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Effects of fatigue induced by repetitive movements and isometric tasks on reaction time

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Abstract

Purpose

The understanding of fatigue of the human motor system is important in the fields of ergonomics, sport, rehabilitation and neurology. In order to understand the interactions between fatigue and reaction time, we evaluated the effects of two different fatiguing tasks on reaction time.

Methods

83 healthy subjects were included in a case-control study with three arms where single and double choice reaction time tasks were performed before and after 2 min fatiguing task (an isometric task, a finger tapping task and at rest).

Results

After an isometric task, the right-fatigued hand was slower in the choice component of a double choice reaction time task (calculated as the individual difference between single and double choice reaction times); also, the subjects that felt more fatigued had slower choice reaction time respect to the baseline assessment. Moreover, in relationship to the performance decay after two minutes, finger tapping task produces more intense fatigability perception.

Conclusions

We confirmed that two minutes of isometric or repetitive tasks are enough to produce fatigue. The fatigue perception is more intense for finger tapping tasks in relation to the performance decay. We therefore confirmed that the two fatiguing tasks produced two different kind of fatigue demonstrating that with a very simple protocol it is possible to test subjects or patients to quantify different form of fatigue.

Keywords

Fatigue; Repetitive movements; Isometric contractions; Human; Reaction time

1. Introduction

The understanding of fatigue of the human motor system is of paramount importance in the fields of ergonomics, sport, rehabilitation and neurology. The interest for the impact of fatigue in neurological disorders and in neurorehabilitation is growing fast due to its high prevalence (Cudeiro-Blanco et al., 2017; Kuppuswamy, Turner, Rothwell, & Ward, 2015; Stocchi et al., 2014; Zwarts, Bleijenberg, & van Engelen, 2008). The neural basis of fatigue has been studied extensively in the case of isometric contractions, either maximal or submaximal (Duchateau, Balestra, Carpentier, & Hainaut, 2002; Gandevia, 2001a, Gandevia, 2001b; Klass, Lévénez, Enoka, & Duchateau, 2008; Maluf & Enoka, 2005; Janet L Taylor & Gandevia, 2008; Williams, Hoffman, & Clark, 2014), and there is strong evidence that isometric fatiguing tasks induce a reduction in the excitability of circuitry in both the spinal cord (Butler, Taylor, & Gandevia, 2003; Duchateau et al., 2002; Gandevia, 2001a, Gandevia, 2001b; J L Taylor, Butler, Allen, & Gandevia, 1996) and motor cortex (Di Lazzaro et al., 2003; S C Gandevia, Allen, Butler, & Taylor, 1996; Taylor et al., 1996). However, cortical and spinal adaptations to fatigue are known to be task dependent (Barry & Enoka, 2007; R. M. Enoka & Stuart, 1992; Roger M Enoka et al., 2011; Roger M Enoka & Duchateau, 2008). While neural mechanisms related to fatigue during isometric tasks have been thoroughly studied, those related to fatigue during repetitive movements have been much less studied. Previous studies suggest that the origin of fatigue induced by sustained isometric contraction has, at least, a component that takes origin at spinal level. Conversely, brief and fast un-resisted repetitive movements induce a form of fatigue that appears not to be spinal in origin (Arias et al., 2015; Madrid, Valls-Solé, Oliviero, Cudeiro, & Arias, 2016), without affecting muscle force or central drive to the muscle (Madrid, Madinabeitia-Mancebo, Cudeiro, & Arias, 2018).

