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Effects of Spontaneous Neural Activity during Learning Football Juggling—A Randomized Control Trial

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Abstract: To establish the characteristics of spontaneous neural activity during learning football juggling. We used fMRI to see which parts of the brain were changed by learning football juggling. Through recruitment, 111 college students (37 females and 74 males) were selected and randomly divided into football juggling (FJ) (n = 68, 23 females and 45 males) and a control group (CON) (n = 43, 14 females and 29 males). The FJ group learned football juggling 70 times, while CON had regular study sessions at the same time. Static functional magnetic resonance imaging (fMRI) was used to measure the dynamic changes of spontaneous nerve activity during learning football juggling. The result shows that the ALFF value in the right cerebellum 8 area was significantly higher than that before the 70 times of learning football juggling. The present study provides initial evidence that learning football juggling 70 times effectively increased the level of spontaneous neural activity in the cerebellum region. These promising findings provide new evidence to fully reveal the relationship between motion learning and brain plasticity.

Keywords: football juggling; spontaneous neural activity; rs-fMRI; ALFF

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1. Introduction

Motor learning is the core content of daily sports teaching competition and rehabilitation training [1,2], aimed on developing motor control and performance, especially inducing plasticity in the premotor cortex and skeletal muscles [3–5]. It is the process of moving from incapability to proficiency through practice, which involves changes in both external behavior and internal brain plasticity [6]. Due to the limitation of technology, motor learning research focuses more on the external behavior and less on the changes of the plasticity of the inner brain [7]. Recently, with the rapid development of functional magnetic resonance imaging (fMRI) technology, it is possible to reveal the relationship between motor learning and brain plasticity in a non-invasive and quantitative manner [4,8].

Brain is plasticity, which is mainly manifested by structural plasticity and functional plasticity. Prior studies have found that the brain is plasticity throughout an individual's developing life [5,6,8,9]. Motor learning and training are considered to be important means to affect the structural and functional plasticity of the brain [10]. The fMRI is a reliable method to assess motor learning and brain plasticity. Furthermore, the results of previous studies have shown that fMRI reliability might be specifically dependent by combinations of different factors [11,12]. Mainly by linear correlation analysis of the function of spontaneous neural activity connection, through the local feature analysis of low-frequency oscillation amplitude and regional homogeneity, such as spontaneous neural activity features [13]. Zou, et al. [14] proposed a low-frequency fluctuation amplitude (ALFF) indicator called resting-state fMRI (rs-fMRI) signal to reflect the intensity of spontaneous activity in the region. The rs-fMRI might provide functional connectivity analysis due to task-independent alterations in brain function and provide information according to experience-dependent brain plasticity [15]. The ALFF reflects the level of spontaneous activity of the various carcinoids from an energy perspective, which the researchers believe can reflect the spontaneous neuronal activity. ALFF's data analysis results come from the data itself, and there is no need to assume in advance that the brain region of interest is delineated, which makes it more objective [14,15].

Previous studies have shown that there are more detailed or in-laboratory tasks, such as finger [16] and visual sequence learning [17]. However, those studies have lower requirements on abilities such as multi-limb coordination perception, resulting in low ecological validity and external validity of the obtained results, which cannot be extended to the complex and real motor skill learning environment [16,17]. Football juggling refers to using the foot instep to keep the ball, ensure the ball does not fall to the ground of complex motor skills, toss the ball for the coordination of goal-directed limb movements, necessary visual and spatial orientation transformation of space movement, direction judgment motion speed, and motor coordination ability with high-performance requirements [5,9,18]. Football juggling is a complex movement that requires the coordination of sensory perception and cognitive functions of multiple parts of the body [19], as well it affects brain plasticity by vertical and horizontal integration [9].

Based on this, our study selected the football juggling as the learning task of motor learning, and adopted the resting functional magnetic resonance imaging (fMRI) technology to investigate the characteristics of the periodic changes of the spontaneous nerve activity during the learning process of football juggling, providing new evidence to fully reveal the relationship between motion learning and brain plasticity. Therefore, the study on the dynamic changes of the spontaneous neural activity during the learning process of football juggling in the real learning environment is helpful to fully understand the relationship between motor learning and brain functional plasticity. Based on the above knowledge, this study hypothesized that: learning football juggling 70 times can effectively increase the level of spontaneous nerve activity.

