta power and MBP, and a better learning effect in PBL method in sports physiology teaching. So PBL can be an effective learning mechanism because the students are engaged actively within the sports physiology teaching.

In PBL, students learn by discussing professionally relevant problems enhancing integration and application of knowledge, which is considered as a way to encourage students towards a deep learning approach, so students are intrinsically interested and try to understand what they are learning.[11] In PBL group, the subjects could understand the physiology basic theory through micro-course video, then understand content together with the processes of relating and structuring ideas, and look for underlying principles, weighed the relevant evidence, and critically evaluating knowledge. From the quiz, the mean of students' marks was significantly higher in the quiz of PBL than in TTM, so the learning effect of PBL method is better than that of TTM.

EEG provides a physiological basis to detect and record brain wave activity and to explain such recordings in terms of attention, alertness, concentration, and relaxation.[12] The alpha band, (8–13 Hz), is primarily associated with inhibition processes, less attention, and the mechanisms of consciousness and attention.[13] The increased of alpha power is believed to reflect cortical inhibitory processes,[14] while the decrease of alpha power, especially in prefrontal and posterior prestimulus, is associated

**Table 4.** The change of TcpO2 and MBP in two groups.

| | Grupo PBL | | Grupo TTM | | Signif. | | |
|---|---|---|---|---|---|---|---|
| | Baseline | Test value | Baseline | Test value | Time × group | Time | Group |
| MBP (PU) | 8.2 ± 0.5* | 11.0 ± 0.6※ | 8.1 ± 0.3 | 9.3 ± 0.3 | 0.226 | 0.025 | 0.048 |
| TcpO2 (mmHg) | 29.5 ± 2.22 | 31.1 ± 3.6 | 28.8 ± 2.9 | 29.1 ± 2.6 | 0.315 | 0.148 | 0.245 |

* Significant difference vs. baseline data (P<0.05). ※Significant difference between different groups at the same time (P < 0.05).

**Table 2.** The changes of alpha power in two groups.

| | PBL group | | TTM group | | Sig. | | |
|---|---|---|---|---|---|---|---|
| | Baseline | Test value | Baseline | Test value | Time × group | Time | Group |
| F7 | 1.29 ± 0.68※ | 0.81 ± 0.35 | 0.93 ± 0.48 | 0.89 ± 0.41 | 0.131 | 0.83 | 0.036 |
| Pz | 0.49 ± 0.35※ | 0.17 ± 0.11 | 0.19 ± 0.14 | 0.14 ± 0.06 | 0.058 | 0.13 | 0.014 |
| F3 | 1.49 ± 1.65* | 0.80 ± 0.59 | 1.21 ± 1.26 | 0.81 ± 0.52 | 0.071 | 0.006 | 0.102 |
| T3 | 1.21 ± 0.21* | 0.79 ± 0.17 | 1.25 ± 0.34 | 0.94 ± 0.12 | 0.489 | 0.001 | 0.138 |
| C3 | 0.99 ± 0.83 | 0.37 ± 0.18 | 0.51 ± 0.47 | 0.37 ± 0.19 | 0.095 | 0.12 | 0.181 |
| P3 | 1.09 ± 0.71* | 0.36 ± 0.17 | 0.70 ± 0.66 | 0.46 ± 0.23 | 0.099 | 0.003 | 0.428 |
| O1 | 1.24 ± 0.46* | 0.74 ± 0.30 | 1.28 ± 0.34 | 0.91 ± 0.16 | 0.534 | 0.001 | 0.347 |

* Significant difference vs. baseline data (P<0.05). ※Significant difference between different groups at the same time (P<0.05).

