



Detection of the Electromyographic Threshold in Finger Flexor Muscles Using Intermittent Isometric Contraction Tests

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Abstract

The electromyographic threshold (EMGT) is the relative exercise intensity at which a nonlinear increase in electromyographic (EMG) activity is observed. It has only been detected in monoarticular and biarticular muscles of the lower limbs, but not in multiarticular muscles. Intermittent isometric contraction tests (IICTs) may facilitate EMGT detection; however, the short inter-set rest intervals used in these protocols may affect its detection. Our objectives were (1) to explore EMGT detection in multiarticular upper-limb muscles, such as the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS), using an IICT with a short inter-set rest interval of 30 s (SR-IICT), and (2) to compare the SR-IICT results with those obtained using a protocol with long inter-set rest intervals of 120 s (LR-IICT). Ten participants (24.49 ± 4.04 years) completed both protocols, while EMG activity in the FDP and FDS and force output were recorded. The EMGT was determined in both tests for both muscles, as were the intensity and force levels reached at the end of each test. The LR-IICT facilitated EMGT detection in more participants (6 out of 10). Additionally, the LR-IICT enabled participants to finish the test while exerting greater absolute force and completing more sets. Our results show that detecting the EMGT in the FDS and FDP using IICT protocols is challenging, but also indicate that extending inter-set rest intervals may facilitate its detection, possibly by allowing greater force to be exerted during the final set.

Keywords: adults, electromyographic activity, intermittent incremental test, isometric force, multiarticular muscles

Introduction

Physiological threshold detection makes it possible to identify changes in the pattern of the body's biological responses. They have therefore become a fundamental tool for planning and monitoring physical training. Traditionally, physiological threshold detection has focused on systemic or metabolic aspects, whereas few studies have sought to identify thresholds related to muscle electromyographic (EMG) activity (Ertl et al., 2016).

EMG activity during incremental tests has been suggested to follow an exponential growth pattern (Iannetta et al., 2017), in which the nonlinear increase would correspond to increased recruitment of high-threshold motor units (MUs) (Ertl et al., 2016; Hug et al., 2006b; Lucía et al., 1999; Moritani & DeVries, 1978). According to the "size principle" (Henneman et al., 1965), the type of muscle fibers recruited depends on muscle contraction intensity (force output). At low muscle contraction intensities, recruitment predominantly involves type I fibers (smaller MUs with lower activation thresholds), whereas at higher intensities, type II fibers (larger MUs with higher activation thresholds) are also recruited to meet force demands (Cornett et al., 2000). Following this reasoning, the electromyographic threshold (EMGT) was defined as the relative exercise intensity at which a nonlinear increase in EMG activity is observed (an increase in the slope of an exponential growth curve) (Lucía et al., 1999). EMGT detection would therefore make it possible to identify the force magnitude at which an individual begins to recruit type II muscle fibers to a meaningful extent.

When estimating the EMGT, it should nevertheless be considered that its identification may be influenced by several physiological factors, including muscle fatigue (Woods et al., 2019), which may cause adjustments in the muscle activation signal, reduce force-generating capacity, and consequently affect neuromuscular activation patterns throughout exercise (Enoka & Duchateau, 2016). Although the EMGT has been successfully identified in lower-limb muscles during continuous incremental cycle ergometer tests, for example, in the vastus lateralis (Moritani & DeVries, 1978; Viitasalo et al., 1985), the fatigue accumulated during a continuous incremental test may prevent participants from reaching force levels at

which type II fiber recruitment increases sufficiently or may alter the rate of increase in type II fiber recruitment, thereby hindering the emergence of the EMGT. To address this issue, the use of an intermittent isometric contraction test (IICT) has been proposed (Woods et al., 2019). In previous studies, this protocol enabled participants to reach higher relative force output values than continuous incremental protocols (Long et al., 2017; Pitt et al., 2015), thereby facilitating EMGT detection (Woods et al., 2019).

Despite the advantages of IICTs for EMGT detection, they have only been applied to monoarticular and biarticular muscles of the lower limbs (De Ruiter et al., 2016; Woods et al., 2019, 2020), and their ability to detect the EMGT in upper-limb and/or multiarticular muscles therefore remains unknown. Moreover, the usual inter-set rest interval in an IICT, typically 30 s, may be insufficient, and some authors have suggested that extending it could improve the sensitivity of threshold detection (De Ruiter et al., 2016; Woods et al., 2019).