2. Materials and Methods

2.1. Study Design

This experiment was a cross-sectional and a randomized control trial single-blind study involving two repeated physical quality and MRI acquisition measurements taken before and after a football juggling learning. Group allocation was randomized and generated using Research Randomizer (Version 4). Participants were selected into two groups: (1) football juggling group (FJ, n = 68) and (2) control group (CON, n = 43) (Figure 1). Each measurement included: (1) physical fitness tests (lower limb strength, speed agility, and flexibility) and (2) spontaneous neural activity. All participants read and signed an informed consent form approved by the Ethics and Human Protection Committee of the Affiliated Hospital of Yangzhou University (2017-YKL045-01). The study was conducted according to the principles of the World Medical Association Declaration of Helsinki.

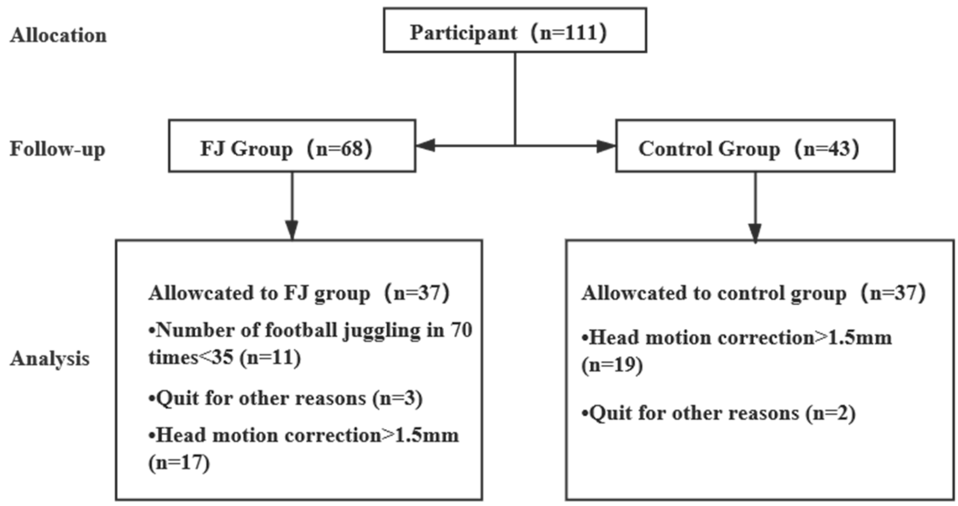

Figure 1. Randomization and follow-up of participants allocated to the intervention group (football juggling) or control group.

2.2. Subjects

The eligible population of the study included a group of 68 students divided into a football juggling (FJ) group (M/F = 45/23) and 43 students in a control (CON) group (M/F = 29/14) (Figure 1). Students were not eligible, if they met one of the following exclusion criteria: (1) history of serious physical disease, history of drug and alcohol dependence, brain trauma, and neurological disorders; (2) different nationality (There are 56 nationalities in China, among which there are great differences); (3) left-handed; (4) visual and auditory disorders; (5) with intellectual abnormalities; (6) with a BMI of 28 or greater; (7) received football training or regular participation in physical exercise in the past 6 months; (8) implanted metal (such as metal dentures) and electronic magnetic or mechanical devices (such as cardiac pacemakers).

Final inclusion: 59 subjects entered the experiment, including 37 in the FJ group (12 females and 25 males) and 22 in the control group (7 females and 15 males). Screening of reason: (1) The number of football juggling for 70 times fails to reach 35 (n = 11); (2) Quit for other reasons (n = 5); (3) Head motion correction >1.5 mm (n = 36), as shown in the Figure 1.

