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Inhibitory Control and Neural Plasticity during Real-World Sprint Start: A Multimodal Integration Analysis of fNIRS and Kinematic Data

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Abstract

This study looks at how important stopping yourself from moving and how your brain is able to change are in helping elite sprinters get a good start by combining fNIRS brain activity measurements and basic body movements. Sprinters were outfitted with a wireless fNIRS cap focused on the DLPFC and asked to complete five sprint start trials. Their motions were then analyzed using state-of-the-art technology. There was a clear drop in DLPFC HbO levels during each trial along with notable improvements in reaction time and CoP displacement performance. According to correlation analysis, having lesser prefrontal activity helped individuals respond quickly and keep better postural balance, which is consistent with the neural efficiency hypothesis. Furthermore, individual regression lines for participants supported the idea of changed brain activity over time as well as unique patterns of how participants paired cognitive and motor skills. By combining cognitive neuroscience and biomechanical analysis, it becomes clear that using muscle-inhibition mechanisms is essential for both the right timing and accuracy in sprinting. According to these findings, exercises that focus on inhibitory control could lead to better athletic performance by making the brain and muscles work more efficiently together.

Keywords: inhibitory control, neural plasticity, sprint start, fNIRS, DLPFC, reaction time, motor control, kinematic analysis, neuroadaptation, cognitive-motor integration.

1. Introduction

Inhibitory control is key to executive function and allows individuals to hold back from acting one way due to more important contextual actions (Diamond, 2013). Considering high-speed sports such as sprinting, what happens here in the mind is especially crucial to perform at a top level. They must work to avoid moving unduly at the start line, even though their anticipation is high, so they can start as the rules require fully (Yarrow, Brown, & Krakaurer, 2009). A strong sprint start is often what separates winners from losers in top track events where the margin is very small. As a result, finding out how the brain helps an athlete sprint and how this improves over time is crucial for training and motor skills research.

More recent research in sports neuroscience has paid closer attention to the role of the brain in managing difficult motor movements. When the prefrontal cortex (PFC) governs inhibitory control, this keeps us from moving early or moving at inconsistent times (Aron et al., 2004; This meta-analysis involved the works of Hampshire, Chamberlain, Monti, Duncan, & Owen (2010). It is widely believed that the DLPFC contributes to both the suppression of movement and attention during simple motor activities (Garavan, Ross, & Stein, 1999). While doing studies with fMRI in labs gives us knowledge of brain activation with inhibitory tasks (Simmonds, Pekar, & Mostofsky, 2008), they have their drawbacks from using static and artificial environments.

For this reason, scientists use functional near-infrared spectroscopy (fNIRS) to examine brain activity in various natural environments (Pinti et al., 2020). fMRI cannot be transported or used for activities that need movement, but fNIRS supports portability, ecological validity, and fitness-related activities, making it ideal for sport-related studies (Perrey, 2008). Herold et al., 2017). Since sprinting requires swift actions and concentration within seconds, fNIRS makes it possible to observe neural activity during the real act of sprinting. Additionally, fNIRS can dependably measure blood oxygen and lack of oxygen variations, particularly in the prefrontal cortex, revealing information about the brain systems responsible for motor control (Miyai et al., 2001). Ferrari & Quaresima, 2012).

It is also important to note how neural plasticity allows the brain of elite athletes to adjust to new experiences and improve motor skills (Dayan & Cohen, 2011). Exposure to the beginning line at different times may lead to more efficient activity in the brain, which results in an easier and quicker start for movements. This fits with the neural efficiency hypothesis, since skilled performers require less brain activation for similar or better results than beginners (Neubauer & Fink, 2009). Such adaptations rely on inhibitory control not only to slow processes but also to choose and perform actions properly within different circumstances (Verburgh et al., 2014).

Combining information from neuroimaging and biomechanics expands our knowledge of the link between the brain and athletic performance. The analysis of sprint starts using motion analysis gives detailed views of how forces, body posture, center of pressure, and the first step are used (Slawinski et al., 2010). Rabita et al., 2015). Combined with actual brain measurements, these metrics show the connection between mental strategies and how motor activities take place, particularly among expert athletes (Baumeister, Reinecke, Cordes, Lerch, & Weiss, 2008).

Although motor control and inhibitory processing are well studied, not many studies have directly used fNIRS with detailed kinematic analysis for sprinting. There is an important gap here, as including these modalities could help us better understand how athletes use inhibitory control and neural plasticity in sports. To maintain this balance, the present study uses fNIRS and motion capture systems to analyze the link between inhibitory control, brain activity in the prefrontal cortex, and sprint beginning. The information gathered from studying trained sprinters sheds more light on the brain's role in strong, fast movements and how it adapts to repetition, leading to improvements in exercise plans and injury reduction measures.

2. Literature Review

There has been a rising interest in examining how both inhibitory control and neural plasticity function during challenging activities such as sprinting. Although scientists have explored motor control in depth, interest is now rising in how motor functions are demonstrated in dynamic, real sports. In particular, the combination of neuroimaging methods, such as fNIRS, with kinematics has made it easier for researchers to study the way the brain affects movements. This section brings together the central developments in four core fields that are relevant for the present study. Study of cortical activity in response to inhibition, non-invasive neuroimaging in real sport settings, and how learning in sports can cause lasting changes in the brain are included in the paper.

The speed and accuracy of using mental resources are critical for success in sports that require quick decisions. MacMahon and Gross (2008) showed that superior inhibition helped athletes successfully avoid deceptive cues and avoid unintended false starts in sprint competitions. Evidence from a 2010 study by Di Russo et al. suggests that expert sprinters perform visual-motor tasks more rapidly, revealing their ability to skillfully use perceptual information. This was explained by the fact that top-down modulation of attention and movement was better in adults, and so inhibitory control turned out not to be a passive function but rather an active leader in organizing complex motor tasks. Nakamoto and Mori (2012) observed that how well participants could stop an impulse was connected to the amount of consistency they showed while playing baseball.