Improving EMGT detection procedures and exploring their potential application to upper-limb muscles could advance the study of electromyographic thresholds, particularly in the muscles involved in handgrip, as handgrip is a highly reproducible task that is easy to implement experimentally and widely used in clinical settings. These advances could also enhance the practical applications of the EMGT. In clinical settings, it could be used to diagnose neuromuscular disorders, as the early occurrence of the EMGT during an IICT could reflect an earlier need to recruit type II fibers, which could indicate impaired neuromuscular efficiency (Voet et al., 2022). In physical training, the EMGT could also be used to prescribe training intensities and identify neuromuscular adaptations, providing a functional marker complementary to traditional metabolic thresholds (Voet et al., 2022).

Accordingly, the objectives of this exploratory methodological study were: (1) to apply the IICT protocol to detect the EMGT in multiarticular upper-limb muscles, specifically the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS); and (2) to compare the ability to detect the EMGT in the FDS and FDP using an IICT with 30-s inter-set rest intervals (short-rest IICT, SR-IICT) and an IICT with 120-s inter-set rest intervals (long-rest IICT, LR-IICT).

Method

Participants

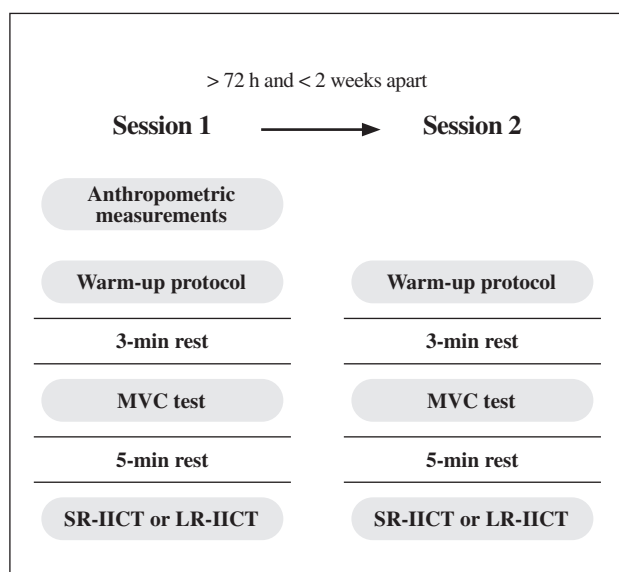
Ten healthy, physically active male participants took part in the study (age = 24.49 ± 4.04 years; height = 175.09 ± 5.22 cm; body mass = 74.16 ± 7.06 kg). The study was approved by the Clinical Research Ethics Committee of the Consell Català de l'Esport (02/CEICGC/2021). All participants received detailed information about the study objectives, procedures, risks, and benefits before providing written informed consent.

Experimental Protocol

Each participant completed two different experimental sessions in randomized order, without counterbalancing. The sessions were separated by a minimum of 72 h and a maximum of two weeks to ensure sufficient muscle recovery (Figure 1). One session was designed to assess the EMGT using the SR-IICT, whereas the other assessed the EMGT using the LR-IICT. Each session began with a standardized warm-up and a maximum voluntary contraction (MVC) test. In addition, each participant's height and body mass were recorded during the first session. Participants were asked to refrain from consuming coffee or caffeinated products on the day of testing and to avoid training during the preceding 24 h.

Figure 1

Diagram of the experimental protocol



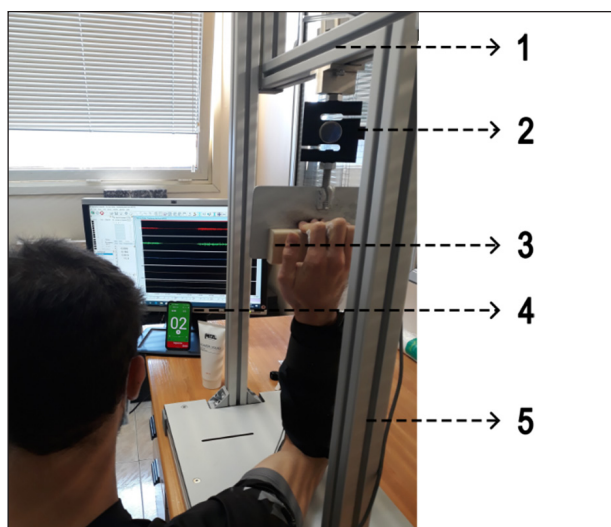
Note. MVC = maximum voluntary contraction, SR-IICT = intermittent isometric contraction test with short 30-s inter-set rest intervals, LR-IICT = intermittent isometric contraction test with long 120-s inter-set rest intervals.