On the other hand, fatigue is known to be a complex entity with different domains. In the motor system, it can originate at the periphery (within the muscle or the neuromuscular junction) or proximally, at central levels (Gandevia, 2001a, Gandevia, 2001b). However, central fatigue has also different expressions not only engaging the motor system. This is the case of mental fatigue (Ishii, Tanaka, & Watanabe, 2014), which is characterized by a practised-dependent reduction in cognitive performance (Ishii et al., 2014). The complexity of fatigue is exemplified by a known interaction between their different expressions. For instance, when healthy subjects were performing a choice reaction time task during a fatiguing isometric motor task, a reduction in cognitive performance was evident (Lorist, Kernell, Meijman, & Zijdewind, 2002). This observation is important either at fundamental and applied levels, either clinical, sports, etc., and might increase the risk of accident in occupational activities (for instance in the case of taxi or bus-drivers…). However, because the expressions of muscle fatigue are known to be task-dependent (Asmussen, 1979; Bigland-Ritchie, Rice, Garland, & Walsh, 1995; R. M. Enoka & Stuart, 1992) and the central origins of muscle fatigue are different for isometric contractions and repetitive movements (Roger M Enoka & Duchateau, 2008; Arias, Robles-García, et al., 2015; Madrid et al., 2016), it is important to understand the interactions between fatigue and cognitive performance, when fatigue is induced by different kinds of muscle activity. In the present work, we have evaluated the effects of two different fatiguing tasks on cognitive performance. One is an isometric task – ISO- (a sustained maximal voluntary contraction, MVC), and the other is maximal rate finger tapping -FT-, which after-effects were tested on single and double choice reaction time tasks. In all cases the fatiguing tasks lasted 120 s. We predict that the effects of fatigue on reaction time (RT) will be different depending on the task employed.

2. Methods

2.1. Subjects

The experiment included 83 healthy subjects (45 women and 38 men, mean age 23.29 ± 4.63 range, 18–47 years). Volunteers had no history of hormonal, metabolic, cardiovascular, psychiatric or neurological disorders, and were medication-free at the time of the study. All were right-handed according to self-report.

The procedures had the approval of the local ethics committee (Toledo Area Ethical Committee for Clinical Investigation, "Hospital Virgen de la Salud" Toledo, Spain) and were conducted in accordance with the Declaration of Helsinki. All subjects signed an informed consent form.

2.2. Study design

Schematic experimental set-up is reported in Fig. 1 (upper panel). The study was a case-control study with three arms (an isometric task, a finger tapping task and at rest). Single and double choice reaction time tasks were performed before (one time point – Baseline) and after (two time points – Post1 and Post2) a fatiguing task (or at rest as control condition); Post1 was tested right at the end of the fatiguing task, and Post2 was tested 5 min after the Post1.The sessions were identical except for the type of fatiguing task executed (see below). To reduce the intersubject variability, the ideal experimental design would have been a pure crossover-design in which each subject would have participated in all the 3 experimental sessions. The price to pay for this kind of design is a high number of drop-out. For this reason, we accept that subjects can participate in only one experimental session (31 subjects participated in rest, 26 subjects participated in finger tapping task and 26 subjects participated in isometric task). Subjects were randomly allocated to each group. (See Table 1.)

2.3. Fatiguing protocol

We evaluated the effects of different types of fatiguing tasks: 1) ISO: MVC isometric task; 2) FT: finger tapping task; 3) CONTROL: during which participants remained at rest. The subjects were sitting comfortably with the elbow flexed at 90–100°. We asked the subjects to execute the task using only the hand and to avoid excessive forearm movements. The forearm was not fixed.

Participants tapped or pressed over a thin metal plate located on the force sensor Biometrics DataLink (Biometrics Ltd., Gwent, NP11 7HZ, UK). All the fatiguing tasks were performed using the right hand (which was the dominant hand of all subjects). A group of participants executed continuous index finger ISO against a force sensor placed flat over a table, the force direction was "towards" flexion of the first metacarpophalangeal joint. A second group of participants were asked to perform index FT, by means of flexo-extension movements around the first metacarpophalangeal joint. A third group did not perform any action (CONTROL). As far ISO concerns, subjects were encouraged to press as hard as they could from the very beginning to the end of the set. For the FT, subjects were asked to "tap at their maximal rate" for as long as the set lasted.

