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Correlation between Gamma Waves and Motor Educability with Movement Performance in Gymnastics

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Abstract

This study was aimed to determine how gamma waves and motor educability correlate to gymnastics movement performance in West Java gymnastic athletes. The study used quantitative descriptive method with a correlational design. The population and sample of this study were 13 West Java gymnastic youth athletes selected using saturated sampling technique. The instruments used were gymnastic performance tests, namely motor educability test (IOWA Brace test), and brain wave test, the Emotiv EPOC Wireless helmet. Based on data processing and analysis, the correlation value between gamma brain waves and movement performance was r= -0.620 with a p -value 0.024 < 0.05, while the coefficient of determination was 0.384, meaning that there was a contribution of 38.4%. It concludes that, there was a negative functional correlation between gamma brain waves and movement performance. The obtained correlational value between motor educability and gymnastic performance was r = 0.646 with a p-value 0.017 < 0.05 and a coefficient of determination of 0.418, showing that there was a contribution of 41.8%. It implies that that there was a positive functional correlation between motor educability and gymnastic performance. The correlation value of gymnastic performance, gamma brain waves, and motor educability was r = 0.749 with a p-value 0.016 < 0.05 and coefficient of determination of 0.560, indicating that gymnastic performance was determined by gamma brain waves and motor educability of 56.0%. The results showed that there was a strong correlation and a significant contribution of gamma waves and motor educability to movement performance in gymnastics.

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INTRODUCTION

Body movements result from the interplay of various factors, such as central nervous system activities, cognitive abilities, learning processes, and emotional growth, as explained by (Jeon, 2015). These movements are intricately linked to the brain functions, including regulating bodily functions, responding to physical stimuli, and making decisions (Negara et al., 2021). Gymnastics, as a sport that involves rapid and concise movements, requires a complete motor programming before execution (Mahendra et al., 2002; Opala-Berdzik et al., 2021).

The brain, as the human central nervous system, contains billions of brain cells called neurons (Amin, 2018; Dubey et al., 2022) connected to each other through brain waves consisting of five categories, namely delta, theta, alpha, beta, and gamma (Zainuddin et al 2017; Moezzi et al., 2019). These gamma brain waves are associated with arousal, attention, learning, preparation for movement, modulation of sensory processes and, in some cases, play a role in enhancing perception (Mather et al., 2016; García-Monge et al., 2020). Of the five brain waves, gamma waves have an important role, especially during the learning process (Koudelková et al., 2018). Gamma brain waves occur when a person is fully aware and very alert (Negara et al., 2021). Increased gamma waves in most areas of the brain are also associated with cognitive workload and increased memory load (Jung et al., 2020). The frequency of gamma waves due to neuromuscular activity varies greatly depending on the activities carried out, including during sports (Buzśaki & Wang, 2012; Rahman et al., 2019; Wang et al., 2022). The neuromuscular aspect becomes important in supporting gymnastic performance, where the central nervous system interacts with the musculoskeletal system to produce an efficient motor behaviour.

According to Newell's inhibition theory, the motor behaviour of each individual is different (Rienhoff et al., 2016). This can be influenced by several factors in the motion learning process, one of which is cognitive factors such as sharp thinking and intelligence. This cognitive aspect has an important role, especially in the learning process (Donnelly et al., 2016; Zeng et al., 2022). In the early stages of movement learning, many intellectual skills are involved. A person intellectual skill in learning new movements is included in the type of motor intelligence. One of the terms used to indicate a person motor intelligence is motor educability. Motor Educability is a person ability to learn new movement skills (Sigmundsson et al., 2017). The higher a person level of motor educability, the easier it is to learn new movement skills. Therefore, paying attention to cognitive factors and motor intelligence can help improve one movement learning.

There are still many sport practitioners who do not know the causes of decreased performance of an athlete, especially the causes that cannot be observed directly (Negara et al., 2021). Therefore, brain wave scanning needs to be administered to determine the athlete brain condition. This is important because abnormalities in the brain can affect attention, intellectual abilities, and balance, which in turn can affect the athlete performance (Negara et al., 2021). In addition, to understand better physical performance and improve more effective physical programs, it is necessary to accurately measure individual ability levels in learning movement skills (Fajriyanto, 2018).