Exercise Protocols

All protocols involved isometric finger-flexor contractions and used an ergometer specifically designed for this study, with a structure similar to that used by Philippe et al. (2012) (Figure 2). Before testing, participants sat sideways beside the ergometer, and the height of the hold was adjusted to standardize their position, approximately as follows: 90° of glenohumeral abduction and 60° of horizontal shoulder adduction, with 90° of elbow flexion (Figure 2). The dominant hand, as self-reported by the participant (Scharoun & Bryden, 2014), gripped the hold using a specific grip commonly referred to as a half-crimp or crimp (Ferrer-Uris et al., 2023): the proximal interphalangeal joint was flexed to 90°, the distal interphalangeal joint was extended or hyperextended, the metacarpophalangeal joint was in a neutral or slightly flexed position, and the thumb was not involved. The non-tested arm was positioned beneath the table on which the ergometer was placed. Verbal encouragement was provided to participants during all protocols (McNair et al., 1996).

Figure 2

Ergometer used and participant body position



Note. 1 = adjustable aluminum frame, 2 = strain gauge, 3 = wooden hold, 4 = timer, 5 = vertical aluminum support structure.

Maximum voluntary contraction test

All participants completed two MVC test attempts with a 2-min rest interval. During each attempt, participants were asked to exert the greatest possible finger-flexion force without losing the prescribed position, progressively increasing force and maintaining their maximum force for 5 s. The highest value on the smoothed force curve (see the “Data Reduction and EMGT Determination” subsection) was considered representative of the maximum isometric force for that session ($MVC_{SR-IICT}$ and $MVC_{LR-IICT}$) and was used to calculate the relative intensities in the SR-IICT and LR-IICT.

Short- and long-rest intermittent isometric contraction tests

The IICT protocol described by Woods et al. (2019) provided the basis for the design of the SR-IICT and LR-IICT. Both tests consisted of sets of five 5-s isometric contractions, with a 3-s rest interval between contractions. Both protocols began at an intensity of 25% of $MVC_{SR-IICT}$ and $MVC_{LR-IICT}$, respectively, and the target force was increased by 3% in each set. The difference between the two tests was the inter-set rest interval: 30 s for the SR-IICT and 120 s for the LR-IICT. The test ended when the participant failed to reach the target force in three of the five contractions in a set. During the rest intervals between contractions within the same set, participants were instructed to maintain their position on the hold without exerting force. During inter-set rest intervals, participants were asked to rest their arm on their thighs with the palm facing upward. Participants received real-time visual feedback on the force exerted, as well as visual and auditory feedback on contraction and rest times during both protocols.

Data Acquisition

The force exerted during each contraction was recorded throughout all tests using a strain gauge (SB1000, Biometrics Ltd, Newport, UK). Surface electromyography (EMG) was recorded simultaneously using bipolar Ag-AgCl surface electrodes (10-mm diameter, 20-mm center-to-center distance) (SX230, Biometrics Ltd, Newport, UK). The electrodes were attached over the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) muscles following the electrode placement procedure described by Ferrer-Uris et al. (2023).

Force and EMG data were recorded synchronously at a sampling frequency of 1000 Hz using the same data acquisition system (DataLink DLK 900, Biometrics Ltd, Newport, UK).

Data Reduction and EMGT Determination

The raw force and EMG signals were filtered using a fourth-order low-pass Butterworth filter with a cutoff frequency of 20 Hz and a fourth-order band-pass Butterworth filter with a range of 20–450 Hz, respectively.