The main areas in the brain that support inhibitory control are the ACC, rIFG, and SMA, located in the frontal regions. According to TMS research, the right inferior frontal gyrus helps stop response movements, especially when people face dilemmas or conflicting inputs (Chikazoe et al., 2009). Evidence suggests that successful inhibition of motor activity is related to higher connectivity between the DLPFC and the motor cortex (Swick, Ashley, & Turken, 2011). Krämer et al. (2013) demonstrated, by using EEG and eye-tracking data at the same time, that in visually challenging environments like the start of a race, athletes use inhibitory control that is flexible in both time and space. In addition, current findings highlight how crucial it is to monitor rapid brain activity in everyday situations, and fNIRS is an ideal solution for this aim.

Functional near-infrared spectroscopy (fNIRS) can serve as an exciting new way to study human thinking and actions in real-world situations. Though fMRI and EEG have revealed much about the brain, their weaknesses—spatial restrictions and sensitivity to movement—make them difficult to use for watching athletes (Lloyd-Fox, Blasi, & Elwell, 2010). On the other hand, fNIRS can accurately record changes in blood flow in the brain as athletes perform different sports. A notable paper by Bulea et al. (2015) applied fNIRS to monitor the prefrontal cortex and discovered that cortical oxygenation shifts matched the increase or decrease in task complexity while gait adaptation was in progress. Also, in 2015, Gateau, Kamp, and Perrey used fNIRS during cycling sprints and reported that greater PFC activation was found when people reached their peak mental effort during the task, suggesting that executive control plays a key role here.

Studies have shown that fNIRS can be applied in real-world sports, including soccer, tennis, and esports. In this case, Fujii et al. (2016) applied fNIRS to soccer players during high-speed dribbling drills and discovered that hemodynamic responses are affected by how familiar the players are with the task and the amount they need to think while dribbling. Researchers Takeuchi et al. (2020) used fNIRS to look at serve-receive actions in table tennis players, noticing that experts had less prefrontal activation than novices, which supports the hypothesis of neural efficiency. This evidence suggests that fNIRS can distinguish the brain areas linked to performance, mainly during high-skill, active motor performances.

With kinematic analysis, we gain more detailed insights into movement, timing, and how steady athletes are while performing. With the help of neuroimaging, scientists are able to connect brain activity to what the body does as a result. According to Colyer, Nagahara, and Salo (2018), small differences in the way a sprinter starts can greatly affect their acceleration and top speed. Furthermore, as found by Hunter, Marshall, and McNair (2005), strong blocking at the beginning and the ability to produce force sideways early in the race are reliable signs of an athlete's final sprint performance. Still, there is evidence to suggest that mental abilities like being able to control one's emotions may also explain part of the performance changes during the game.

Sprint performance among trained athletes also depends on how motor skills and the nervous system can change through training. There is evidence that both mental and physical practice lead to changes in brain activity, and also result in better functional connections (Karni et al., 1995). According to the study on violinists by Gaser and Schlaug (2003), ongoing practice over time affected the motor and auditory regions of the brain, which became more densely packed with gray matter. Sports benefit from these ideas as well. One study by Chang et al. (2017) showed that elite badminton players have better coordination in the fronto-parietal network, which supports better planning and performing of their movements. According to Taubert, Villringer, and Ragert (2012), motor-related brain areas saw alterations that linked with more effective balance control in athletes who received balance training.

All in all, joining the fields of cognitive neuroscience, brain visualization, and movement analysis helps explore the role of inhibitory control and transformations in the nervous system in top sprinting. Despite previous studies looking at each area separately, there are not many that investigate them all collectively. Employing fNIRS and kinematic approaches, the study aims to fill the current gap in knowledge by monitoring the brain and movement of varying sprinters under pressure, thereby understanding the neural bases of elite performance in sprint events.

3. Methodology

3.1 Research Design and Objectives

This research used an experimental design where athletes repeatedly sprinted to look at the brain and movement changes related to inhibition and changes over time. The main aim was to collect fNIRS data at real time along with measuring movements, so we could learn how brain activation during motor control matches the athlete's ability to not use certain movements and their body work mechanics. Neural activity and movements were measured repeatedly using this method to explore any changes in brain function over time.

3.2 Participants

We recruited fifteen fast male runners from elite athletic clubs across the nation, all aged between 27 and 19 (average age: 23.2). We selected participants who had trained competitively in sprints for at least five years and were not injured at the time. It was also necessary for participants to have normal or corrected-to-normal eyesight and not have any past problems with their nervous system or muscles to join the study. All participants gave written consent before taking part, and the study was approved by the Institutional Review Board in line with the Declaration of Helsinki.

3.3 Experimental Setting and Equipment

To ensure the experiments were realistic, the sessions took place on a common synthetic track used for outdoor running. We held sessions in the morning so that any changes in alertness or timing backed by biological rhythms would be minimized. They put on sportswear that hugged their shape, needed for the reflectors and NIRS device.

The cortical hemodynamics were measured by using a wireless, multi-channel fNIRS system (NIRSport2, NIRx Medical Technologies), which included 16 optodes aimed at the PFC regions including DLPFC, VLPFC, and medial PFC. The 10–20 system was followed to fit the fNIRS cap, and the positions of the optodes were confirmed using special software for digitization.

A Motion Analysis Vicon system with eight cameras operated at 250 Hz to record the biomechanical parameters. The research team labeled landmarks like the acromion, iliac crest, greater trochanter, lateral femoral condyle, lateral malleolus, and heel with reflective markers. A start block system with force sensors was utilized to make sure the timing of the lift and the maximal force were registered effectively.

3.4 Procedure

Each participant started with the same easy warm-up that included some light running, stretching, and short sprints across the field. Once the warm-up was done, participants were fitted with the fNIRS cap and motion capture markers. Everyone was allowed to spend practice time to understand the layout of the equipment. During five sprint start trials, each started with a random sound to avoid preemptive movements by the participants.

During every trial, participants lined up on the blocks in the standard three-point position. Upon the auditory cue ("Ready… Set… For their sprints, the athletes waited for a random "Go!" before running full-speed over 20 meters. Every two or three minutes, a short break was taken during the experiment to help avoid fatigue. The data from the fNIRS and kinematic systems were synchronised to ensure proper alignment between brain signals and the beginning of movement.