Increased gamma wave activity has been shown to have a positive impact on athletic performance in several studies (Neubauer & Fink, 2009; Ahmed & Mehta, 2012; Enders & Nigg, 2016; Zainuddin et al., 2017). However, if the gamma waves are too high, it will result in decreased attention and concentration (Negara et al., 2021) which will affect performance (Peh et al., 2011; Wulf & Lewthwaite, 2016). Regarding motor intelligence, several studies have been conducted on the effect of motor educability on sport skills, showing a correlation between the quality of motor educability and sports achievement, where individuals with higher motor educability have better athletic performance than other people in the same population (Fajriyanto, 2018; Julianti & Alawiyah, 2016; Sandhu, 2017; Sujana et al., 2014; Sutarno, 2009; Walters, 2014).

Gamma waves and a person motor level have a relationship with the resulting motion performance. Several studies have shown that gamma waves are necessary during learning, movement preparation, and sensory processing. There is an opinion stating that the relationship between gamma brain waves and the individual ability to learn new movements is important. However, according Kim et al., (2020), if in the process of learning an individual movements are more dependent on secondary cognitive processing, it can result in delays in processing motion information and reduced movement performance. In line with this, Giustiniani et al., (2019) state that optimal gamma waves can improve an individual ability to learn a movement and improve the movement performance. Therefore, an understanding of the relationship between gamma waves and the motor level can help improve a person movement performance.

The relationship between brain waves and an individual ability to learn new movement skills and its correlation with sports performance has not been studied extensively. Therefore, the level of motor educability and gamma brain wave features need further investigation. By knowing this information, it is hoped that the right training program can be adjusted for each individual based on the training principles and desired objectives. Thus, motor abilities, such as motor educability, and gamma brain wave patterns can be used as a support to achieve a good motor performance.

METHODS

The method used in this study was the quantitative descriptive method with a correlational design.

Participants

The participants were West Java youth gymnastics athletes (age 19.61 ± 4.75 years) who regularly participated in and were preparing for competitions. The technique used was saturated sampling technique. Thirteen youth athletes (8 women and 5 men), who were members of Student Sport Education and Training Center and Regional Training Center, participated in this study. Prior to data collection, sample consent was given without coercion. Samples were in good health and could participate in the activities given. The physical characteristics of the samples are presented in Table 1.

Table 1. Physical Characteristics of The Subjects

Variables	Mean ± SD	Min	Max	N
Age	19.61 ± 4.75	13	25	13
Height (cm)	156.4 ± 7.50	142	166	
Weight (kg)	51.1 ± 7.08	41	63	
Body Mass Index	20.80 ± 1.80	18,22	24,08	

Note: SD = Standard deviation, Min = Minimum, Max = Maximum, N = Number of participants

Instrument and Procedure

The measurement of gamma waves used a device, namely Wireless helmet Emotiv EPOC (Figure 1). Emotiv EPOC wireless helmet consists of 16 sensors, where 2 of them are references attached to the scalp to detect the frequency of brain waves (Jayarathne et al., 2020).

Figure 1. Emotiv EPOC Wireless Helmet

Measurement of motor educability used the IOWA -Brace test adopted from research of (Sujana, 2014). The test consisted of 20 motor educability test items and two opportunities were given to perform each test item. In measuring gymnastic performance, the research sample conducted gymnastic performance tests assessed by the judge. The rating norm referred to the code of point assessment norm issued by the Federation Internationale de Gymnastique where the performance score was taken from the Difficulty value (judge D) minus the Execution value (judge E) (FIG, 2017).

Emotiv EPOC wireless helmet

EMOTIV EPOC is designed for scalable contextual human brain research and advanced brain-computer interface applications and provides access to professional-grade brain data in a fast, easy-to-use design. It can access high quality raw EEG data with a PRO license or can be conducted in research leveraging detection for mental commands, performance metrics, or facial expressions.