During FT, the DataLink system recorded the inter-tap intervals at 0.1KHz with a thin metal plate (place flat and secured over a dynamometer P200) and a metal ring, the latter adapted to the distal phalanx of the index finger. The dynamometer recorded (0.1 KHz) the isometric force exerted during the maximum voluntary contraction (MVC), during the ISO task.

The following dependent variables were analysed during fatiguing task execution: 1) the maximal torque during the ISO (the force peak = ISOmax), 2) the force applied during ISO (the area under the curve = ISOarea) and 3) the finger tapping frequency at maximal rate (FTFr).

For each of the variable we considered six blocks of 20 s that were embedded within task execution. Thus, for each variable we obtained six time points that were included in the statistical analysis to evaluate the temporal decay of the ISOmax, ISOarea and FTFr.

Using the same data, we also obtained a simplified variable mainly to be used for correlation analysis. Thus, we evaluated the decay over the 2 min as a marker of fatigability by computing the ratio of the motor output in the last 20 s of the task/first 20 s in the task. This was done for FTFrF, ISOareaF and ISOmaxF. We will refer to this variable as FATIGABILITY. These scores were used to performed correlation analysis together with the rate of perceived exertion (RPE), for this purpose all subjects were asked to report their level of perceived fatigue during the fatiguing task using an 11 points-scale from 0 (no fatigue) to 10 (extreme fatigue), the RPE tested at the end of each session. We also calculated the ratio between FATIGABILITY and RPE to quantify the impact of the task fatigability (decay of the performance) and the perceived fatigue, this was done for FTFrRF, ISOareaRF and ISOmaxRF. These variables are calculated like FTFrF/RPEft, ISOareaF/RPEiso and ISOmaxF/RPEiso. We will refer to this variable as RATIO FATIGABILITY.