**Table 3.** The changes of beta power in two groups.

| | PBL group | | TTM group | | Sig. | | |
|---|---|---|---|---|---|---|---|
| | Baseline | Test value | Baseline | Test value | Time × group | Time | Group |
| F7 | 3.57 ± 152* | 5.71 ± 1.01 | 4.48 ± 2.13 | 5.47 ± 1.00 | 0.202 | 0.002 | 0.589 |
| Pz | 0.99 ± 0.59 | 1.24 ± 0.63† | 0.85 ± 0.60 | 1.03 ± 0.65 | 0.797 | 0.176 | 0.032 |
| F3 | 3.77 ± 1.26* | 5.11 ± 1.00 | 4.11 ± 1.30 | 4.58 ± 1.58 | 0.045 | 0.001 | 0.862 |
| T3 | 2.36 ± 1.41*※ | 3.42 ± 0.98 | 2.66 ± 1.62* | 3.44 ± 1.09 | 0.754 | 0.047 | 0.009 |
| C3 | 2.10 ± 0.50* | 3.40 ± 0.74 | 2.05 ± 0.79 | 2.37 ± 1.08 | 0.04 | 0.002 | 0.072 |
| P3 | 2.38 ± 0.63* | 3.08 ± 0.67 | 2.10 ± 0.50 | 2.43 ± 0.65 | 0.363 | 0.017 | 0.247 |
| O1 | 2.17 ± 0.85* | 4.36 ± 1.31 | 2.93 ± 1.16* | 4.42 ± 1.22 | 0.278 | 0.001 | 0.329 |

* Significant difference vs. baseline data (P<0.05). ※Significant difference between different groups at the same time (P<0.05).

with concentration and better task performance.[15] Likewise, the role of the beta (14–24 Hz) band in top–down visual attentional processing is widely documented. Occipito-parietal beta power is associated with better performance in tasks which recruit attentional processes.[16] When increased in beta power is also functionally associated with the execution of voluntary movements. Watson et al reported similar results that higher alertness and lower fatigue, which is related to the increase in beta power and suppression of alpha spectral power.[12] In this study, the subjects' alpha power decreased and beta power increased in two groups during the test. However, the areas were larger and the amplitude was higher in PBL group (Table 2 and 3), which means the students in PBL group were more focused and less fatigue than those in TTM group.

The main function of the circulatory system is to transport materials by convection throughout the body,[17] and to control the flow according to requirements that change with time and position.[18] Among many substances that must be distributed and removed, oxygen is one of the most critical. Many tissues, notably brain, have a high and continuous demand for oxygen, and suffer damage rapidly if the supply fails, so the control of cerebral perfusion is important for maintaining an adequate neuronal micro-environmental homeostasis as well as autonomic function.[19] Sugiura et al. reported that compared with the resting state, a significant increase in regional cerebral blood flow was observed after reading novels on a table.[20] Viski et al. demonstrated that reading alone resulted in the increase in flow velocity by approximately 8–10% in the artery supplying the occipital cortex,[21] which indicated there is a positive correlation between neuronal activity and cerebral blood flow. In this study, the subjects' MBP increased significantly during the test period compared with that in the rest period in PBL group. However, the TcpO2 didn't change significantly between the baseline and during the test in two groups. This indicated the subjects' energy consumption increased more in PBL group, which means more neuronal activity in PBL group.

To date, this is the first study showing the association between PBL achievement and students' neurophysiological characteristics. It explained the physiological mechanism why students were more concentrate, less fatigue, and stronger neuronal activity during PBL class. From the study, we know PBL can promote teaching reform and accelerate the improvement of teaching outcomes, so it is an effective method in sports physiology teaching.

The main limitation of the present study was that the subjects just sat quietly, which may lead to the reduction of the activities in the class. In the future study, we should let the students express their opinions during the discussion, and we will extend the test time to the entire teaching process.

## CONCLUSION

In summary, PBL teaching method can significantly improve students' beta power and MBP. Compared with TTM method, the learning effect is better, and the students have more active roles and neuronal activities, and their attention is more focused in the PBL, So PBL can be an effective learning mechanism given that the students are engaged actively within the sports physiology teaching.


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