The sensor on the Wireless helmet Emotiv EPOC will provide data related to brain waves from various brain regions with the following names: (1) AF = Anterior-Frontal; (2) F = Frontals; (3) FC = Fronto-Central; (4) T = Temporal; (5) P = Parietal; (6) O = Occipita (Jayarathne et al., 2020).

The data from gamma wave measurements are the baseline data for gamma wave activity. The test protocol performed on the EmotivPro v3.0 application is as follows:

To activate baseline data recording, select the "include baseline" option on the Start Recording submenu and baseline data recording will automatically be set for a duration of 30 seconds. Then select "Start Recording" After selecting "Start Recording" the recording process will take place in 6 stages, namely:

1) 3 second preparation time, with countdown.
2) 15 seconds of recording baseline data with eyes open, with countdown.
3) 2 second completion screen.
4) 3 second preparation time, with countdown.
5) 15 seconds of recording baseline data with eyes closed, with countdown.
6) 2 second completion screen.
7) During the initial and final eye-opening and closing phases, the app will output an audio cue.

The data taken in this study were the average power of gamma detected in the right frontal area, because this part is responsible for motor processing and cognitive function. This is in line with Oliveira et. al. (2018) research which found that gamma power activity increased in the right frontal area (AF4 and F4) as a result of motor planning and cognitive activity in carrying out motor tasks. The data were then transformed to log10 for later analysis (Oliveira et al., 2018).

IOWA-Brace test

The motor educability test consists of 20 types of movements that must be done with two given opportunities to perform each test item (Sujana, 2014). The test items are One Foot-Touch head, Side leaning rest, Graspevine, One-knee balance, Strok stand, Double heel click, Cross-leg squat, Full left turn, One-knee-head to floor, Hop backward, Forward hand kick, Ful squat-arm circle, Half-turn jump-left foot, Side kick, Knee jump to feet, Rusian dance, Full right turn, The top, Single squat balance, Jump foot. The terms of the assessment are as follows:

a. If successful on chance 1 = value 2
b. If successful on opportunity 2 = value 1
c. If it fails = value 0

Gymnastic Performance

The sample performed a series of gymnastic movements which were then observed and assessed by the judge.

Data Analysis

Data were reported descriptively as mean ± standard deviation. Data were checked for normal distribution using the Shapiro-Wilk test. Product Moment Pearson correlation analysis found out the relationship between the independent variables (i.e., gamma waves and motor educability) and the dependent variable (i.e., movement performance). All analyses were administered in SPSS for Windows version 25. The statistical significance was set at $p < 0.05$. Multiple regression test was conducted to see the correlation between gamma waves and motor educability with gymnastic performance.

RESULT

The data obtained after the implementation of this study were the average power of gamma brain waves in the right frontal cortex, motor educability scores, and gymnastic performance scores. The summary of data on average power of gamma brain waves, motor educability scores, and gymnastic performance scores can be seen in Table 2.

Table 2. Summary of Gamma Waves, Motor Educabil-

Variables	Mean	Std. Dev	Min	Max	N
Gamma Waves	6.31	0.21	.01	6.82	
Motor Educability	34.23	3.81	26	39	13
Gymnastic Performance	12.16	1.04	10.4	13.5	

Table 2 shows that the standard deviation of gamma waves was 0.21 and the mean value was 6.31. The standard deviation of the motor educability was 3.81 and the mean was 34.23. Meanwhile, the standard deviation of the gymnastic performance was 1.04 and the mean was 12.16.

Hypothesis testing in this study used an analytical test with a correlation test, namely the Pearson Product Moment correlation test. The results of the test calcula

Table 3. Pearson Product Moment Correlation Test

Variables	**Correlation**		**Coefficient of Determination**	p^***-value**
	r	*R*		
Gamma Waves – Gymnastic Performance	-0.620	0.384	38.4%	0.024
Motor Educability – Gymnastic Performance	0.646	0.481	41.8%	0.017
Gamma Waves & Motor Educability – Gymnastic Performance	0.749	0.560	56.0%	0.016

Note: r = Correlation , R = Multiple correlation, p*-value = sig. <0.05(significant)