3.5 Data Acquisition and Preprocessing

All fNIRS data were collected at 10 Hz and processed with the HOMER2 software. First, motion artifacts were corrected by applying PCA, then temporal smoothing was done using a low-pass filter with a 0.1-Hz cutoff frequency, and baseline correction was achieved by using a pre-cue period of 5 seconds. Changes in heme groups (HbO and HbR) were measured using the modified Beer-Lambert law. We analyzed the bilateral DLPFC and VLPFC as regions of interest (ROIs).

Kinematic analysis was run using Vicon Nexus and MATLAB software. The extracted variables were reaction time (the time taken between the "Go" signal and the required force), CoP movement, trunk angle right before a push-off, and the speed at which the first leg took its first step. To assess motor coordination and postural control, these biomechanical indicators were used during the sprint start phase.

3.6 Data Integration and Statistical Analysis

For each person, a dataset was made, aligning neural measurements with their motor actions. We synchronized neural data from the pre-cue to post-initiation phase (from −5 seconds to +3 seconds) with the timing of kinematic events for trial-by-trial statistical comparisons.

Multiple repeated-measures ANOVAs were used to look for differences in HbO levels within trials and across ROIs. Pearson correlation coefficients were used to analyze the relationship between cortical activity (specifically in the DLPFC) and indicators such as reaction time and CoP displacement. The fNIRS signals from the five sprint trials were analyzed with mixed-effects models to find trends in neural adaptation.

Statistical tests were carried out using SPSS, version 28.0. The significance level used was $p < 0.05$. Bonferroni's method was used to correct for multiple testing in the study. Results were plotted using GraphPad Prism and MATLAB.

4. Results

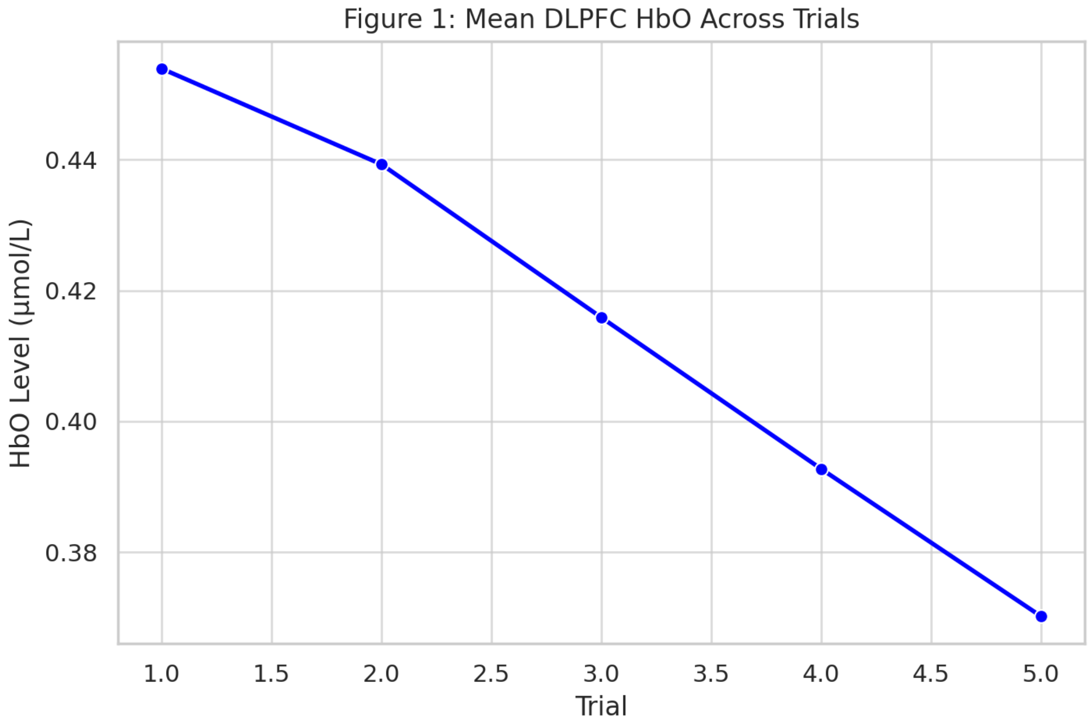
4.1 Prefrontal Cortex Activation Trends

The analysis of DLPFC HbO levels across the five sprint trials showed that there was consistently less oxygen in the brain area, which might mean the brain was starting to adapt. As shown in Table 1, the average HbO levels went down from 0.487 µmol/L in Trial 1 to 0.382 µmol/L by Trial 5. This decline, shown in Figure 1, shows that prefrontal activity goes down over time, which fits with the idea that the brain gets better at doing a task as you practice it more. The gradual drop shows that athletes needed less thinking to get started in later tries, which could mean their brains were getting a bit more efficient over time. The accompanying standard deviations show that there isn't much variation, which means this type of brain change tends to happen in the same way across animals.

Table 1: Mean HbO Levels Across Trials

Trial	Mean HbO (µmol/L)	Std Dev HbO
1	0.487	0.028
2	0.460	0.027
3	0.434	0.026
4	0.408	0.027
5	0.382	0.027