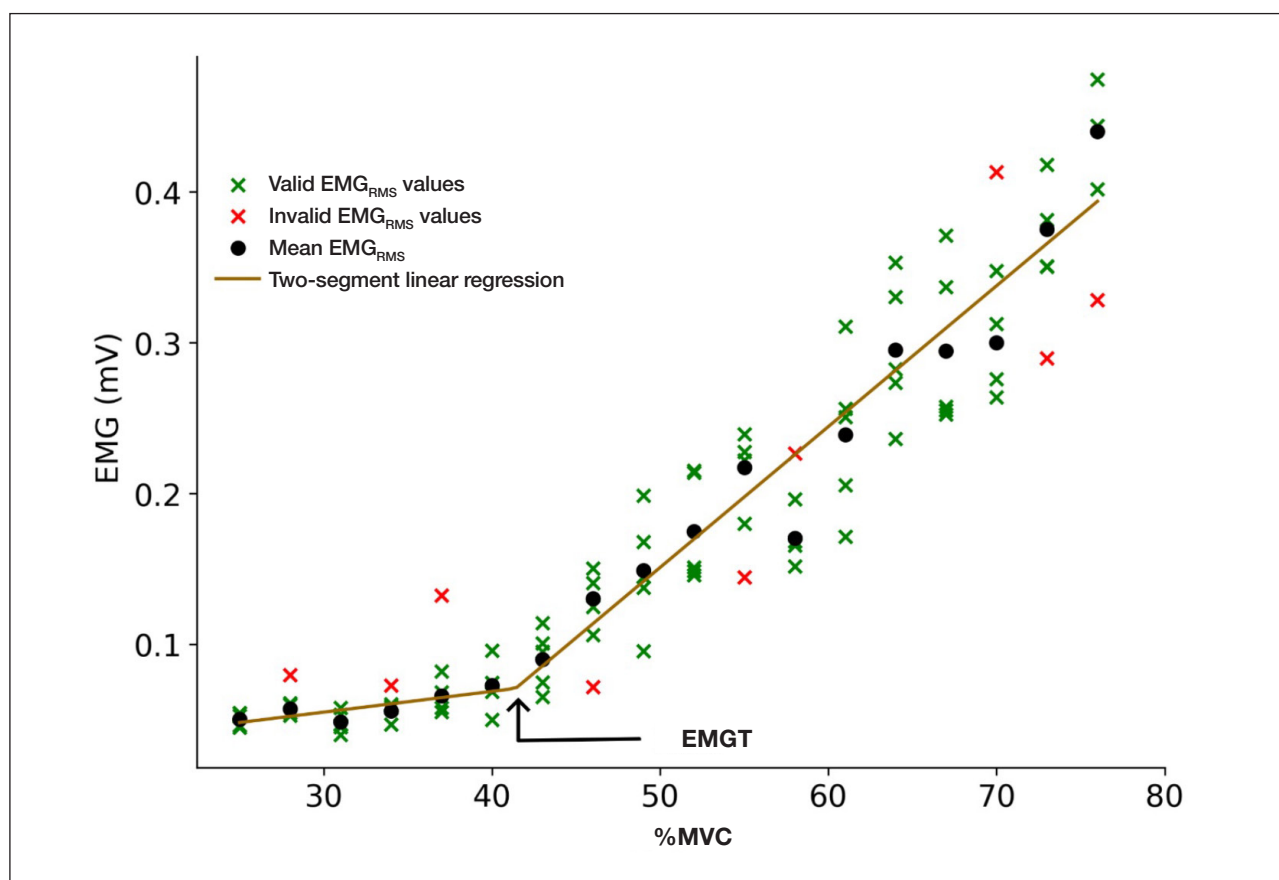
After filtering, the force data obtained during each MVC attempt were smoothed using a 500-ms recursive moving

average. The highest value from the two attempts in each session was considered the maximum value ($MVC_{SR-IICT}$ and $MVC_{LR-IICT}$). For the SR-IICT and LR-IICT, the filtered force signal was used to identify the onset and end of each contraction and to verify that the participant exerted the target force. The onset of each contraction was defined as the point at which force exceeded 12.5% of maximum force ($MVC_{SR-IICT}$ and $MVC_{LR-IICT}$), whereas its end was defined as the point at which force output fell below this 12.5% threshold. Contractions that did not meet these onset and end criteria were excluded from subsequent analyses. Only completed sets were used to determine the EMGT (at least three contractions had to reach and maintain the required percentage of MVC for 3 s in each set). In addition, the following variables were calculated from the final completed set in each protocol (SR-IICT and LR-IICT): (1) the percentage of MVC reached ($\%MVC_{SR-IICT}$ and $\%MVC_{LR-IICT}$) and (2) the arithmetic mean of the force exerted during the valid contractions, a variable termed “final force” ($\bar{x}_{FF_{SR-IICT}}$ and $\bar{x}_{FF_{LR-IICT}}$).

For the analysis of each muscle’s EMG activity during both IICTs, signal amplitude was calculated from the filtered signal as the root mean square (EMG_{RMS}) of each contraction. Specifically, EMG_{RMS} was calculated for each contraction within a 2-s window corresponding to the time interval during which the mean contraction force was closest to the target force intensity. The five contractions within each set were then checked to ensure that they showed similar EMG_{RMS} levels. To do so, the number of standard deviations (SDs) by which the EMG_{RMS} value of each contraction differed from the mean of the other four contractions in the set was calculated. Contractions whose EMGRMS values deviated by more than 3 SD from the mean were excluded. The mean EMGRMS of the retained contractions in each set ($\bar{x}_{EMGRMS}$) was then calculated (Woods et al., 2019).