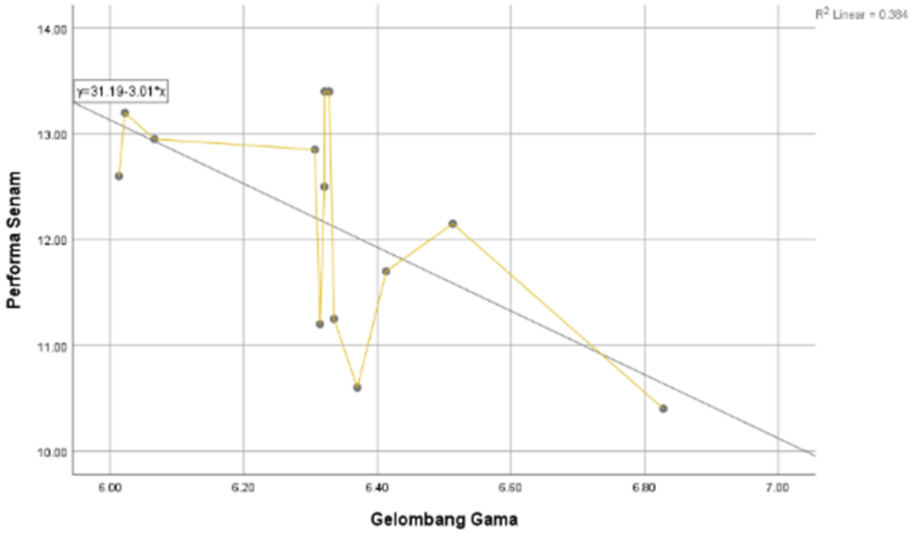

Figure 2. Scatter Plot of Gamma Wave and Gymnastic Performance

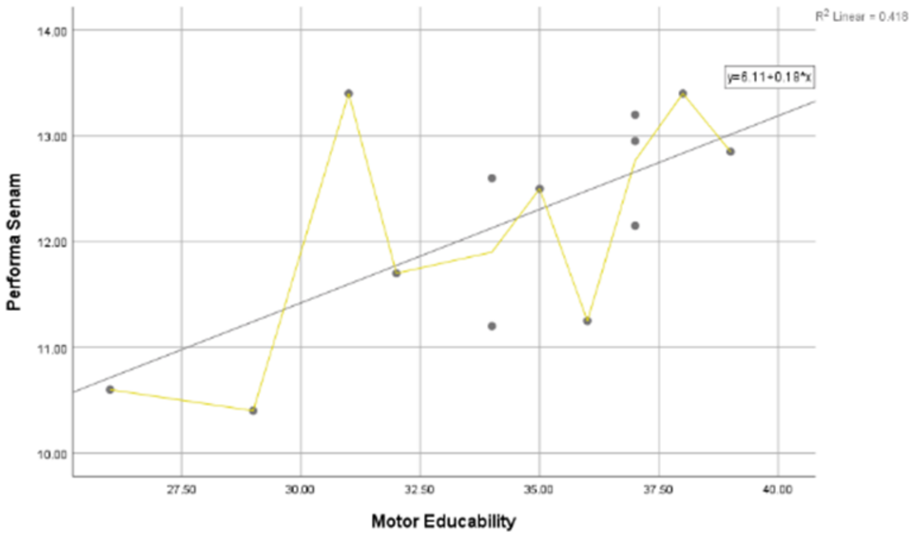

Figure 3. Scatter Plot of Motor Educability and Gymnastic Performance

tions can be seen in Table 3 and Table 4. The result of multiple regression test is presented in the Table 5.

Based on the results of the correlation and multiple correlation tests (Table 3), there was a negative functional correlation between gamma waves and gym nastic performance, shown by a correlation of r = -.620 with a p-value of 0.024. By interpreting the level table of the correlation coefficient according to the Negara et al. (2019), it was found that the strength of the relationship between gamma waves and gymnastic performance was quite strong. In addition, the coefficient of determination was 0.384, meaning that the gamma wave variable contributed 38.4%. There was a positive functional correlation between motor educability and gymnastic performance, shown by a correlation of r = 0.646 with a p-value of 0.017. It was found that the strength of the relationship between motor educability and gymnastic performance was quite strong. In addition, the coefficient of determination was 0.418, meaning that the motor educability variable contributed 41.8%.

