



## Are EMG and visual observation comparable in determining resting motor threshold? A reexamination after twenty years



Dear Editor:

Resting motor threshold (rMT) determination is important for safe and effective transcranial magnetic stimulation (TMS). rMT determination methods include visual observation (VO) or electromyography (EMG). Many TMS providers do not have access to EMG equipment, so VO was explored as an alternative in early TMS development. Pridmore and colleagues (1998) demonstrated that rMT determined by observation of TMS-induced visible movement caudal to the wrist was roughly equivalent to EMG [1]. Neuronetics used VO for their pivotal trial [2], however other trials used EMG [3–5]. Additionally, Parameter Estimation by Sequential Testing (PEST) further improved VO rMT determination [6,7].

The Pridmore study contained only 6 subjects and no one has since formally compared VO to EMG rMT. One study demonstrated that given a single muscle, EMG produces lower rMT than does visual movement of that isolated muscle [8]. VO of the muscles caudal to the wrist, the clinically adopted method, was not examined. We reexamined this important question.

### Study overview

We enrolled 17 healthy individuals (mean age 31.1 (SD 9.0), 7 female) in this randomized study comparing VO vs EMG rMT. Participants signed informed written consent, were screened for TMS eligibility using the TMS Adult Safety Screen (TASS), and attended a single experimental session. After finding the individual's motor

hotspot, we conducted 4 sequential rMTs (2 rMTs per determination method – VO and EMG – counterbalanced over all participants, Fig. 1a). TMS operators were blind to rMT values.

### TMS administration

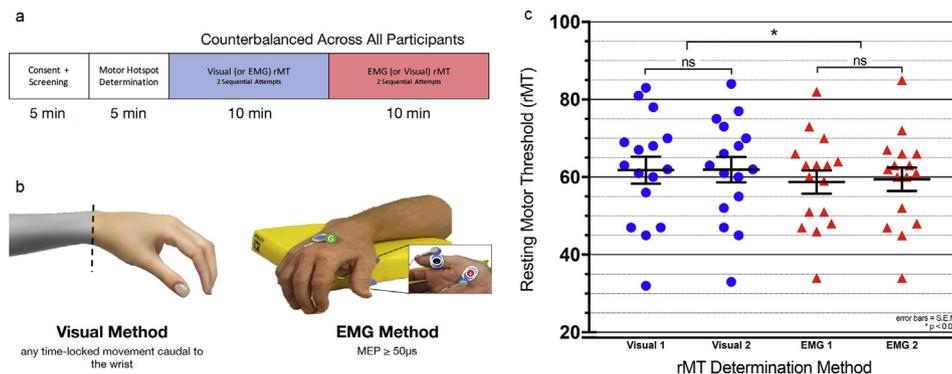
Each participant had one of either two designated expert TMS operators with high inter-tester reliability locate their motor hotspot and determine all 4 rMTs. We administered TMS using the Neuronavigation-assisted Horizon System's (Magstim, UK) MT coil held by a clamp and fixed in place on the scalp.

### Motor hotspot determination

We systematically delivered single supra-threshold TMS pulses to the left motor cortex to locate the “hotspot” eliciting the largest visible isolated right thumb twitch. This was conducted once, digitally marked on the neuronavigation software, and used as the target for all four rMTs.

### Visual rMT determination

Single TMS pulses were delivered to the motor hotspot (<0.3Hz) using PEST ([www.clinicalresearcher.org](http://www.clinicalresearcher.org); start: 50, step: 7, difference: 0.45) to determine machine output settings. The TMS operator (standing on the participant's left side) observed motor twitches elicited by TMS (any muscle activation caudal to the right



**Fig. 1.** a) overall timeline of the experimental visit. b) hand representations demonstrating how the motor threshold was determined. For visual method, any muscle movement caudal to the wrist was considered a “yes” response. For EMG methods, electrodes placed as shown measure MEP’s. c) rMT values for each of the 4 attempts (n = 16 per attempt) reveal that within-methods, Visual and EMG rMTs are non-significantly different and consistent between test 1 and test 2. Between-methods reveal EMG rMT as slightly lower than visual method.

wrist) Fig. 1b. The right hand was resting palm-down on a flat foam pad with no muscles working against gravity Fig. 1b. After each pulse, “yes” or “no” was input into PEST by a software operator who adjusted machine output accordingly until rMT was determined. rMT and number of steps required were recorded.

#### EMG rMT determination

Identical methods were used as above, with the exception that surface EMG electrodes were placed on the participant's right thumb (APB) Fig. 1b. TMS was delivered to the motor hotspot and MEPs were recorded [6] on the Magstim StimGuide platform. Criteria for “yes” response was  $>50\mu\text{V}$ .

#### TMS operator blinding

The PEST/machine operator sat behind a screen that concealed all numerical values from the TMS operator.

#### Analysis

rMT and number of PEST steps were analyzed in both within- and between-method design using paired sample t-tests in Prism 7 (GraphPad Software, USA). Intraclass correlation (ICC(3,1)) analysis was conducted to determine rMT test-retest reliability (IBM SPSS 25, SPSS Inc. Prior to any analysis, one participant's data was removed, as that session was disrupted and data deemed unreliable.

#### Results

Within-method analysis revealed non-significant differences between rMTs conducted in each determination method [(Mean  $\pm$  SEM): VO rMT 1 =  $61.81 \pm 3.48$  vs rMT 2 =  $61.94 \pm 3.31$ ,  $n = 16$ /attempt; EMG rMT 1 =  $58.75 \pm 2.99$ , rMT 2 =  $59.44 \pm 3.02$ ,  $n = 16$ /attempt].

Between-method analysis comparing the mean combined rMT of VO vs EMG revealed that the EMG method generated lower rMT values [(Mean  $\pm$  SEM): VO rMT =  $61.88 \pm 3.345$ , EMG rMT =  $59.09 \pm 2.75$ ; mean difference = 2.781,  $n = 16$ /method,  $p = 0.03$ ,  $t = 2.394$ ] Fig. 1C.

High within-method reliability (between repeated attempts 1&2) was found for both methods [(alpha, 95%CI) VO: 0.940, 0.838–0.979; EMG: 0.957, 0.882–0.985] confirming within-method consistency.

Both methods required approximately the same number of TMS pulses to determine rMT (mean  $\pm$  SEM) (VO:  $16.41 \pm 1.01$ , EMG:  $18.19 \pm 1.20$ , ns).

#### Conclusions

VO and EMG approaches yield nearly equivalent rMT results and ICC findings reveal both are highly consistent and reliable in determining rMT over repeated attempts. Although the differences between VO and EMG rMT were statistically significant with paired values each taken twice, the mean absolute difference of 2.8 points does not likely impact safety or dosing in the practical administration of therapeutic TMS. Visual rMT determination appears to be a dependable option for TMS users without an EMG system.

#### Conflicts of interest

ML is an employee of eemagine Medical Imaging Solution GmbH. AW is an employee of Magstim. Ly and Willis were involved

with StimGuide product development. The Magstim StimGuide TMS Navigation System was provided on loan to MUSC, had no impact on the outcome of the study, and no financial incentive was provided to MUSC for its use. We further confirm the order of authors listed in this manuscript has been approved by all of us and that the work described in this manuscript is not currently under consideration for publication in another journal.

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