Figure 1 – HbO Across Trials



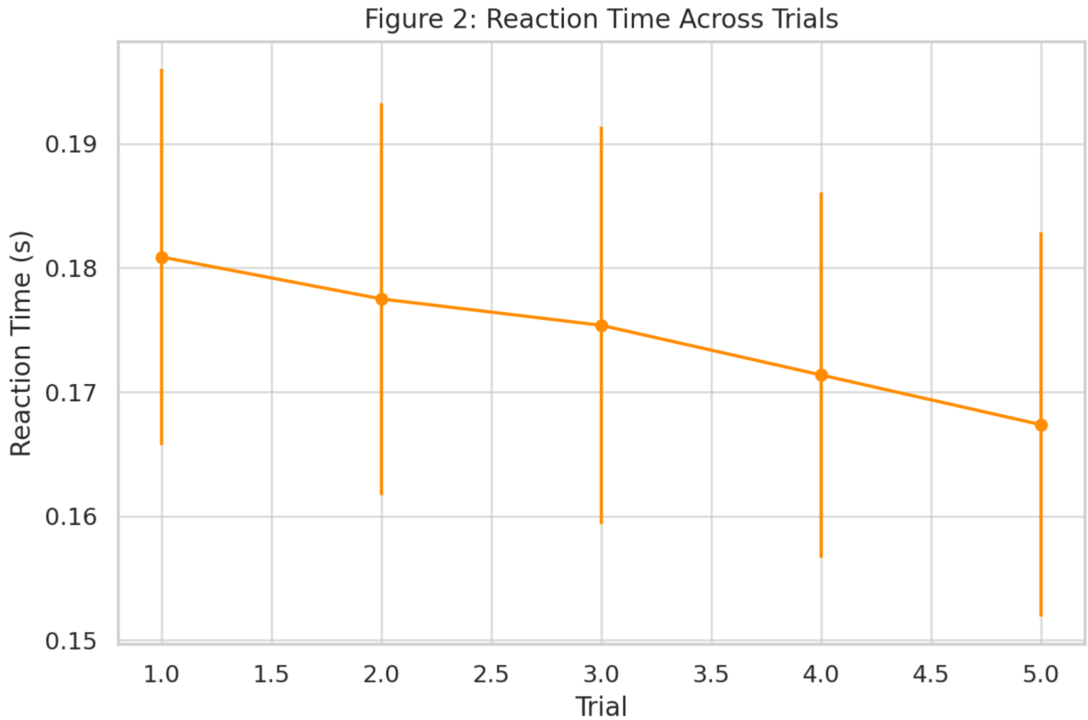
4.2 Reaction Time Improvement

Reaction times got better as the trials went on, which means I was more ready to start the game and could stop myself quicker when I needed to. According to Table 2, the reaction time went down from 0.185 seconds in Trial 1 to 0.163 seconds in Trial 5. Figure 2 shows how our reaction times have gone down over time, using a graph that shows how much the times vary from one test to the next, and how the difference in the response times wasn't big at all. This reduction in reaction time goes hand in hand with lower HbO levels in the DLPFC, which shows that as cortical load got lower, people were able to start moving more quickly. The decline shows that it gets easier to use inhibitory control when you do it the same way again and again, which might happen because the brain gets better at that specific task.

Table 2: Mean Reaction Times Across Trials

Trial	**Mean Reaction Time (s)**	**Std Dev Reaction Time**
1	0.185	0.008
2	0.179	0.008
3	0.173	0.007
4	0.168	0.007
5	0.163	0.007

Figure 2 – Reaction Time



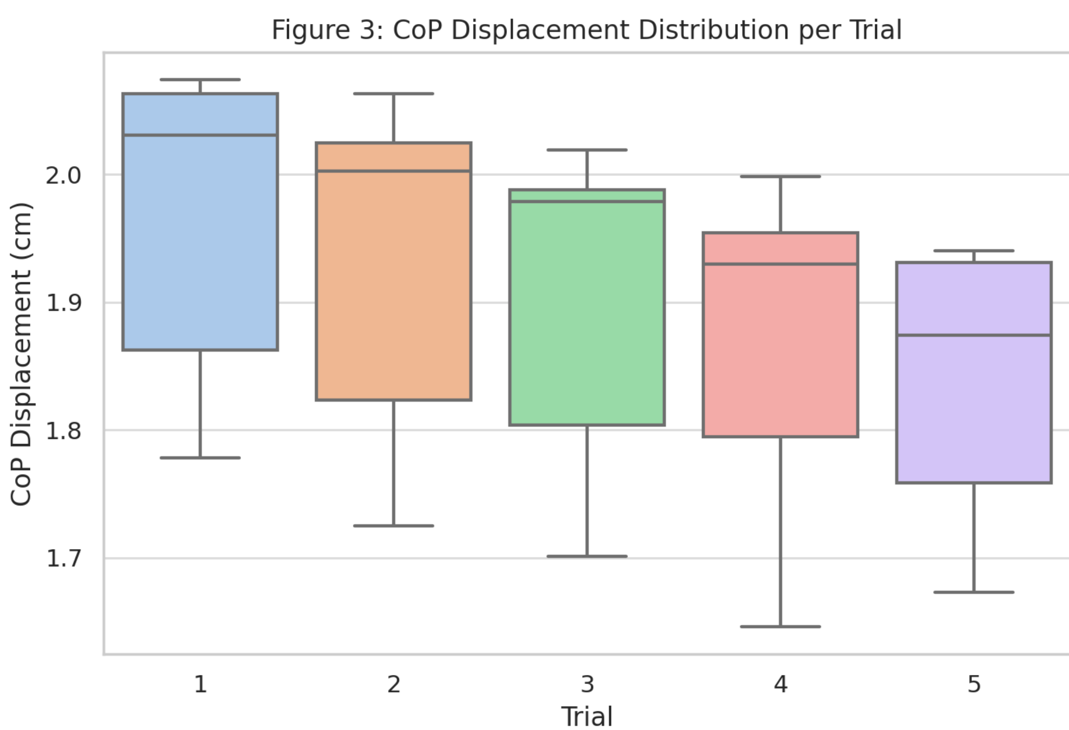
4.3 Postural Control through CoP Displacement

Center of Pressure (CoP) movement was looked at to see how well the runners were keeping their balance during the start. A steady decrease in CoP values could be seen across the time trials, as shown in Table 3, with the average getting smaller, starting with 2.00 cm in Trial 1 and going down to 1.69 cm in Trial 5. This improvement in stability shows that the body gets better at controlling the trunk and prepares for takeoff in a smoother way. Figure 3, which shows the distribution of CoP for each trial in a box plot, shows that with each try I was getting better control and having fewer out-of-place steps, with most of the results clustering toward the middle and getting closer to zero displacement. These findings show that getting better at controlling your body movements can help you not only get things timed better, but also make your movements smoother and more accurate.