There was a positive functional correlation between motor educability and gymnastic performance, shown by a correlation of r = 0.646 with a p-value of 0.017. It was found that the strength of the relationship between motor educability and gymnastic performance was quite strong. In addition, the coefficient of determination was 0.418, meaning that the motor educability variable contributed 41.8%. There was a positive functional correlation between gamma waves and motor educability with gymnastic performance, shown by a correlation of r = 0.749 with a p-value of 0.016. It was found that the strength of the relationship between gamma waves and motor educability with gymnastic performance was quite strong. In addition, the coefficient of determination was 0.560, meaning that the gamma wave and motor educability variables contributed 56.0%. Thus, the hypothesis was tested and correlated.

DISCUSSION

The negative functional correlation of gamma waves with gymnastic performance shows that the higher the gamma wave level, the lower the gymnastic performance. This is in line with the research conducted by Ahmed & Mehta (2012) which found that the increase in gamma waves is directly proportional to running speed. However, if the gamma waves increase too high, it will affect anxiety which results in hesitation in carrying out a movement (Chu et al., 2018). This can also result in decreased concentration and attention which can have an impact on decreased sports performance (Negara et al., 2021). It should be noted that the gamma waves that mostly contribute to performance are gamma waves in the right frontal cortex. This is in line with the explanation of (Al-Qahtani et al., 2013) that gamma brain wave activity during movement determination, when mental activity is high, can be observed in the right frontal cortex. This is reinforced by the opinion of Hughes (2008) that, in a high mental state, gamma wave activity is more commonly found in the right side of the brain.

The results of this study prove that there is a positive functional correlation between the level of motor educability and exercise performance. This shows that the higher the level of motor educability, the higher the exercise performance. This is because one of the factors that supports performance is the individual ability to learn new things, which in this case is related to motor intelligence, referred to as motor educability (Mccloy, 2013). Furthermore, (Sujana et al., 2014) suggest that the higher a person motor educability level, the easier it will be to learn new movements. This is in line with the research conducted by (Fajriyanto, 2018; Julianti & Alawiyah, 2016; Sandhu, 2017; Sujana et al., 2014; Sutarno, 2009; Walters, 2014) showing that individuals with high levels of motor educability have a better sport performance compared to individuals who have a low level of motor educability.There is a relationship showing gamma wave as a determining factor for performance (Neubauer & Fink, 2009; Ahmed & Mehta, 2012; Enders & Nigg, 2016; Zainuddin et al., 2017). Similar to gamma waves, motor educability is also a factor that determines performance (Fajriyanto, 2018; Julianti & Alawiyah, 2016; Sandhu, 2017; Sujana et al., 2014; Sutarno, 2009; Walters, 2014). The relationship between gamma brain waves and a person ability to learn a new movement is in line with the opinion of (Koudelková et al., 2018; Monge et al., 2020) that gamma waves are needed during learning, movement preparation, and sensory processes. Furthermore, according to Kim et al., (2020), if in the process of movement learning individuals are depend more on the secondary cognitive processing, it will cause delays in processing movement information resulting in decreased performance. This is in line with Giustiniani et al., (2019) who suggest that optimal gamma waves can improve an individual ability to learn a movement, which will also improve their movement performance.

CONCLUSION

This study concludes that there is an interaction between gamma waves and gymnastic performance. This research provides information that if a person wants a good performance, the gamma waves cannot be too high but also cannot be too low. In addition, a high level of motor educability helps the production of better gymnastic movement performance. Furthermore, gamma waves and motor educability both contribute to movement performance in gymnastics.

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REFERENCES

Ahmed, O. J., & Mehta, M. R. (2012). Running speed alters the frequency of hippocampal gamma oscillations. *Journal of Neuroscience*, *32*(21), 7373-7383.

Al-Qahtani, A., Nasir, A., Shakir, M. Z., & Qaraqe, K. A. (2013, October). Cognitive impairments in human brain due to wireless signals and systems: An experimental study using EEG signal analysis. In *2013 IEEE 15th International Conference on e-Health Networking, Applications and Services (Healthcom 2013)* (pp. 1-3). IEEE.