2.3. Procedure

All subjects were asked to recruit on the same day to provide demographic information and fill out the handedness questionnaire, symptom checklist (SCL-9017) [20] questionnaire, and Raven's standard progressive matrices (RPM18) [21]. Chinese scholars referred to the handedness questionnaire of the Annett and Edinburgh handedness questionnaire of Oldfield, and formulated the handedness questionnaire suitable for Chinese people according to the situation of our country [22]. The SCL-90 questionnaire is mainly used to measure the mental health status of the population [23]. Many research results show that the scale has good reliability and validity and is widely used in the screening of the mental health examination. The Raven's standard progressive matrices applies to all people over the age of 5.5 with normal intellectual development, and is not restricted by culture, race, or language. With good reliability and validity, the scale is widely used to measure intellectual ability [24–26]. The subjects were also asked whether they had experienced the football training of system or football training experience and inquired whether the condition of magnetic resonance scanning is met, then signed informed consent, finally according to the selection criteria selected to meet the requirements. According to the principle of random allocation, the subjects were divided into the FJ group of learning football juggling for 70 times and the control group of normal learning and life.

Before learning football juggling and after the 70 times of learning, the two groups of subjects were respectively led by the same examiner to the hospital for magnetic resonance scanning, and completed the resting functional magnetic resonance image scanning of pre-test (T1) and post-test (T3). On the second day after the end of the T1 MRI scan, the FJ group learned football juggling 70 times, while the control group received routine normal learning and life on the second day after the end of the scan.

2.4. Physical Measurement

The physical fitness test was divided into three parts: lower limb strength, speed agility, and flexibility. The test item of the lower limb strength part was standing long jump (cm), the test item of the speed-sensitive part was mainly 50 m run (s), and the test item of the flexibility part was sitting body forward bend (cm).

2.5. Learning Program

Based on the research of motor learning and brain plasticity at home and abroad, a learning scheme of football juggling was developed by referring to the content of football juggling.

The teaching implementation was based on self-study and self-practice and adopted the way of organizing to watch teaching videos and provide guidance on the way. Before learning football juggling each time, learners were required to first do a warm-up exercise for 8–12 min (including jogging and freehand drill) and then practice independently according to the exercise methods and action points explained in the teaching video. During the 30-minutes learning process, the teaching video could still be watched at any time, and fixed professionals could use unified instruction language to correct and guide learners' wrong actions. After learning, learners took 8–10 min to relax.

The learning time was 70 times, place fixed, once a day [26]. The subjects were required to bounce the ball on a 5 × 5 m flat field for one minute, and stop the test when the ball fell or exceeded the designated area halfway. The test was conducted twice a day after the end of the study, and the best score was recorded. When the number of football juggling reached 35, the learning was considered complete. The standards for the completion of the study in this paper refer to the standard for the football juggling of Students Soccer Skilled Rating Standard issued by the Ministry of Education of the People's Republic of China. The number of motion learning selected in this study is based on the teaching experience of experts in football teaching courses and the results of preliminary experiments.

2.6. MRI Acquisition

All the brain functional image data were collected in the MRI room of the Affiliated Hospital of Yangzhou University using a 3.0 t MRI scanner (GE Discovery MR750W 3.0T). To ensure the safety of the experiment and the effectiveness of the scan, the subjects had to wear a special scanning suit and take off all metal objects before entering the scan. Then, they entered the MRI scan room and laid down in a comfortable position. To reduce the impact of head movement on the data, the experimenters repeatedly instructed the head to remain as still as possible during the MRI scan and fixed the subjects' heads with a foam plate. The subjects wore earplugs to stop the noise generated by the subject during machine scanning. The rs-fMRI scan parameters (plane echo pulse train (EPI) scan): TR/TE = 2000/30 ms, layer number = 28, layer thickness = 3.0 mm, spacing = 1 mm, flip angle = 90°, acquisition matrix = 64 × 64, FOV = 224 × 224 mm. Preprocessing of low frequency amplitude (ALFF) value: In this study, the DPABI3.1software package was used to preprocess the experimental data. The software package needs to call the SPM8 software package and run in the MATLAB2013b environment. The whole pretreatment process was mainly divided into the following steps: (1) DICOM to NIFIT: The collected data were converted from DICOM format to NIFTI format which can be processed by software package; (2) Slice timing: The images in this study were interlayer scanning, with a total of 28 layers, and the reference layer is the 28th layer; (3) Realign: Checking the head movement parameters and eliminating the subjects whose translation was greater than 1.5 mm and rotation was greater than 1.5 to prevent signal changes caused by excessive head movement; (4) Reorient: Redefine the origin of each brain map; (5) Normalize: Use the default template provided by the software, the sampling rate was 3 × 3 × 3 mm; (6) Smooth: 6 mm half-height full-width smoothing kernel was used to perform Gaussian smoothing on the image to improve the signal to noise; (7) Detrend; (8) Regress Out Covariates: Taking Friston24 head motion parameter as co-variable, the influence of head motion on image was regressive; (9) Calculation of low-frequency amplitude: The range of 0.01–0108 hz was used for filtering to reduce low frequency drift and high frequency physiological noise. The ALFF value of each voxel was calculated, and then the calculated ALFF value was divided by the mean value of the whole brain to obtain the ALFF value through standardization to eliminate differences in the overall level of whole brain ALFF between individuals. The specific calculation principle and method of ALFF was described by Zang et al. [27].