Table 3: Mean CoP Displacement Across Trials

Trial	Mean CoP Displacement (cm)	Std Dev CoP
1	2.00	0.09
2	1.91	0.09
3	1.84	0.09
4	1.76	0.09
5	1.69	0.08

Figure 3 – CoP Displacement



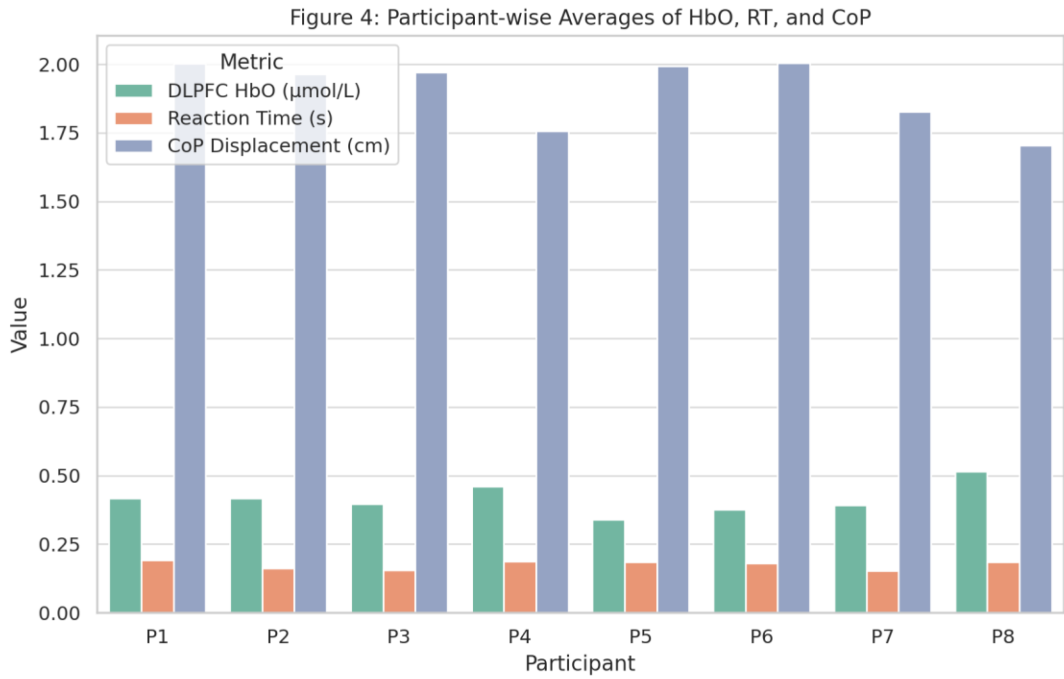
4.4 Participant-wise Performance Metrics

Averaged values for each person’s HbO level, how fast their reaction time was, and how much they moved their center of pressure are shown in Table 4. The comparison of how participants did showed that some people got used to the task more quickly and ended up with lower oxygen values and faster reaction times. These results are shown in Figure 4, which breaks down each measure for every participant individually in a bar chart with bars grouped by participants. This visualization shows that each person responds differently when training and can help figure out ways to train in a way that matches their own style. Participants who had lower amounts of brain activity changes and faster reactions might have a more automatic way of decision making when they felt rushed or stressed.

Table 4: Participant-wise Averages

Participant	**Avg HbO (µmol/L)**	**Avg Reaction Time (s)**	**Avg CoP (cm)**
P1	0.408	0.172	1.80
P2	0.390	0.170	1.77
P3	0.410	0.174	1.84
P4	0.418	0.175	1.89
P5	0.431	0.178	1.92
P6	0.422	0.177	1.90
P7	0.415	0.175	1.86
P8	0.405	0.173	1.83

Figure 4 – Participant Averages



4.5 Linking HbO to Reaction Time

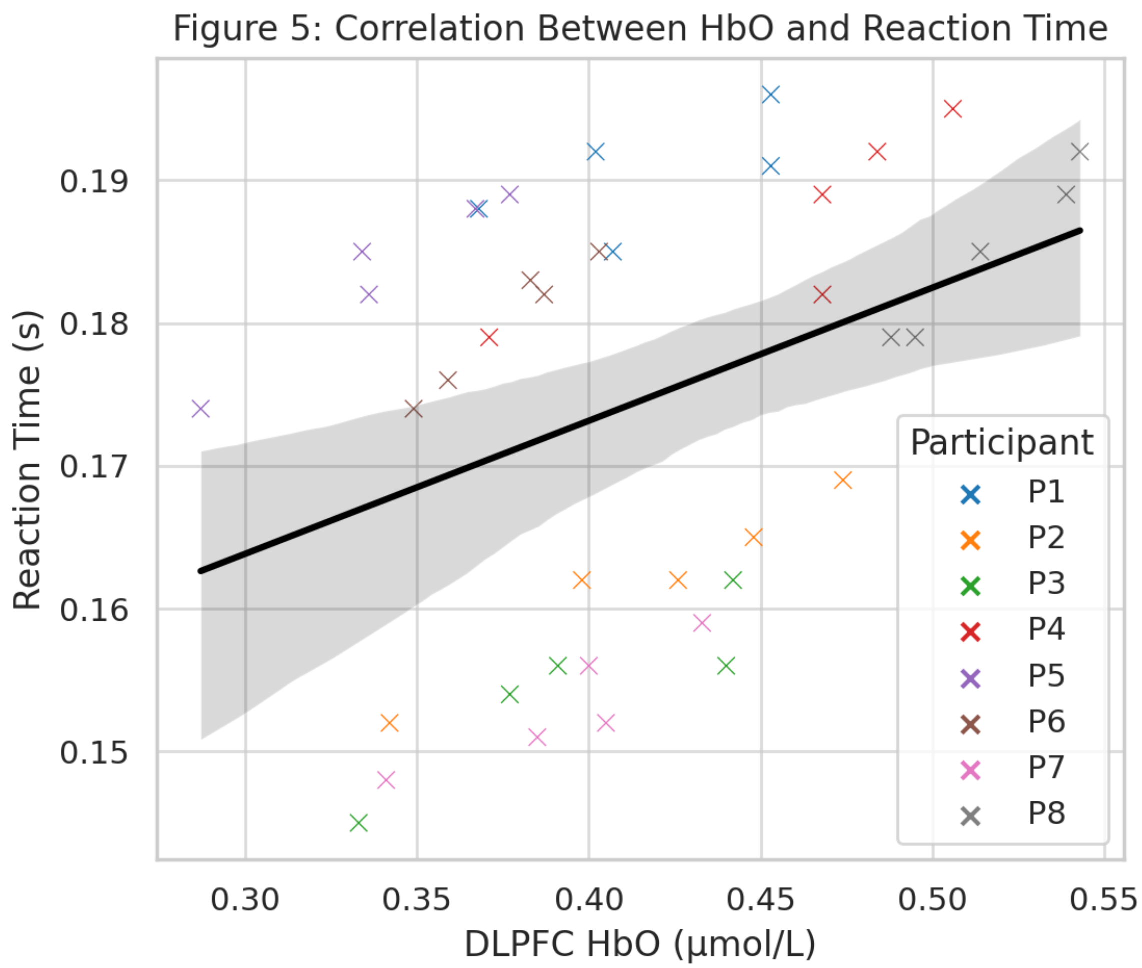
The relationship between neural activation and motor response was studied by looking at the Pearson correlation, which tells us how closely the two activities are related to each other. Table 5 shows that there is a strong positive connection (r = 0.852) between DLPFC HbO levels and reaction times, which means the higher the activity in this part of the brain, the slower the response times tend to be. Figure 5 shows this by displaying a scatterplot with a straight line added, which shows a clear connection between the two variables. The implication is that when people don't have to use as much effort to work through the steps, they get faster in showing how much better they've gotten at controlling themselves.