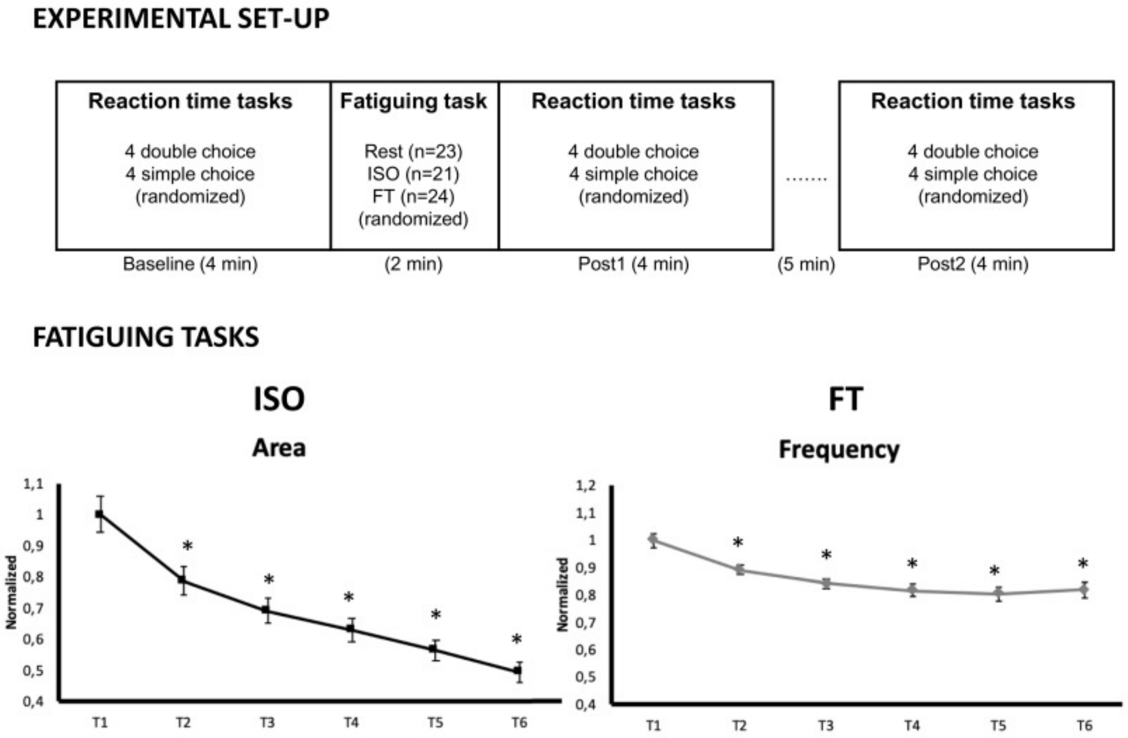

Fig. 1. Upper panel. Experimental set-up: A simple and a double choice reaction time task were performed before (one time point - Baseline) and after (two time points - Post1 and Post2) a fatiguing task (or at rest as control condition). Lower panels. Fatiguing tasks: Left. During the execution of an isometric task force is recorded, and the area under the curve was calculated in six block of 20 s each and plotted. Right. During the execution of FT task, the tapping frequency was calculated in six block of 20 s each one and plotted. Normalized data are reported and expressed as mean ± SEM. * = $p < 0.05$.

Table 1. Demographic and Baseline data.

	REST	ISO	FT
Demographic variables			
N	31	26	26
Age	23 ± 4	24 ± 7	23 ± 3
Sex (males n)	12	15	11
Fatiguing tasks			
ISOmax		31.48 ± 8.98 N	
ISOarea		48,318.91 ± 14,164.05 N*s	
ISOareaF		51.25 ± 16.22%	
ISOmaxF		56.55 ± 17.11%	
FTfr			5.73 ± 0.73 Hz
FTFrF			82.09 ± 11.39%
RPEiso		8.23 ± 0.99	
RPEft			8.00 ± 0.91
ISOmaxRF		6.97 ± 2.22%	
ISOareaRF		6.35 ± 2.25%	
FTFrRF			10.45 ± 1.79%
RT tasks			
sRTrighthand (ms)	251.37 ± 33.05	253.71 ± 25.75	257.20 ± 36.00
dcRTrighthand(ms)	347.37 ± 24.04	344.18 ± 17.74	357.28 ± 28.15
sRTlefthand(ms)	248.06 ± 34.33	253.28 ± 30.21	257.33 ± 37.24
dcRTlefthand(ms)	349.49 ± 26.57	351.54 ± 22.68	363.12 ± 33.39
DeltaRTrighthand(ms)	96.00 ± 27.80	91.11 ± 31.35	100.08 ± 29.87
DeltaRTlefthand(ms)	101.43 ± 25.63	98.26 ± 23.76	105.79 ± 40.15

2.4. Reaction time studies

The single and double choice reaction time tasks were randomly presented before and after the fatiguing tasks (or rest condition) for evaluation of psychomotor performance. Subjects were asked to react to visual signals by pressing as fast as possible the corresponding buttons on the keyboard with the index finger of their dominant (right) or non-dominant (left) hand, and were asked to press using index finger, avoiding other arm movements (e.g. wrist and elbow). Subjects were informed by screen information if they had to perform a single or double choice reaction task.

For single reaction time task (sRT), the hand they had to use was also indicated. The go signal was preceded by an acoustic warning signal (“beep”) one second before. The go signal was the appearance of a 3D ball in the middle of the screen, the subject had to react using the previously indicated hand. For double choice reaction time task (dcRT), the go signal was the appearance, in the middle of the screen, of a white arrow pointing left or right. The subject has to react using the hand indicated by the arrow (e.g. left pointing arrow-left hand). Visual stimuli were repeated every 2.5–3 s. Simple and double choice reaction time tasks were randomly presented to the subject at each testing time point. At each testing time point (Baseline-Post1-Post2), participants performed 8 blocks with 8 reactions each one: 2 blocks single choice with the left hand, 2 blocks single choice with the right hand, and 4 blocks double choice (2 blocks with the right and 2 blocks with the left hands). In the whole session there were 64 reactions in each testing time point; we did not increase the number of reactions to avoid task-induced fatigue previously reported by our labs in RT protocols (Arias, Corral-Bergantiños, Robles-García, Madrid, Oliviero, & Cudeiro, 2016), nor included training trails in order to evaluate the learning effects.