3. Statistical Analysis

The prior sample size was calculated using G*Power [28] while we selected key parameters: (1) a medium effect size (Cohen's f = 0.8), (2) power of 0.80, (3) alpha of 0.05, and (4) difference between two independent means (FJ and CON). This indicated that a sample of twenty-six can generate a statistical significance.

The SPSS 18 statistical software (SPSS Inc., Chicago, IL, USA) was used for data analysis. Descriptive statistics (means ± standard deviation, SD) for physical fitness tests were calculated.

The Chi-square test was used to analyze the differences between males and females, however the independent sample t-test was used to conduct a homogeneity of the physical fitness test of the FJ and CON.

Statistical analysis of brain images was conducted by SPM8 flexible factorial design, and was used to analyze the differences between the FJ and CON in the pre-test and post-test low-frequency amplitude values, and to obtain the differences in the level of spontaneous nerve activity caused by learning football juggling A p-value < 0.05 was considered as statistically significant.

4. Results

4.1. Participant Characteristics

Chi-square test showed that there was no statistical significance in the number of male and female students in the two groups (x^2 = 1.39, p = 0.24); The independent sample t-test was used to analyze the ages of the two groups [t (59) = −0.21, p = 0.83].

The results showed that there was no statistical significance in the ages of the two groups; The independent sample t-test was used to analyze the BMI of the two groups of college students [t (59) = −0.67, p = 0.51], The results showed that the BMI of the two groups of college students had no statistical significance; The physical quality of the two groups of college students was analyzed by independent sample t-test: strength [t (59) = 0.97, p = 0.34], speed-sensitive [t (59) = 0.66, p = 0.521], flexibility, [t (59) = 0.19, p = 0.85]. The results showed that the physical quality of the two groups of college students had no statistical significance, indicating that the two groups of college students had homogeneity in demographic indicators and physical quality indicators. The demographic characteristics of participants in both groups are summarized in Table 1.

Table 1. Baseline characteristics of participants (M ± standard deviation (SD)).

	FJ Group	Control Group
Age (years)	18.24 ± 0.55	18.27 ± 0.46
Gender (males/females)	25/12	15/7
BMI	20.65 ± 2.95	21.17 ± 2.79
Strength (cm)	1.96 ± 0.26	2.05 ± 0.41
Speed (s)	7.93 ± 0.75	7.79 ± 0.86
Flexibility (cm)	13.18 ± 7.31	13.56 ± 7.71

FJ: football juggling; BMI: body mass index.

4.2. Spontaneous Nerve Activity

In this study, the SPM8 software package of MATLAB was used to establish flexible factorial design. The changes of ALFF values in the pre-test and post-test brain regions of the FJ group and CON were analyzed and the statistical threshold was set as $p < 0.01$ and the voxel as 50. The results showed that in the control group, the low frequency amplitude of their brains did not change significantly before and after the experiment, so there was no change in spontaneous neural activity in the control group. Different from the control group, the low frequency amplitude of the FJ group was significantly increased. It shows that football juggling 70 times effectively caused the enhancement of spontaneous neural activity in the FJ group. The brain region was right cerebellum 8 (RCbe8) as presented in Figure 2.