Finally, to identify the EMGT of the FDS and FDP for each participant and protocol ($FDS-EMGT_{SR-IICT}$, $FDP-EMGT_{SR-IICT}$, $FDS-EMGT_{LR-IICT}$, and $FDP-EMGT_{LR-IICT}$) (Figure 3), a scatterplot was created relating $\bar{x}_{EMG_{RMS}}$ values to exercise intensity (the required percentage of maximum force). A two-segment linear regression model was applied to these data (Hug et al., 2006a; Lucía et al., 1999; Woods et al., 2019). The EMGT was defined as the percentage of MVC (x-coordinate) at which the two linear regression lines intersected. Because the intersection point in a two-segment model is always mathematically calculated

Figur 3
Procedure for determining the electromyographic threshold (EMGT)



Note. The EMGT was defined as the intersection of the two linear regressions obtained from the relationship between the relative intensity of the target force (expressed as a percentage of maximum voluntary contraction, %MVC) and muscle electromyographic (EMG) activity (expressed as the root mean square EMG_{RMS}). In this illustrative example of a participant's data, the crosses represent the EMG_{RMS} values for each contraction, with valid values shown in green and invalid values in red (values were considered invalid when the EMG_{RMS} deviated by more than 3 SD from the mean of the contractions performed at the same relative force intensity). Each black point, $\bar{x}_{EMG_{RMS}}$, corresponds to the mean EMG_{RMS} of all contractions performed at the same relative intensity.

and does not necessarily coincide with a measured value, an EMGT value was only accepted when at least one measured value belonging to the second regression line, which also had a positive but steeper slope, exceeded the extrapolated line of the first regression by +3 SD (Woods et al., 2019). When this condition was not met or the data did not show an adequate fit to a two-segment function, EMGT identification was considered unsuccessful.

Statistical Analysis

First, $MVC_{SR-IICT}$ and $MVC_{LR-IICT}$ were compared using a paired-samples *t*-test to verify that the initial force conditions were similar between the two sessions. The $\%MVC_{SR-IICT}$ and $\%MVC_{LR-IICT}$ variables, as well as $\bar{x}_{FF_{SR-IICT}}$ and $\bar{x}_{FF_{LR-IICT}}$, were also compared using a

paired-samples *t*-test to determine the overall effect of the inter-set recovery time on the intensity and absolute force reached at the end of the tests. EMGT detection was then compared for each muscle and protocol. Due to the low detection rate, a descriptive comparison was made between the EMGT values obtained in the SR-IICT and LR-IICT. When the EMGT was not detected, a qualitative analysis of the profile obtained using the two-segment linear regression model was performed to identify the possible reasons for the lack of detection. Before conducting any paired-samples *t*-test, data normality was examined using the Shapiro–Wilk test and Q–Q plots. A significance level of $p < .05$ was set for all comparisons, and the effect size for the *t*-tests was calculated using Cohen's *d* (Cohen, 2013). All statistical analyses were performed using JASP version 0.19.3 (JASP Team, 2025).

Results

Force results

The maximum force values obtained at the beginning of the sessions, $MVC_{SR-IICT}$ and $MVC_{LR-IICT}$, did not differ significantly ($t(9) = -0.139$; $p = .892$), suggesting that there was no learning effect or significant change in the participants' finger-flexor contractile capacity during the time

between sessions. A comparison of the values reached at the end of the two protocols showed that the LR-IICT enabled participants to reach higher relative intensities and force-output levels: $\%MVC_{SR-IICT}$ compared with $\%MVC_{LR-IICT}$ ($t_{(9)} = -3.025$; $p = .014$; $CI = (-11.535) - (-1.665)$; $d = 0.957$) and $\bar{x}_{FF_{SR-IICT}}$ compared with $\bar{x}_{FF_{LR-IICT}}$ ($t_{(9)} = -2.741$; $p = .023$; $CI = [-55.277, -5.287]$; $d = -0.867$) (Table 1 and Figure 4).

Table 1

Number of electromyographic thresholds (EMGTs) detected by protocol and muscle, and means and standard deviations for the EMGT, session maximum voluntary contraction (MVC), and force values reached in the final set of the test

	SR-IICT		LR-IICT	
	FDS	FDP	FDS	FDP
EMGT detection	$n = 2$ (20 %)	-	$n = 4$ (40 %)	$n = 2$ (20 %)
EMGT detection (%MVC)	45.4 ± 12.7	-	38.4 ± 5.8	35.2 ± 1.0
MVC (N)	384.2 ± 93.4		385.8 ± 92.8	
Final set expressed as %MVC	64.3 ± 8.7		$70.9 \pm 9.8^*$	
$\bar{x}_{FF}$ (N)	248.7 ± 76.3		$278.99 \pm 100.3^*$	

Note. CSR-IICT = intermittent isometric contraction test with short inter-set rest intervals (30 s); LR-IICT = intermittent isometric contraction test with long inter-set rest intervals (120 s); FDS = flexor digitorum superficialis; FDP = flexor digitorum profundus; EMGT = electromyographic threshold; MVC = maximum voluntary contraction; %MVC = percentage of maximum voluntary contraction reached in the final set of the test; $\bar{x}_{FF}$ = mean force output in the final set.