We evaluated the difference between the means of the double choice reaction time and the single choice reaction time, either for the right-fatigued hand and the left-non fatigued hand. This variable measures a more cognitive part of the RT (the “choice” reaction time). We will refer to this variable as DeltaRTrighthand and DeltaRTlefthand for the results section (including table) and as “choice RT” in the discussion section. We also recorded the number of errors (when subjects used the wrong hand to press the computer key) for double choice reaction time. All variables were evaluated also in the group of subjects at REST. Trials with a RT of less than 100 ms or longer than 600 ms were eliminated (Arias et al., 2016). Overall, less than 3% of trials were eliminated.

In summary, the following dependent variables were calculated before and after execution: 1) the single choice reaction time duration of right-fatigued (sRTrighthand) and left-non fatigued hand (sRTlefthand); 2) the individual difference of single and double choice reaction time duration of right-fatigued (DeltaRTrighthand) and left-non fatigued (DeltaRTlefthand); 3) the number of errors. For all of them we considered the mean of the repetitions of each condition. Baseline dcRT raw data are reported in the table and the time curse was not analysed.

2.5. Statistical design

Data are reported as mean and standard deviations if not otherwise indicated.

2.5.1. Statistical design for studying behaviour during fatiguing tasks

Fatigue induced by the ISO (ISOarea and ISOmax) and FT (FTFr) tasks were evaluated with independent ANOVA with repeated measures. In case of significant effects, we used Tukey's test for Post-Hoc analysis. During ANOVA execution, the degrees of freedom were corrected with Greenhouse Coefficients if sphericity could not be assumed.

The ISOmaxF, ISOareaF and FTFrF (i.e., ratio of the motor output in the last 20 s of the task/first 20 s in the task, for each variable) were calculated and compared using unpaired t-test. RPE of the two tasks was compared using Mann-Whitney test. Results were considered significant at $p < 0.05$.

2.5.2. Statistical design for studying effects of fatiguing tasks on RT

As far as rest condition concerns, data were normalized by dividing each individual value to the baseline mean of all subjects (each task and hand separately). As far as rest condition concerns, normalized data were entered into ANOVA, with RT TASK (sRT and DeltaRT), HAND (right-fatigued and left-non fatigued) and TIME (baseline and two time points after the intervention) as main factors. We used Tukey's test for post-hoc analysis.

As far as fatiguing conditions (ISO and FT) concerns, data were normalized by dividing each individual value to the mean value obtained from the group at rest (each task, time points and hand separately). This normalization was done to exclude any effects that can be due by the RT task itself like practice, boringness or fatigue (due to the RT task itself).

The normalized data were entered into mixed model ANOVA, with FATIGUING TASK (ISO and FT), RT TASK (sRT and DeltaRT), HAND (right-fatigued and left-non fatigued) and TIME (baseline and two time points after the intervention) as main factors. FATIGUING TASK was analysed as between-subject factor an all the other were considered as within-subjects factor. We used Fisher LSD test for post-hoc analysis.

Very few errors were observed (<5%) in the double choice RT tasks in all conditions and they were not analysed.

Correlation analysis was performed to quantify the association between task fatigue (ISOmaxF, ISOareaF and FTFrF), perceived fatigue (RPEiso and RPEft) and the % changes of RT after the fatiguing tasks (normalized to rest group values). RT % changes were estimated by the following formula: RTpost/RTbaseline*100. We used Pearson test for parametrical variables and Spearman test for non-parametrical (RPEiso and RPEft).

All statistical analyses were performed with the software STATISTICA. Results were considered significant at $p < 0.05$.