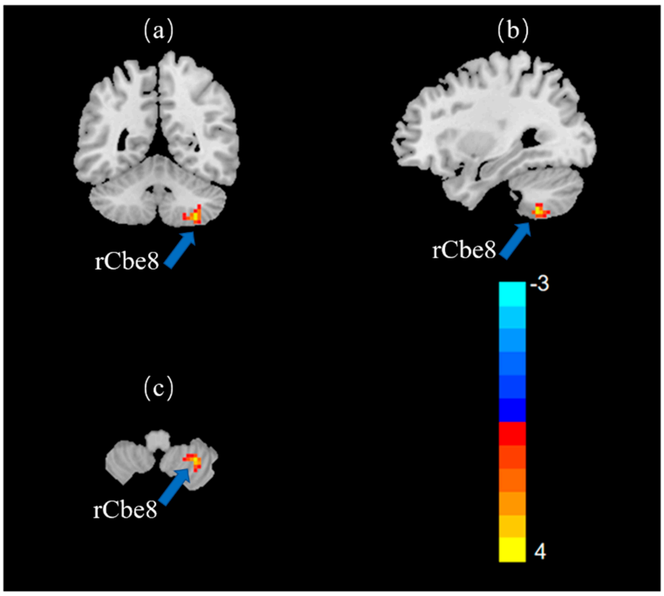

Figure 2. Brain regions with significantly increased ALFF values after learning football juggling 70 times. Note: the yellow highlight area is the right cerebellum area 8 (rCbe8), (**a**) is the coronal plane, (**b**) is the Sagittal plane, (**c**) is the axial plane.

5. Discussion

The present study investigated the effects of spontaneous neural activity during football juggling learning. With the continual employment of fundamental movement skill training and learning football juggling, the main findings revealed that learning football juggling for 70 times had effectively caused the enhancement of spontaneous neural activity in right cerebellum 8 (RCbe8).

5.1. Spontaneous Nerve Activity

Compared with the control group that did not learn the football juggling, the ALFF value of the right cerebellum area 8 of the FJ group that learned the football juggling increased. It is suggested that learning football juggling can cause an increase in the level of spontaneous nerve activity in the cerebellum of the college student.

Previous studies have shown that motor learning can cause the occurrence of brain plasticity, and the development of motor behavior must be accompanied by the change of internal neural mechanisms [1,2,4,18]. The findings of this study are consistent with previous studies that motor learning leads to an increase in the ALFF value of the cerebellum region [29–31]. The cerebellum is crucial for both motor control and learning, therefore due to regulation to multi-joint movements during motor control tasks [32]. Daskalakis et al. [33] reported that the cerebellum may be related to the learning process, and studies have shown that cerebellum activity changes significantly before and after motor learning. An action learning task in the experiment, research has been conducted for adults' and children's PET scans and functional magnetic resonance imaging [9,11,12,15], confirming the cerebellum activation in the process of learning, and found that activation of the decrease of the area is highly correlated with reductions of motion error, and activates the changing area is located in the left cerebellar hemisphere, also found on the right side and the former vermis cerebellar hemisphere activation associated with the subjects' ability and speed of finish [1]. In other words, when more mistakes are made during motor learning, more spontaneous neural activity will occur in the brain and the corresponding area of activation will also increase. In the process of learning football juggling, it is inevitable to experience body tension and stiffness, low degree of completion of movements, and many mistakes. Therefore, the corresponding activation area is bound to increase. In another study, participants were given a finger sequence exercise for 41 days, followed by functional magnetic resonance imaging scans before and after learning [34]. The results showed that both sides of the cerebellum were activated. In the case that the exercise frequency was controlled, the activation volume of the training sequence and the control sequence significantly changed during learning, which is believed to be related to the balance and coordination ability of the body [35]. In the process of learning football juggling, coordination and cooperation of multiple limbs are needed, especially the coordination and cooperation between the lower limbs. Untrained individuals generally have poor coordination ability of the lower limbs, and due to learning football juggling in the real environment, the movement of the ball and the changes of the surrounding environment should receive attention in the process of kicking the ball alternately between the lower limbs, which requires dynamic adjustments to maintain the balance of the body. Therefore, with the accumulation of learning time of football juggling, the demand for the control of balance and coordination of the body is increasing, which leads to the plasticity change of the cerebellum areas [36–39].