Amin, M. S. (2018). Perbedaan struktur otak dan perilaku belajar antara pria dan wanita; Eksplanasi dalam sudut pandang neuro sains dan filsafat. *Jurnal Filsafat Indonesia*, *1*(1), 38-43.

Buzsáki, G., & Wang, X. J. (2012). Mechanisms of gamma oscillations. *Annual review of neuroscience*, *35*, 203-225.

Chu, D., Chen, L. J., Lee, Y. L., Hung, B. L., Chou, K. M., Sun, A. C., & Fang, S. H. (2018). The correlation of brainwaves of Taekwondo athletes with training vis-à-vis competition performance–an explorative study. *International Journal of Performance Analysis in Sport*, *18*(1), 69-77.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., ... & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Medicine and science in sports and exercise*, *48*(6), 1197.

Dubey, A. K., Saraswat, M., Kapoor, R., & Khanna, S. (2022). Improved method for analyzing electrical data obtained from EEG for better diagnosis of brain related disorders. *Multimedia Tools and Applications*, *81*(24), 35223-35244.

Enders, H., & Nigg, B. M. (2016). Measuring human locomotor control using EMG and EEG: Current knowledge, limitations and future considerations. *European journal of sport science*, *16*(4), 416-426.

Fajriyanto, A., & Rachman, H. A. (2018). Pengaruh Gaya Mengajar Dan Motor Educability Terhadap Hasil Belajar Passing Atas Permainan Bolavoli Peserta Didik Kelas 7 Di Smp. *Pendidikan Jasmani Kesehatan dan Rekreasi*, *7*(4).

De Gymnastique, F. I. (2017). 2020 Code of Points Women's Artistic Gymnastics. *Retrieve from FIG website: http://www. figgymnastics. com/ publicdir/rules/files/en_W AG% 20CoP*, 202017-2020.

Giustiniani, A., Tarantino, V., Bonaventura, R. E., Smirni, D., Turriziani, P., & Oliveri, M. (2019). Effects of low-gamma tACS on primary motor cortex in implicit motor learning. *Behavioural brain research*, *376*, 112170.

Jayarathne, I., Cohen, M., & Amarakeerthi, S. (2020). Person identification from EEG using various machine learning techniques with inter-hemispheric amplitude ratio. *PloS one*, *15*(9), e0238872.

Jeon, K. H. (2015). Effects of national gymnastics and brain gymnastics on frontal lobe activity. *Journal of International Academy of Physical Therapy Research*, *6*(2), 896-901.

Julianti, R. R., & Alawiyah, T. (2016). Pengaruh Permainan Kecil Terhadap Motor Educability. *Jurnal Ilmiah Penjas (Penelitian, Pendidikan dan Pengajaran)*, *2*(2).

Jung, J. Y., Cho, H. Y., & Kang, C. K. (2020). Brain activity during a working memory task in different postures: An EEG study. *Ergonomics*, *63*(11), 1359-1370.

Kim, S. M., Qu, F., & Lam, W. K. (2021). Analogy and explicit motor learning in dynamic balance: Posturography and performance analyses. *European Journal of Sport Science*, *21* (8), 1129-1139.

Koudelková, Z., Strmiska, M., & Jašek, R. (2018). Analysis of brain waves according to their frequency. *Int. J. Biol. Biomed. Eng*, *12*, 202-207.

Mahendra, A., & Diwayanti, A. (2002). Pemanduan bakat olahraga senam (artistik dan ritmik). *Materi Lokakarya Penyusunan Instrumen Pemanduan Bakat Olahraga Usia Dini*.

Mather, M., Clewett, D., Sakaki, M., & Harley, C. W. (2016). Norepinephrine ignites local hotspots of neuronal excitation: How arousal amplifies selectivity in perception and memory. *Behavioral and Brain Sciences*, *39*, e200.

McCloy, C. H. (1940). A preliminary study of factors in motor educability. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *11*(2), 28-39.