3. Results

All the participants tolerated the whole experimental procedure and none experienced side effects.

3.1. Fatiguing tasks

The mean ISOmax at baseline (first 20 s) was 31.48 ± 8.98 N, that progressively decayed (~45%) up to 17.22 ± 5.26 N (ANOVA: $F_{5,125} = 62.5651$ $p < 0.001$). Post-hoc analysis demonstrated significant reduction (Tukey Honest, $p < 0.001$) at each step compared to the baseline (first 20 s). The mean ISOarea at baseline was 48,318.91 ± 14,164.05 N*s, that progressively decayed (~50%) up to 23,936.01 ± 7992.78 N*s (Fig. 1 (lower panel); ANOVA: $F_{5,125} = 69.7854$ $p < 0.001$). Post hoc analysis demonstrated significant reduction at each step compared to the baseline (Tukey Honest, $p < 0.001$). The mean FTFr at baseline was 5.73 ± 0.73 Hz, that progressively decayed (~18%) up to 4.68 ± 0.79 Hz (Fig. 1 (lower panel); ANOVA: $F_{5,125} = 41.834$ $p < 0.001$). Post-Hoc analysis demonstrated significant reduction at each step compared to the baseline (Tukey Honest, $p < 0.001$).

The ISOmaxF was 56.55 ± 17.11% (which is the score at last 20 s/first 20 s in the 2 min task, expressed in %), the ISOareaF was 51.25 ± 16.62% and FTFrF was 82.09 ± 11.39%. The fatigability of the ISO task was significantly higher than for the FT (ISOmaxF vs FTFrF and ISOareaF vs FTFrF unpaired t-test, $t(55) > 6.33$, $p < 0.0001$). On the other hand, the effort perceived by the participants, expressed by the RPE was similar for ISO than for the FT tasks; they were 8.23 ± 0.99 and 8.00 ± 0.91 for ISO and FT respectively (Mann-Whitney, $p = 0.45$). The RATIO FATIGABILITY that we used to quantify the impact of the task fatigability (decay of the performance) and the perceived fatigue were 6.97 ± 2.22% for ISOmax (ISOmaxRF), 6.35 ± 2.25% for ISOarea (ISOareaRF) and 10.45 ± 1.79% for FTfr (FTFrRF). The ratio FATIGABILITY/RPE was higher for FT than for ISO tasks (ISOmaxRF vs FTFrRF and ISOareaRF vs FTFrRF, unpaired t-test, $t(55) > 6.1$, $p < 0.0001$).

3.2. Reaction time tasks

As expected, the baseline dcRT was longer than the baseline sRT both in the right and left hand (Table 1; all $p < 0.05$) in all groups. No differences were observed in the RT of the different hands (Table 1; all $p > 0.05$).

3.2.1. Rest group

The repeated measure ANOVA showed no significant HANDxTIME interaction and no changes over the three testing-time points of all variables (all $p > 0.05$).

3.2.2. Fatiguing groups

ISO and FT data were normalized by dividing each individual value to the mean value obtained from the group at rest (each task, time point and hand separately). Only sRT and DeltaRT were separately analysed. The normalized data were entered into two separate ANOVAs (ISO and FT separately), with HAND (right-fatigued and left-non fatigued) and TIME (baseline and two time points after the intervention) as main factors.

3.2.3. Simple RT

As SimpleRT concerns, ANOVA showed significant HANDxTIME interaction only for ISO task (rmANOVA, HANDxTIME: F2,50 = 5.076, p = 0.0098) and not for FT (rmANOVA, HANDxTIME: F2,50 = 1.306, p = 0.280). As ISO concerns, post-hoc analysis detected a significant decrement of sRT at Post2 in right-fatigued hand suggesting a faster recovery after fatiguing task (Fisher LSD, Baseline vs Post2, p = 0.014048, Post1 vs Post2, p = 0.000706) and a significant difference between hands at Post2 (Fisher LSD, Post2lefthand vs Post2righthand, p = 0.009434) being the left hand slower than the right hand, see Fig. 2.