Furthermore, the above hypothesis has been confirmed in various studies. The design eliminated the influence of independent variables on the research results; thus, it might be scientifically explained that the changes in the level of spontaneous nerve activity of college students in this study were caused by learning football juggling 70 times. In the process of learning football juggling 70 times, the demand for an individual's ability of body coordination, body posture regulation, movement proficiency, and so on, increased, which caused the plasticity change of cerebellar related brain area, resulting in the increase of ALFF value in the right cerebellum 8 area.

To sum up, in this study, ALFF changes in the brain area caused by learning football juggling 70 times were investigated. It was found that football juggling caused the ALFF value of the right cerebellum 8 area to change significantly in college students. It supports the theory that motor learning can cause brain plasticity, and suggests that the learning of football juggling can cause change in brain plasticity, which provides new evidence for the relationship between motor skill learning and brain plasticity. This study explores the complex learning of football juggling handling in the real learning environment, so that the research results have better ecological validity and external validity.

5.2. Strengths and Limitations

A clear strength of our study is that it is the first time discussed the level of spontaneous nerve activity changes in the real learning environment and the complex learning process of football juggling. A further strength of this study is the rigorous control for several potential confounders, which could strengthen the assumption that learning football juggling can change the level of spontaneous nerve activity. Nevertheless, it is important to emphasize that there are still several limitations in the current study which need further discussion. Since baseline scores were not significantly different between the two groups, this non-random assignment may not affect our findings. We found the spontaneous activity level enhancement in the cerebellum was caused by learning football juggling 70 times. This can be discussed in the following research: In the different stages of learning football juggling, the brain may exhibit dynamic changes in the level of spontaneous neural activity.

6. Conclusions

This study has investigated changes in the level of spontaneous nerve activity during the complex learning process of football juggling in the real learning environment for the first time. It was found that learning football juggling 70 times effectively increased the level of spontaneous nerve activity in the cerebellum region. The results provide new evidence for the relationship between motor learning and brain plasticity, expanding the research field of motor learning and brain plasticity, and contributing to a comprehensive and in-depth understanding of the relationship between motor learning and brain plasticity. Further research is needed to investigate different stages of learning football juggling where the brain may exhibit dynamic changes in the level of spontaneous neural activity.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gaetano, R. Motor learning and didactics into physical education and sport documents in middle school-first cycle of education in Italy. *J. Phys. Educ. Sport* **2012**, *12*, 157.
2. Weigelt, C.; Williams, A.; Wingrove, T.; Scott, M. Transfer and motor skill learning in association football. *Ergonomics* **2000**, *43*, 1698–1707. [CrossRef] [PubMed]
3. Wei, G.; Luo, J. Sport expert's motor imagery: Functional imaging of professional motor skills and simple motor skills. *Brain Res.* **2010**, *1341*, 52–62. [CrossRef] [PubMed]
4. Niu, C.; Cohen, A.D.; Wen, X.; Chen, Z.; Lin, P.; Liu, X.; Menze, B.H.; Wiestler, B.; Wang, Y.; Zhang, M. Modeling motor task activation from resting-state fMRI using machine learning in individual subjects. *Brain Imaging Behav.* **2020**, *15*, 1–11. [CrossRef] [PubMed]
5. Hirano, M.; Kubota, S.; Morishita, T.; Uehara, K.; Fujimoto, S.; Funase, K. Long-term practice induced plasticity in the primary motor cortex innervating the ankle flexor in football juggling experts. *Mot. Control* **2014**, *18*, 310–321. [CrossRef]
6. Green, C.S.; Bavelier, D. Exercising your brain: A review of human brain plasticity and training-induced learning. *Psychol. Aging* **2008**, *23*, 692. [CrossRef]
7. Shea, C.H.; Wulf, G. Enhancing motor learning through external-focus instructions and feedback. *Hum. Mov. Sci.* **1999**, *18*, 553–571. [CrossRef]