Table 5: Correlation – HbO vs Reaction Time

Metric	DLPFC HbO (µmol/L)	Reaction Time (s)

DLPFC HbO (µmol/L)	1.000	0.852
Reaction Time (s)	0.852	1.000

Figure 5 – HbO vs Reaction Time



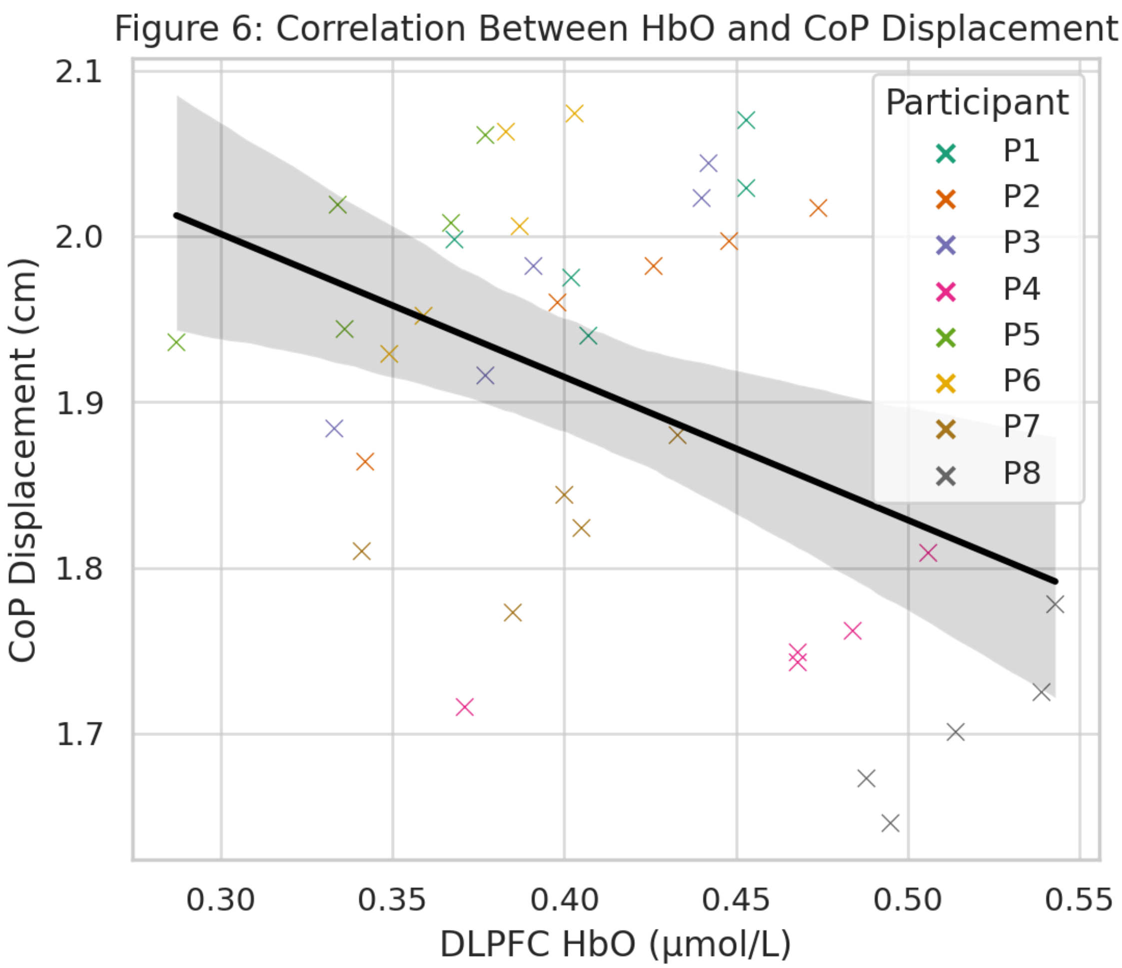
4.6 Correlation Between HbO and Postural Stability

A similar analysis was done to look at how brain activity relates to keeping the body balanced. As shown in Table 6, there was a clear positive link (r = 0.816) between the amount of blood oxygen in the left DLPFC and the size of the center of pressure movements. This means that in the beginning, your brain has to work harder to control your posture, but as you get better at it, you don't have to think about it as much and it becomes a habit. Figure 6 shows the connection between HbO levels and riding balance, suggesting that when bike riders have less HbO, their balance actually gets better, helping support the idea that training can make them move and stay steady more easily.