* = significant difference between protocols based on a paired-samples t -test ($p < .05$).

Figure 4

Individual values (colored markers and lines) and sample mean and standard deviation (bar and error bar) for the relative maximum voluntary contraction value (%MVC) in the final set of the intermittent isometric contraction protocol with short inter-set rest intervals (30 s; SR-IICT) and long inter-set rest intervals (120 s; LR-IICT)

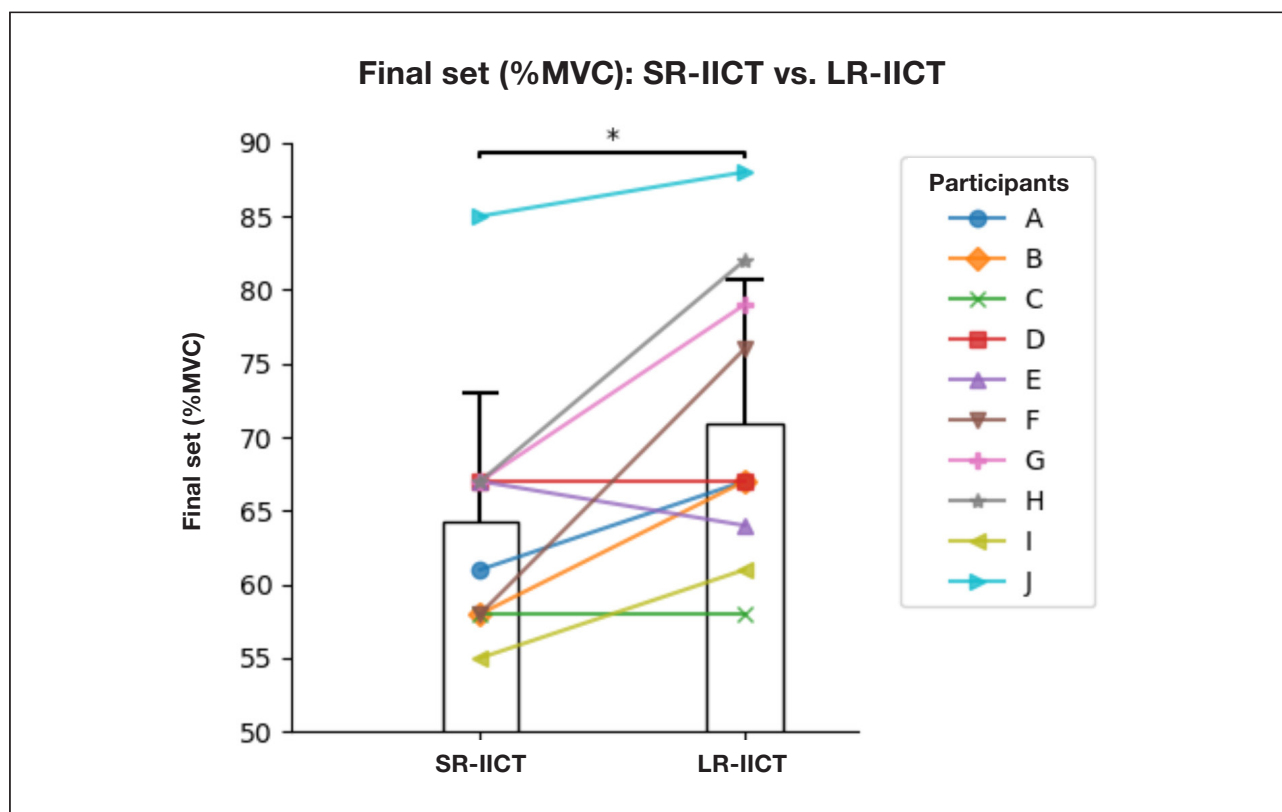


Table 2

Electromyographic threshold (EMGT) values for the participants in whom it was detected, expressed as a percentage of maximum voluntary contraction, and detection protocol

	FDS-EMGT _{SR-IICT}	FDS-EMGT _{LR-IICT}	FDP-EMGT _{SR-IICT}	FDP-EMGT _{LR-IICT}
Participant A	-	-	-	34.54
Participant B	-	-	-	35.92
Participant C	-	39.01	-	-
Participant D	-	42.89	-	-
Participant E	45.41	40.41	-	-
Participant F	32.80	41.42	-	-

Note. FDS-EMGT_{SR-IICT} = electromyographic threshold of the flexor digitorum superficialis during the intermittent isometric contraction test with short inter-set rest intervals (30 s); FDS-EMGT_{LR-IICT} = electromyographic threshold of the flexor digitorum superficialis during the intermittent isometric contraction test with long inter-set rest intervals (120 s); FDP-EMGT_{SR-IICT} = electromyographic threshold of the flexor digitorum profundus during the intermittent isometric contraction test with short inter-set rest intervals (30 s); FDP-EMGT_{LR-IICT} = electromyographic threshold of the flexor digitorum profundus during the intermittent isometric contraction test with long inter-set rest intervals (120 s).