8. Kim, J.J.; Cunnington, R.; Kirby, J.N. The neurophysiological basis of compassion: An fMRI meta-analysis of compassion and its related neural processes. *Neurosci. Biobehav. Rev.* **2020**, *108*, 112–123. [CrossRef]
9. Berchicci, M.; Quinzi, F.; Dainese, A.; Di Russo, F. Time-source of neural plasticity in complex bimanual coordinative tasks: Juggling. *Behav. Brain Res.* **2017**, *328*, 87–94. [CrossRef]
10. Calmels, C. Neural correlates of motor expertise: Extensive motor training and cortical changes. *Brain Res.* **2020**, *1739*, 146323. [CrossRef]
11. Caceres, A.; Hall, D.L.; Zelaya, F.O.; Williams, S.C.; Mehta, M.A. Measuring fMRI reliability with the intra-class correlation coefficient. *NeuroImage* **2009**, *45*, 758–768. [CrossRef]
12. Bennett, C.M.; Miller, M.B. fMRI reliability: Influences of task and experimental design. *Cogn. Affect. Behav. Neurosci.* **2013**, *13*, 690–702. [CrossRef]
13. Wang, J.-J.; Chen, X.; Sah, S.; Zeng, C.; Li, Y.-M.; Li, N.; Liu, M.-Q.; Du, S.-L. Amplitude of low-frequency fluctuation (ALFF) and fractional ALFF in migraine patients: A resting-state functional MRI study. *Clin. Radiol.* **2016**, *71*, 558–564. [CrossRef] [PubMed]
14. Zou, Q.-H.; Zhu, C.-Z.; Yang, Y.; Zuo, X.-N.; Long, X.-Y.; Cao, Q.-J.; Wang, Y.-F.; Zang, Y.-F. An improved approach to detection of amplitude of low-frequency fluctuation (ALFF) for resting-state fMRI: Fractional ALFF. *J. Neurosci. Methods* **2008**, *172*, 137–141. [CrossRef] [PubMed]
15. Guerra-Carrillo, B.; Mackey, A.P.; Bunge, S.A. Resting-state fMRI: A window into human brain plasticity. *Neuroscientist* **2014**, *20*, 522–533. [CrossRef] [PubMed]
16. Ma, L.; Narayana, S.; Robin, D.A.; Fox, P.T.; Xiong, J. Changes occur in resting state network of motor system during 4 weeks of motor skill learning. *NeuroImage* **2011**, *58*, 226–233. [CrossRef]
17. Lefebvre, S.; Dricot, L.; Gradkowski, W.; Laloux, P.; Vandermeeren, Y. Brain activations underlying different patterns of performance improvement during early motor skill learning. *NeuroImage* **2012**, *62*, 290–299. [CrossRef]
18. Alesi, M.; Bianco, A.; Padulo, J.; Luppina, G.; Petrucci, M.; Paoli, A.; Palma, A.; Pepi, A. Motor and cognitive growth following a Football Training Program. *Front. Psychol.* **2015**, *6*, 1627. [CrossRef]
19. Hou, W. A comparison of attention between outstanding young female soccer athletes and ordinary female middle-school students: Constructing a distinction equation based on parameter differences. *Chin. J. Tissue Eng. Res.* **2007**, *7*.
20. Bech, P.; Allerup, P.; Maier, W.; Albus, M.; Lavori, P.; Ayuso, J. The Hamilton Scales and the Hopkins Symptom Checklist (SCL–90). *Br. J. Psychiatry* **1992**, *160*, 206–211. [CrossRef]
21. Raven, J.C.; Court, J.H. *Raven's Progressive Matrices and Vocabulary Scales*; Oxford pyschologists Press: Oxford, UK, 1998; Volume 759.
22. Li, X.-T. The distribution of left and right handedness in Chinese people. *Acta Psychol. Sin.* **1983**, *15*, 27–35.
23. Jiao, T.; Yong-Hong, M.; Ming-Juan, S.; Jing, L.; Ke, M.; ZHANG, R.-Q. Survey on Mental Health Status of Urban Community Residents in Xi'an Based on SCL-90 Psychological Scale. *Soc. Sci. Educ. Hum. Sci* **2019**. [CrossRef]