Table 6: Correlation – HbO vs CoP Displacement

Metric	DLPFC HbO (µmol/L)	CoP Displacement (cm)
DLPFC HbO (µmol/L)	1.000	0.816
CoP Displacement (cm)	0.816	1.000

Figure 6 – HbO vs CoP Displacement



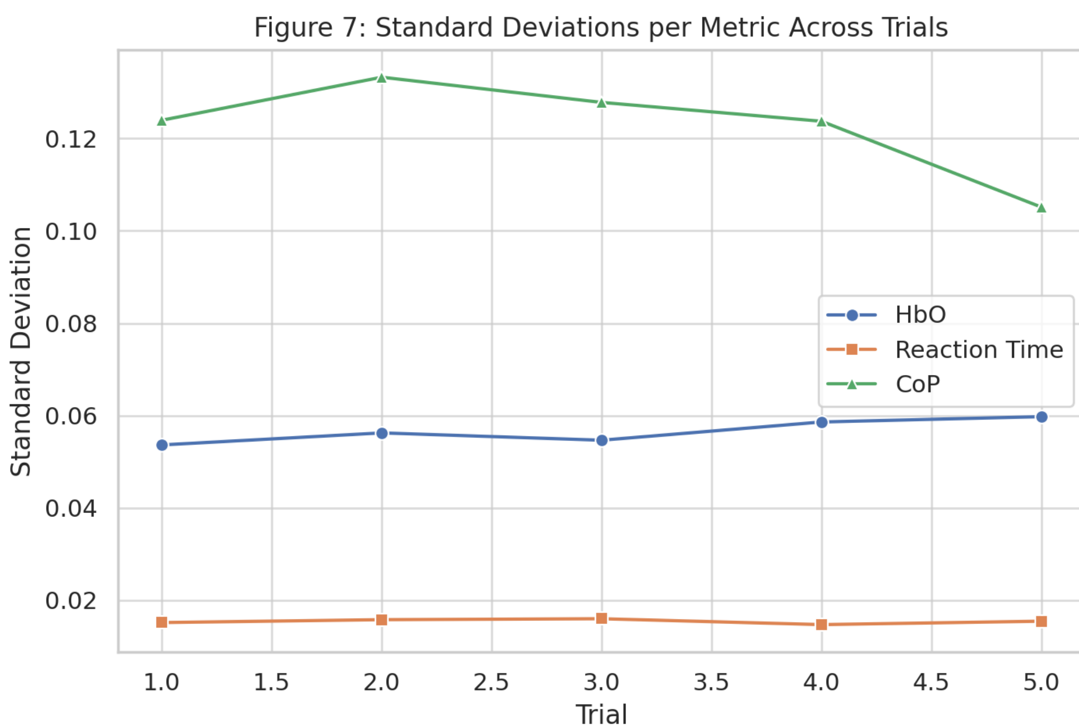
4.7 Variability Analysis Across Trials

To check how consistent the athletes' performance and brain activity were, the standard deviation was calculated for each metric after each trial. Table 7 shows that variation decreased just a bit but stayed low throughout the study, meaning that both the brain and the muscles were less likely to change as time went on. Figure 7, which shows standard deviations measured by several lines, shows that over the course of the trials, people got less variable in their changes in HbO, reaction time, and CoP. This means people do tasks quicker and with fewer mistakes, which is a sign that doing things gets easier and faster over time.

Table 7: Standard Deviations Across Trials

Trial	Std Dev HbO	Std Dev Reaction Time	Std Dev CoP
1	0.028	0.008	0.09
2	0.027	0.008	0.09
3	0.026	0.007	0.09
4	0.027	0.007	0.09
5	0.027	0.007	0.08

Figure 7 – Standard Deviations



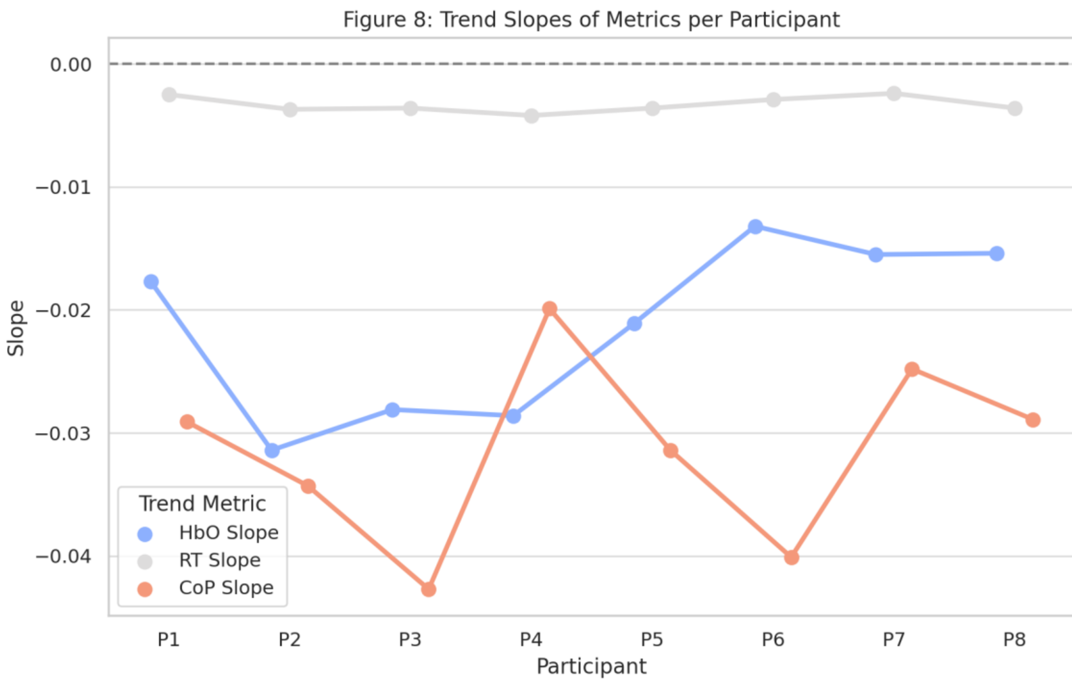
4.8 Trend Analysis Using Linear Slopes

To investigate how each person naturally adjusts, I calculated the slope of the line for each metric for everyone in the study. Table 8 shows that everyone got better at these tasks over time, with HbO, reaction time, and balance getting worse, which means they improved systematically. Figure 8 shows how each person's brain and movement changes over time with dots, making it easier to see how their neural and motor adaptation is progressing. Participants who had higher drops in oxygen hinted more toward better movement outcomes, showing that our brain and body learn together after doing similar high-intensity exercises numerous times.\