EMGT results

During the detection of the different EMGTs, 9.4% of the contractions performed were excluded because they did not meet the previously established inclusion criteria. The SR-IICT only enabled the FDS-EMGT_{SR-IICT} to be identified in 2 participants, whereas the LR-IICT enabled the FDS-EMGT_{LR-IICT} and FDP-EMGT_{LR-IICT} to be detected in 4 and 2 participants, respectively (Table 1). In both cases in which the FDS-EMGT_{SR-IICT} was detected, the FDS-EMGT_{LR-IICT} was also identified, with similar EMGT values obtained in the two protocols (Table 2).

In the SR-IICT, when the linear regression profiles of the FDP and FDS in which no EMGT was detected were considered together, 50% showed a breakpoint at the end of the test, after which the slope changed from positive to negative, with no point on the descending second regression falling more than 3 SD below the extrapolated line of the first regression. By contrast, in the LR-IICT, when the linear regression profiles of the FDP and FDS in which no EMGT was detected were considered together, 43% showed a breakpoint at which the slope of the second regression was steeper than that of the first; however, no point on the second regression exceeded the extrapolated line of the first regression by more than 3 SD (the second regression had a steeper slope, but the increase was not sufficiently pronounced).

Discussion

Our study results demonstrated the difficulty of detecting the EMGT in the finger flexor muscles using intermittent isometric contraction protocols. This finding calls into

question the generalizability of previous findings on the EMGT across different muscles and tasks, highlighting the need to continue exploring methodological approaches to detecting this threshold. Nevertheless, the protocol with longer inter-set rest intervals showed a higher EMGT detection rate (6 of 10 participants) than the short-rest protocol (2 of 10 participants), indicating that methodological modifications may improve the threshold detection rate.

SR-IICT protocol

Although some authors have noted that the EMGT is not always detectable in the agonist muscles studied (Jürimäe et al., 2007; Taylor & Bronks, 1995), the detection rate observed with the SR-IICT contrasts markedly with the rates reported in previous studies using similar protocols, which reached approximately 90% in lower-limb muscles (Ertl et al., 2016). EMGT detection mainly depends on the methodological criteria used for its determination, which must be rigorous and highly precise (Ertl et al., 2016). In our study, we chose to determine the EMGT mathematically, thereby eliminating evaluator subjectivity. An EMGT was only considered to be present when the breakpoint calculated using two-segment regression included at least one point from the second regression that exceeded the extrapolation of the first regression by +3 SD. The studies by Woods et al. (2019, 2020) are the only ones that have also applied this criterion when using an intermittent isometric contraction protocol with short inter-set rest intervals. However, they implemented an additional readjustment procedure when the EMGT was not detected. This procedure involved transferring $\bar{x}_{\text{EMG}_{\text{RMS}}}$ points used in one of the two regressions to the other if

doing so improved the model fit. Had it been applied, this strategy might have contributed to a higher EMGT detection rate in our study, but at the cost of some objectivity and simplicity in the detection process. Consequently, our results show that EMGT determination is highly complex in multiarticular upper-limb muscles when an objective and conservative methodology is used.

In addition to the methodological criteria used, other biomechanical, physiological, and motor-control factors may influence EMGT detection. Although these factors were not directly assessed in our study, they may help explain our findings. First, selecting a movement involving several agonist muscles that cross multiple joints and have several terminal tendons (one for each finger) may have affected our results, as compensation between muscles has been suggested to be one of the main factors affecting the EMG signal when detecting thresholds (Hug, 2010; Kouzaki et al., 2002). Second, previous evidence appears to indicate that the percentage of type IIb fibers in the FDS and FDP is lower than that in lower-limb muscles (Meznaric & Čarni, 2020). Because the EMGT has been associated with increased recruitment of high-threshold MUs (type II) (Ertl et al., 2016; Hug et al., 2006b; Lucía et al., 1999; Moritani & DeVries, 1978), a low proportion of type II fibers may limit the emergence of the EMGT (Jansson, 1996). Finally, differences in the type of isometric action used in the present study, in which we used a pushing isometric muscle action (PIMA), compared with the studies by Woods et al. (2019, 2020), in which a holding isometric muscle action (HIMA) was used, may also have affected EMG amplitude and EMGT detection (Oranchuk et al., 2024).