24. Zhang, H.-C. Standardization research on Raven's standard progressive matrices in China. *Acta Psychol. Sin.* **1989**, *21*, 3–11.
25. Bilker, W.B.; Hansen, J.A.; Brensinger, C.M.; Richard, J.; Gur, R.E.; Gur, R.C. Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment* **2012**, *19*, 354–369. [CrossRef] [PubMed]
26. Taubert, M.; Draganski, B.; Anwander, A.; Müller, K.; Horstmann, A.; Villringer, A.; Ragert, P. Dynamic properties of human brain structure: Learning-related changes in cortical areas and associated fiber connections. *J. Neurosci.* **2010**, *30*, 11670–11677. [CrossRef] [PubMed]
27. Yu-Feng, Z.; Yong, H.; Chao-Zhe, Z.; Qing-Jiu, C.; Man-Qiu, S.; Meng, L.; Yu-Feng, W. Altered baseline brain activity in children with ADHD revealed by resting-state functional MRI. *Brain Dev.* **2007**, *29*, 83–91. [CrossRef] [PubMed]
28. Faul, F.; Erdfelder, E.; Lang, A.G.; Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res. Methods* **2007**, *39*, 175–191. [CrossRef]
29. Yin, Y.; Li, L.; Jin, C.; Hu, X.; Duan, L.; Eyler, L.T.; Gong, Q.; Song, M.; Jiang, T.; Liao, M. Abnormal baseline brain activity in posttraumatic stress disorder: A resting-state functional magnetic resonance imaging study. *Neurosci. Lett.* **2011**, *498*, 185–189. [CrossRef]
30. Di, X.; Zhu, S.; Jin, H.; Wang, P.; Ye, Z.; Zhou, K.; Zhuo, Y.; Rao, H. Altered resting brain function and structure in professional badminton players. *Brain Connect.* **2012**, *2*, 225–233. [CrossRef]
31. Kim, J.H.; Han, J.K.; Kim, B.-N.; Han, D.H. Brain networks governing the golf swing in professional golfers. *J. Sports Sci.* **2015**, *33*, 1980–1987. [CrossRef]
32. Tokuda, I.T.; Hoang, H.; Kawato, M. New insights into olivo-cerebellar circuits for learning from a small training sample. *Curr. Opin. Neurobiol.* **2017**, *46*, 58–67. [CrossRef] [PubMed]
33. Daskalakis, Z.J.; Paradiso, G.O.; Christensen, B.K.; Fitzgerald, P.B.; Gunraj, C.; Chen, R. Exploring the connectivity between the cerebellum and motor cortex in humans. *J. Physiol.* **2004**, *557*, 689–700. [CrossRef] [PubMed]
34. Gordon, A.; Lee, J.-H.; Flament, D.; Ugurbil, K.; Ebner, T.J. Functional magnetic resonance imaging of motor, sensory, and posterior parietal cortical areas during performance of sequential typing movements. *Exp. Brain Res.* **1998**, *121*, 153–166. [CrossRef] [PubMed]
35. Bloedel, J.R.; Bracha, V. Duality of cerebellar motor and cognitive functions. *Int. Rev. Neurobiol.* **1997**, *41*, 613–634.

36. Sanes, J.N.; Dimitrov, B.; Hallett, M. Motor learning in patients with cerebellar dysfunction. *Brain* **1990**, *113*, 103–120. [CrossRef]
37. Appollonio, I.; Grafman, J.; Schwartz, V.; Massaquoi, S.; Hallett, M. Memory in patients with cerebellar degeneration. *Neurology* **1993**, *43*, 1536. [CrossRef]
38. Akshoomoff, N.A.; Courchesne, E. A new role for the cerebellum in cognitive operations. *Behav. Neurosci.* **1992**, *106*, 731. [CrossRef]
39. Van Mier, H.I.; Petersen, S.E. Role of the cerebellum in motor cognition. *Ann. N. Y. Acad. Sci.* **2002**, *978*, 334–353. [CrossRef]