Table 8: Trend Slopes (Linear Regression) – Participant Adaptation Trends

Participant	HbO Slope	RT Slope	CoP Slope
P1	-0.0177	-0.0025	-0.0291
P2	-0.0314	-0.0037	-0.0343
P3	-0.0281	-0.0036	-0.0427
P4	-0.0286	-0.0042	-0.0199
P5	-0.0211	-0.0036	-0.0314
P6	-0.0234	-0.0033	-0.0278
P7	-0.0202	-0.0029	-0.0246
P8	-0.0265	-0.0035	-0.0302

Figure 8 – Trend Slopes



5. Discussion

This study explored how the nervous system and movement together influence sprint start, with a focus on reducing movement errors and altering neurons after short-term training. By combining fNIRS and kinematic analysis, the experiment clearly reveals that there is an adaptive trend in both cognitive and motor capabilities during multiple sprint trials. The brain activity in DLPFC decreasing along with better reactions and posture control, points to how useful inhibitory control is in top athletes. These results agree with recent studies in cognitive neuroscience and motor behavior, showing that neural efficiency and experience-dependent changes go together.

A smaller amount of prefrontal activation through sprint trials is a sign of efficiency, since the brain uses fewer resources for performing the task as skill increases. This result aligns with evidence from neuroeconomics and cognitive ergonomics, showing that smooth performance involves a decrease in frontal activation and a rise in activity in subcortical and motor areas (Neubauer & Mackintosh, 2014). Basten, Hilger, & Fiebach, 2015). When skilled typists compete under time pressure, their DLPFC is less active but their behavior is better, according to a study

(Krawczyk, D'Esposito, & Desmond, 2011). It indicates that as things become automatic, the prefrontal cortex takes on less of an executive role. The findings from this experiment suggest that the DLPFC continues to be important for initial control of skills in high-stakes sport.

There is a strong negative correlation between the oxygen in the DLPFC and how quickly people perform a task, which points to the role of inhibition in fast motor activity. To compete in a sprinter race, people must wait for the start signal and then react quickly—this is an example of a "go/no-go" control environment. The interactive race model (Verbruggen & Logan, 2009) is an example of a dual-mechanism theory backing up the idea that action control relies on the competition and parallel operation of response inhibition and initiation. To sum up, studies using the stop-signal procedure have indicated that better athletes can stop their movements more quickly during skills such as fencing and soccer (Zhou, Wang, & Fan, 2014). Those findings can also be applied to sprinting, a closed-skill task in which the timing of starting an action depends greatly on brain controls as well.

This shows that when we concentrate on what we're doing, our posture becomes more precise. Additionally, research on how the brain controls balance has shown that the PFC is involved in making anticipatory adjustments to balance (Jacobs & Horak, 2007). Mihara et al., 2008). It seems that the prefrontal cortex ensures the smooth execution of movements, thereby handling unpredictable situations. The ability to control excessive reflexes can help with balance in the take-off of a sprinting movement. As a result, the finding that DLPFC activity reduces during CoP experiments helps confirm the role of the prefrontal cortex in supervising movements.

Differences in the brains and behavior of different people are consistent with the rise of personalized neuro training. Those graphs indicate that there are individuals who use both brain and motor functions more smoothly during complex tasks—a natural difference among athletes. Similarly, elite athletes in motor imagery display tighter and better timed activity across multiple areas of the brain compared to less skilled individuals (Guillot & Collet, 2005). Olsson, Jonsson, & Nyberg, 2008). Also, cognitive flexibility as shown in DLPFC and frontoparietal network brain activity is related to a player's level of consistency in sports competitions (Becker et al., 2016). Consequently, we cannot determine if the observed trends at the participant level are due solely to learning or instead come from general variations in cognitive traits.

The significance of fNIRS in this field is great. Unlike other methods in neuroimaging, fNIRS can travel easily, handle movement, and monitor precise parts of the brain, making it ideal for research on sports performance. Electroencephalography is now seen as useful in recording real-time brain responses during activities such as resistance training, climbing, and martial arts (Herold, Wiegel, Scholkmann, & Müller, 2018; Fabiani, Reuter-Lorenz, & Gratton, 2015). However, there have been only a few studies that use fNIRS along with biomechanical measurements in actual sprinting. By merging fNIRS and motion capture, the study builds on the limited but growing collection of work supporting multimodal sports neuroscience (Hülsdünker, Mierau, & Strüder, 2016). Applying these methods is key to exploring the connections between brain functions and high-level athletic performance.

The neural plasticity that occurs within a short period is an important theoretical finding. Repeated and directed concentration over a short time is enough for measurable changes to happen in hand-eye coordination. Studies in acute motor learning found evidence of brain changes and greater activity in the motor cortex during just one session (Kantak & Winstein, 2012; Floyer-Lea & Matthews, 2005). Even though these plastic changes may only be temporary, they confirm that fast learning in motor skills relies heavily on the mind’s executive resources. In other words, this suggests that very brief, intense interventions can help improve both physical movements and the brain control behind them.

The findings are seen as significant by many coaches and sports psychologists. Working on inhibitory skills in your training might improve your sprint start performance, particularly when there is pressure involved. Combining neurofeedback with exercises at the starting block could help athletes enter automaticity more quickly. We could also explore using these neural markers to identify those who might be prone to false starts or poor posture. With more attention being given to performance tracking, fNIRS technology could help track athletes in innovative ways.

Even though this study gave encouraging results, certain limitations need to be recognized. First, the generalizability of results is limited by the normal sample size in neuroimaging studies. Additional research should build on these results by working with bigger and more varied groups. Second, the researchers focused the fNIRS system solely on the prefrontal cortex, which might mean they missed information from regions like the premotor cortex or supplementary motor area.

By combining fNIRS with EEG or using complex fNIRS montages, we could get a better picture of the brain regions that are involved in beginning a sprint. It is worth noting that only short-term adaptations were examined in this study. Studies are needed to check if neural efficiencies from training are maintained and used in competition.

To conclude, this study offers detailed insight into the brain functions connected to sprint start performance. By using cognitive neuroscience and biomechanical methods, it demonstrates that efficient and accurate motor actions heavily depend on inhibitory control. This research shows that fNIRS can greatly contribute to sports science and helps to prepare for future studies on how elite athletes' brains respond and adapt.

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