Thus, although assessing their influence was not an objective of the present study, changes in muscle involvement throughout the test, a low proportion of type IIb fibers in the muscles analyzed, and the type of isometric action used may help explain the difficulty we encountered in detecting the EMGT. In particular, these factors may help explain the cases in which the breakpoint of the two-segment model occurred in the final sets and was followed by a change to a negative slope in 50% of the cases in which the EMGT was not detected using the short-rest protocol. This pattern may be related to a linear increase in EMG activity caused by these factors, with this linearity only being disrupted by the onset of fatigue, which was probably induced by the short rest intervals in the SR-IICT. Even so, the influence of these factors should be addressed in future research.

Comparison of the SR-IICT and LR-IICT protocols

The protocol with long inter-set rest intervals showed a higher EMGT detection rate in both the FDS and FDP than the short-rest protocol. The protocol with long inter-set rest intervals enabled participants to complete more sets and resulted in a higher percentage of maximum force and greater force output in the final set than the short-rest protocol and resulted in a higher percentage of MVC and greater force output in the final set than the short-rest protocol, possibly allowing participants to reach intensities sufficient for EMGT detection through greater recruitment of high-threshold MUs (type II). (Ertl et al., 2016; Hug et al., 2006b; Lucía et al., 1999; Moritani & DeVries, 1978). This argument is supported by the fact that, among the EMGTs not detected using the long-rest protocol, only 14.3% of cases showed a breakpoint across the sets together with a negative slope in the second linear regression, compared with 50% under the short-rest protocol. In addition, 43% of the EMGTs not detected using the long-rest protocol showed a profile with a breakpoint after which the second linear regression had a positive slope, but without meeting the EMGT validation criterion. This may suggest that high-threshold MU recruitment is less abrupt in some individuals than in others and that the EMGT detection methodology should be refined to accommodate different recruitment patterns.

Regardless of the protocol used, more EMGTs were detected in the FDS than in the FDP in our study, which may be attributable to the importance of the FDS in the task performed. Similarly, previous studies conducted in different muscles and primarily using cycle ergometry (see the review by Ertl et al., 2016) reported higher EMGT detection rates in the vastus lateralis, as the main agonist, than in muscles with less prominent involvement (e.g., gastrocnemius, tibialis anterior). For the task performed in our study, both the FDP and FDS have been considered the main agonists (Philippe et al., 2012; Schweizer & Hudek, 2011). Recent research, however, indicates that this type of grip promotes greater FDS activation through active flexion of the proximal interphalangeal joint, whereas the FDP acts as a stabilizer of the distal interphalangeal joint together with the finger extensor muscles (Ferrer-Uris et al., 2023; Schweizer & Hudek, 2011).

Taken together, our results indicate that EMGT detection in multiarticular upper-limb muscles using IICT protocols is limited when objective and conservative methodological criteria are applied. Nevertheless, extending the inter-set rest interval increased the detection rate, probably by enabling higher contraction intensities, promoting greater recruitment

of type II MUs, and mitigating the confounding effects of fatigue. Despite the difficulties in determining the EMGT in the selected muscles, future methodological approaches may therefore improve our ability to detect the EMGT objectively in multiarticular muscles.

It is important to emphasize that the results of the present study should be interpreted with caution because this was an exploratory methodological study, which limits the confirmatory scope of the findings. Furthermore, the sample was relatively small, consisted exclusively of men, and had heterogeneous training levels. Although no learning effect was identified between the two sessions (i.e., no improvement in MVC), it should also be noted that the participants had limited familiarity with the specific task. The results are also not generalizable to the contralateral (non-dominant) limb or to other muscles. Finally, these findings should be extrapolated to populations of other ages with caution, as the location of these thresholds has been reported to shift throughout the lifespan. Thus, in addition to exploring methodological issues in EMGT determination, future studies should assess the implications of using monoarticular and multiarticular muscles to evaluate the EMGT and should include larger and more diverse samples.

Conclusions

Our study showed that detecting the EMGT in multiarticular upper-limb muscles (finger flexors) using intermittent isometric contraction protocols is challenging. Nevertheless, a higher EMGT detection rate was observed with long inter-set rest intervals (120 s) than with shorter rest intervals (30 s). Longer inter-set rest intervals may facilitate EMGT detection, possibly by enabling higher levels of contractile force to be reached, thereby promoting the recruitment of high-threshold (type II) motor units and attenuating the confounding effects of fatigue.

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