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Letter to the Editor: Response regarding "Single-session anodal transcranial direct current stimulation to enhance sport-specific performance in athletes: A systematic review and meta-analysis"

Dear Editor,

We appreciate the valuable input provided by Machado & Amiri (2023). Through this response letter, our aim is to eliminate any uncertainties pertaining to our meta-analysis [1]. Please note that substantive remarks by the authors are condensed for the sake of readability.

An initial comment concerned the inclusion of 1) tDCS studies using multiple target areas and 2) tDCS studies combining stimulation with interventions. Regarding the first point [2], used a dual montage covering both temporal cortex (TC) and primary motor cortex (M1). Crucially, both targets were referenced separately. Such montages are employed to dissect distinct effects arising from two specific target areas within interventions utilizing dual-stimulation protocols. This approach gains particular importance when discrete ergogenic outcomes are associated with each target area, similar to the context highlighted in the study of [2]. When a common reference is used to cover both target areas, the challenge of drawing area-specific inferences becomes intricate due to the dominant influence of the common reference. This can result in potential neural interference or cross-talk, complicating the accurate interpretation of findings. Consequently, the inclusion of [2] was undertaken to address this concern. It acknowledges that using separate references for each target area, as opposed to a common reference, potentially provides a more robust basis for deriving definitive conclusions about the distinct influences exerted by these individual target areas. In another study [3], both M1 hand areas received stimulation, while reference electrodes were placed on spinous processes. This electrode arrangement creates a distinct current flow for this montage, although the main focus of stimulation is on M1. Furthermore, it is important to note that the positioning of reference electrodes is a known factor affecting the variability of tDCS protocols, along with other aspects like current intensity, electrode size, current density, and stimulation duration. For example, a reference electrode using conventional tDCS setups is not necessarily ineffective in modulating underlying brain activity [4]. Therefore, tDCS always modulates several brain regions simultaneously. If we were to overly standardize all these factors, it would make it difficult to combine analyses, identify patterns, or conduct follow-up studies based on them. We are, therefore, confident that the standardization of inclusion criteria adopted in our meta-analysis is restrictive enough to include only studies that are closely related in terms of content and methodology, yet permissive enough to account for the heterogeneity of tDCS protocols. Crucially, all these implications were transparently mentioned as well as discussed in our original meta-analysis.

Concerning 2) [5–7], used a type of Stroop task to induce mental fatigue. Both [5,6] applied tDCS (a-tDCS or sham) during the mental fatigue task. Nikoohaarf Salehi et al. [7] induced mental fatigue before tDCS was applied. In all studies, sport-specific performance was assessed after completion of tDCS. We agree that the induction of mental fatigue in addition to brain stimulation might have influenced the outcome of tDCS. However, we opted to include these studies, since athletes experience mental fatigue and cognitive challenges such as anxiety and performance pressure before competitions, making these studies important for the overall aim of the meta-analysis to investigate the ecological validity of tDCS, or as we explained "investigation of sport-specific performance changes through tDCS seems essential to further approach the understanding of the potential of tDCS applications under real-life conditions compared to highly controlled laboratory settings".

Another point was raised concerning the inclusion of a study by Fortes et al. [8]. Machado & Amiri (2023) assumed that participants should not be eligible for inclusion because they were recreational practitioners, citing Fortes et al. [8] as follows: "Twelve participants were recreationally trained in resistance training". Crucially, the complete statement of the article in question reads: "Twelve participants were recreationally trained in resistance training (i.e., individuals consistently trained from three to ten years, frequency 3–5 sessions per week)". Accordingly, the trained subgroup certainly fits within our athlete inclusion criteria as we included "healthy male or female adult athletes (participating regularly in organized sport for at least 2 years before the experiment)". Importantly, only data from trained participants of this study was included in our meta-analysis.

Moreover, Machado & Amiri (2023) raised concern regarding a study by da Silva Machado et al. [9], where HD-tDCS and conventional tDCS were employed. This study was included in our original meta-analysis, although we chose to include only the data of the conventional tDCS setup of their study for the following reasons: 1) the majority of studies included in the meta-analysis used conventional tDCS, 2) the same brain target (M1) was stimulated, using the same participant sample, so the inclusion of both study arms may have influenced the overall effect. However, to check whether inclusion of the HD-tDCS arm in our meta-analysis would have changed the overall result, we conducted a reanalysis. The overall effect favouring a-tDCS over sham remained the same (SMD = 0.31, p = 0.0002), while the subgroup effect for M1 stimulation changed from SMD = 0.33 (p = 0.01) to SMD = 0.32 (p = 0.008). Therefore, we are confident in our initial

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result. Furthermore, the authors seemed concerned with a subsequent statement in our original manuscript that reads: "One study compared conventional tDCS with HD-tDCS [9]. Because there were no differences between conventional tDCS and HD-tDCS in this study, the focus of the current review was on conventional tDCS." This wording might have led the authors to believe we generally excluded HD-tDCS, which was not the case, as this statement referred exclusively to the study of da Silva Machado et al. [9].

A final issue concerned the practical implications resulting from a combination of findings from both subgroup analyses. We agree, that such implications cannot be drawn, and want to stress that we explicitly state that separate subgroup analyses were performed. At no point in the original article do we draw conclusions based on a combination of both subgroup analyses.

We hope this letter resolves the ambiguities cited and encourage future studies on this vibrant, dynamic topic of tDCS-induced performance enhancement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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