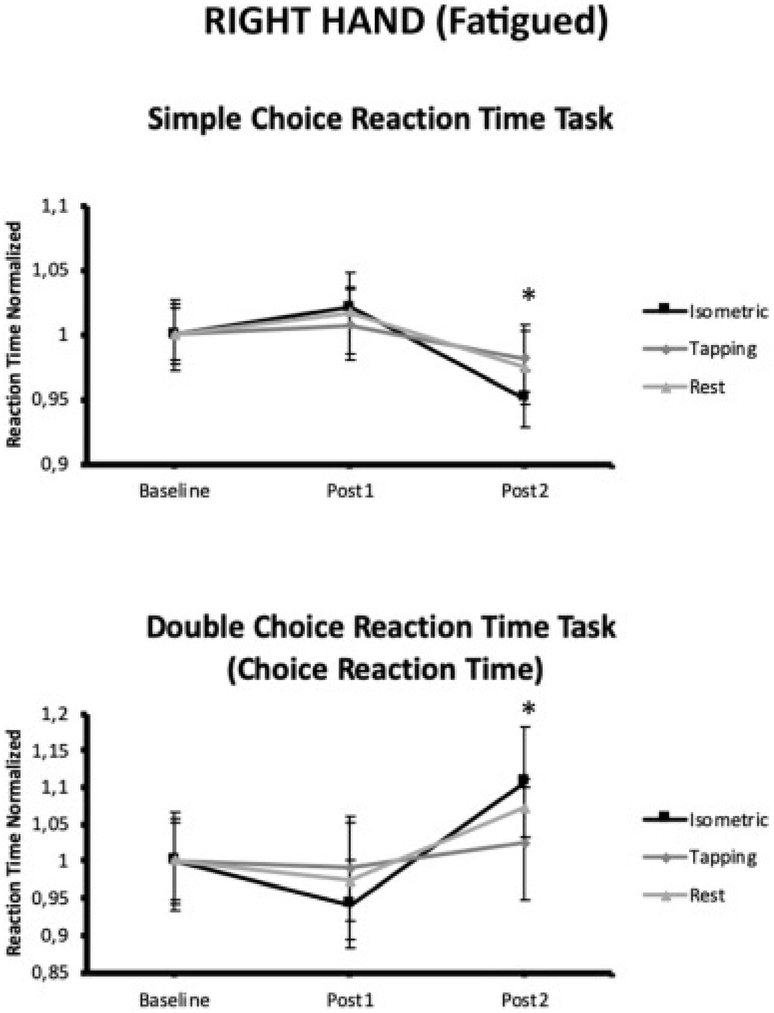

Fig. 2. Reaction Time tasks with right (fatigued) hand. Upper panel. Simple Choice Reaction Time task executed before (Baseline), immediately after (Post1) and 5 min after Post1 (Post2). Lower panel. Delta Reaction Time task (calculated as the difference between double choice reaction time and simple choice reaction time) executed before (Baseline), immediately after (Post1) and 5 min after Post1 (Post2). Normalized data are reported and expressed as mean ± SEM. *p < 0.05 (black * = Isometric).

3.2.4. Double choice RT

ANOVA showed significant HANDxTIME interaction only for ISO task (rmANOVA, HANDxTIME: F2,50 = 3.18, p = 0.050) and not for FT (rmANOVA, HANDxTIME: F2,50 = 0.7743, p = 0.46). As ISO concerns, post-hoc analysis detected a significant increment of DeltaRT at Post2 in right-fatigued hand suggesting fatigability after ISO fatiguing task (Fisher LSD Post1 vs Post2, p = 0.023144), and a significant difference between hands at Post2 (Fisher LSD, Post2lefthand vs Post2righthand, p = 0.018694) being the left-non fatigued hand (unchanged compared to its baseline) faster than the right hand.