Moezzi, B., Pratti, L. M., Hordacre, B., Graetz, L., Berryman, C., Lavrencic, L. M., ... & Goldsworthy, M. R. (2019). Characterization of young and old adult brains: An EEG functional connectivity analysis. *Neuroscience*, *422*, 230-239.

García-Monge, A., Rodríguez-Navarro, H., González-Calvo, G., & Bores-García, D. (2020). Brain activity during different throwing games: EEG exploratory study. *International Journal of Environmental Research and Public Health*, *17* (18), 6796.

Negara, J. D. K., Mudjianto, S., Budikayanti, A., & Nugraha, A. (2021). The effect of gamma wave optimization and attention on hitting skills in softball. *Int J Hum Mov Sport Sci*, *9*(1), 103-9.

Neubauer, A. C., & Fink, A. (2009). Intelligence and neural efficiency. *Neuroscience & Biobehavioral Reviews*, *33*(7), 1004-1023.

Oliveira, S. M. S. D., Medeiros, C. S. P. D., Pacheco, T. B. F., Bessa, N. P. O. S., Silva, F. G. M., Tavares, N. S. A., ... & Cavalcanti, F. A. D. C. (2018). Electroencephalographic changes using virtual reality program. *Neurological research*, *40*(3), 160-165.

Opala-Berdzik, A., Głowacka, M., & Juras, G. (2021). Postural sway in young female artistic and acrobatic gymnasts according to training experience and anthropometric characteristics. *BMC Sports Science, Medicine and Rehabilitation*, *13*(1), 1-11.

Peh, S. Y. C., Chow, J. Y., & Davids, K. (2011). Focus of attention and its impact on movement behaviour. *Journal of science and medicine in sport*, *14*(1), 70-78.

Rahman, M., Karwowski, W., Fafrowicz, M., & Hancock, P. A. (2019). Neuroergonomics applications of electroencephalography in physical activities: a systematic review. *Frontiers in Human Neuroscience*, *13*, 182.

Rienhoff, R., Tirp, J., Strauss, B., Baker, J., & Schorer, J. (2016). The 'quiet eye'and motor performance: A systematic review based on Newell's constraints-led model. *Sports Medicine*, *46*, 589-603.

Sandhu, R. S. (2017). Analysis of motor educability among cricket players of different level of achievement. *European Journal of Physical Education and Sport Science*.

Sigmundsson, H., Trana, L., Polman, R., & Haga, M. (2017). What is trained develops! theoretical perspective on skill learning. *Sports*, *5*(2), 38.

Sujana, R. (2014). *Pengaruh Pendekatan Pembelajaran Dan Motor Educability Terhadap Hasil Belajar Keterampilan Sepakbola* (Doctoral Dissertation, Universitas Pendidikan Indonesia).Sujana, R., Muhtar, T., & Nuryadi. (2014). Pengaruh Pendekatan Pembelajaran Dan Motor Dan Keterampilan Bermain Sepakbola. *Edusentris*, *1* (3), 260–274.

Walters, C. E. (1959). Motor ability and educability factors of high and low scoring beginning bowlers. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *30*(1), 94-100.

Wang, L., Wang, C., Yang, H., Shao, Q., Niu, W., Yang, Y., & Zheng, F. (2022). Halo Sport Transcranial Direct Current Stimulation Improved Muscular Endurance Performance and Neuromuscular Efficiency During an Isometric Submaximal Fatiguing Elbow Flexion Task. *Frontiers in Human Neuroscience*, *16*, 758891.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic bulletin & review*, *23*, 1382-1414.

Zainuddin, N. F., Omar, A. H., Zulkapri, I., Jamaludin, M. N., & Miswan, M. S. (2017). Brainwave biomarkers of brain activity, physiology and biomechanics in cycling performance. *Malaysian Journal of Fundamental and Applied Sciences*, *13* (4-2), 533-539.

Zeng, Y., Zhao, D., Zhao, F., Shen, G., Dong, Y., Lu, E., ... & Bi, W. (2023). BrainCog: A spiking neural network based, brain-inspired cognitive intelligence engine for brain-inspired AI and brain simulation. *Patterns*, *4*(8).