3.3. Correlation analysis

A negative correlation was found between DeltaRT % changes (DeltaRTPost2/DeltaRTbaseline*100) and the rating of fatigue after the ISO task (Spearman: rho = −0.45317, p = 0. 02008), so the subjects that felt more fatigued at the end of the ISO task had slower "choice time" (for an explanation see below). No correlation was found between DeltaRT % changes (DeltaRTPost2/DeltaRTbaseline*100) and the rating of fatigue after the FT task (Spearman: rho = 0.018, p = 0. 933).

4. Discussion

We confirmed that two minutes of maximal isometric or repetitive tasks are enough to produce fatigue. The performance reduction (FATIGABILITY) is much less evident at the end of the FT task than for ISO task (aprox. 20% vs 50% reduction compared to the baseline), while the fatigue perception is similar for isometric than for finger tapping tasks. This indicates that FT task produces more intense fatigability perception in relationship to the performance decay over two minutes.

The effects of two minutes of both ISO and FT tasks had no effects on the contralateral (left-non fatigued) hand both on the sRT and choice RT. As far as right-hand (fatigued) concerns, FT task has no effects on RT (both sRT and choice RT). ISO task reduced the sRT tasks executed with the right-fatigued hand suggesting a more pronounced practice effect. On the contrary, ISO task increased the choice RT executed with the right-fatigued hand. The right- fatigued hand became slower only few minutes after the ISO fatiguing task (speculatively, this may suggest a summation of the general fatigue induced by ISO plus the fatigue of the RT task). Moreover, the increased choice RT task executed with the right-fatigued hand correlated with the perceived fatigue after the ISO task (the subjects that felt more fatigued at the end of the ISO task had slower choice RT).

In previous studies, a different origin of fatigue induced by FT and ISO tasks was suggested. The present work reinforces the idea that the origin of the fatigue leading to FT frequency reduction is different from the origin of fatigue caused by maintained isometric effort. The main results of this study can be summarized as follow: 1) prolonged isometric task has a differential effect on simple and choice RT performed with the fatigued hand; 2) the ISO effects on the choice RT correlates with the perceived fatigue; 3) FT produces similar level of perceived fatigue but has no effects of the RT tasks; 4) FT task produces more intense fatigability perception in relationship to the performance decay over two minutes of task.

Moreover, we observed changes, after ISO fatiguing tasks, only in the more cognitive component of the task ("choice RT"), and not in the more attentional and motor components of the task (simple RT). This may suggest that 2 min fatiguing task is enough to fatigue the part of the brain that has to make a "choice", but not to fatigue the motor execution time (including attention and all the motor system from brain to muscle).

The isometric fatiguing task has after-effects only in the fatigued hand. The FT fatiguing task has stronger effects in the perception of fatigue. The part of motor system that is fatigued may be of higher level and also the not-fatigued hemisphere is involved. The FT fatiguing task has two main differences respect to the isometric fatiguing task: 1) there is an involvement of the brain pacemakers; 2) the activation of the sensory system is rhythmic and probably more intense. Previous studies described that self-paced FT is highly demanding (Gerloff et al., 1998) and that motor and non-motor network may be activated also bilaterally (Anwar et al., 2016; Rubia et al., 1998). This may explain the results of a more intense fatigue perception with less task performance reduction. One limitation of this study may be the fact that we matched the two tasks for execution time (2 min) and not for performance decay. Future studies will try to match this parameter (e.g. by reducing the ISO or by increasing the FT task duration). Our experiments do not allow going further into the physiological mechanisms producing the fatigue. On the other hand, we confirmed that the two fatiguing tasks produced two different kind of fatigue. We demonstrated that with a very simple protocol it is possible to test subjects or patients to quantify different form of fatigue.

Disclosure

The Authors declare no conflict of interests.

The results of the present study do not constitute endorsement by ACSM. The results of the present study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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