THE INFLUENCE OF HAND GUARDS ON EXPLOSIVE FORCE AND PAIN AND EXERTION PERCEPTION IN A HANG HOLDING TASK

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Original article

Abstract
We investigated whether hand guards (HG) influence the perception of pain and exertion during the execution of a standardized task on high bar to induce forearm muscle fatigue as well as a decline in grip strength after the task. Design: A cross-over study design was employed 15 healthy and physically active volunteers completed static bodyweight holds (8 cycles of 20 second load in hang and 10 second rest), on a high bar. The exercise protocol was performed with and without HG. Perception of pain and exertion during the task were recorded. Peak handgrip force and explosive force parameters (i.e., rate of force development [RFD] and contractile impulse [CI] at 30 to 200 ms) were obtained from force-time curves. Peak force and explosive force parameters were normalized (i.e., POS/PRE) for statistical analysis. The use of a HG significantly attenuates pain perception ($p < 0.05$), with a moderate to large effect size ($d = 0.52$), but did not alter the perception of exertion during the task, nor did it alter peak force, RFD, or CI. The use of HG reduces the perception of local pain during static holds. However, HG do not alter the perception of exertion during the task nor do they alter the gripping force ability immediately afterwards. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Keywords: *mixed modality training, hand guards, rate of force development, safety, gymnastics.*

INTRODUCTION

High-intensity functional training (HIFT) programs, which comprise the basis of world-renowned programs such as Crossfit™, among others (Neto & Kennedy, 2019), have been growing in popularity and recruiting adherents from diverse age ranges (children, youth and the elderly). These training programs use weightlifting (e.g., clean, jerk, snatch) and gymnastic movements (e.g., pull up, ring muscle up, bar muscle up, handstand push up, handstand walking) and as such justify the recent use of the term "mixed modality training" (MMT) (Figueiredo, Pereira, & Neto, 2018; Marchini, Pereira, Pedroso, Christou, & Neto, 2017) to designate this training methodology.

Generally, this training method aims to develop a set of muscle strength and endurance, cardiorespiratory conditioning and motor skills (Brisebois, Rigby, & Nichols, 2018; Maté-Muñoz, Lougedo, Barba, García-Fernández, Garnacho-Castaño & Domínguez, 2017), obtained with workouts that involve one or more of the previously mentioned movements and seeking to perform as many repetitions as possible in a given time interval (i.e., As Many Rounds-Reps As Possible (AMRAP)), or every minute (i.e., Every Minute One Minute (EMOM)), or even performing a certain number of repetitions as quickly as possible (also called "for time workouts" or "time-limited physical workouts"). Thus, MMT training involves a constant quest for performance improvement.

The culture of challenging oneself to improve partly explains the popularity of this training method, since it arouses great motivation. However, as with any high-intensity physical activity, excessive workloads can endanger the practitioners' physical safety. In this context, as in any other sport, protective equipment is widely recommended and used (Church, Allen, & Allen, 2016; Colado & Garcia-Massó, 2009; Kulund, Dewey, Brubaker, & Roberts, 1978), including lifting belts (Renfro & Ebben, 2006), knee-pads or knee wraps (Baltaci, Aktas, Camci, Oksuz, Yildiz & Kalaycioglu, 2011), weightlifting shoes (Sato, Fortenbaugh, & Hydock, 2012), and hand guards for gymnastic bar exercises (Wettstone, 1941).

Though proposed as a safety measure, a possible positive effect of wearing "protective equipment" on physical performance cannot be neglected. For instance, wearing knee wraps has been found to directly increase squatting strength through the spring effect (Lake, Carden, & Shorter, 2012). This raises debates about the legality of their use for competitive purposes. In the gymnastics field, hand protection could be ensured by magnesium (Pušnik & Čuk, 2014) and/or equipment commonly referred to as hand guards (HG) as safety equipment for bar exercises (Neal, Kippers, Plooy, & Forwood, 1995; Wettstone, 1941; Eckers, Fischer & Tscholl, 2020).

Wettstone describes the great importance of HG during periods of practice as it protects against the development of blisters, allowing the gymnast to have a longer period of practice (Wettstone, 1941). This description makes clear the protective purpose of this equipment. Additionally, Neal et al. (1995) studied the influence of the use of different types of HG on hand and wrist tension forces and the electromyographic (EMG) activity of the wrist and fingers flexor and extensor muscles during 3 giant swings on the high bar. The authors demonstrated that the use of this equipment increases wrist tension and bar forces, but did not observe any difference in EMG activity, indicating that the use of this equipment does not change the demand of the muscles involved in the body support during the studied gymnastic exercise. It is important to note that the movement studied (i.e., giant swings) is applied to artistic gymnastics, but is not typically practiced in HIFT programs.

In the context of HIFT, the use of HG, in addition to the safety aspect, may involve an aspect of "advantage" by allowing athletes to perform a greater volume of gymnastic movements, such as pull ups, kipping pull up, chest-to-bar, toes-to-bar and bar muscle ups, which may be related to two aspects: 1) minimize skin friction with the bar, thereby reducing local pain and blistering, and/or 2) mechanically favour the performance of the movements, reducing the demand of the forearm muscles. It is important to note that in many typical HIFT workouts, gymnastic exercises are succeeded by exercises that require strength and endurance of forearm flexors and extensors, such as deadlift, clean and snatch exercises, so that the performance in subsequent tasks can be optimized if the use of hand guards minimizes the effort of the aforementioned muscles, allowing a smaller decline in the capacity to produce force after gymnastic exercises.

Thus, the present study aimed to investigate whether the use of HG influences the perception of pain and exertion during the execution of a standardized task on high bar to induce forearm muscle fatigue as well as the decline in force after the task. Our hypothesis is that HG can minimize the perception of pain in hands, while not reducing the exertion from the forearm muscles.

METHODS

In this cross-over study design, 15 healthy and physically active volunteers (9 men / 6 women; 26.0 ± 3.9 years, 70.0 ± 10.0 kg, 170.1 ± 6.4 cm) were submitted to the same protocol to support their own body weight in hang on two non-consecutive days (1 week apart). All volunteers were regular HIFT practitioners and had prior experience with gymnastic exercises, such as pull ups (at least 6 months of training experience).

Before starting the study, the volunteers were informed about the study procedures and signed an informed consent form, which was evaluated and approved by the local (Universidade Estadual do Sudoeste da Bahia) Research Ethics Committee. Additionally, volunteers were instructed to avoid the practice of exercises in the 24 hours preceding each experimental session.

In order to induce fatigue of the forearm flexor and extensor muscles, all volunteers underwent a protocol to support their own body weight from a high bar (diameter = 2,8 cm). The protocol consisted of 8 cycles of 20 seconds load in hang and 10 seconds rest, totaling 160 seconds sustaining their own body weight. This choice of testing with a static hold was used to ensure reproducibility of the session volume, as performing pull ups could lead to great variability in the degree of exercise-induced fatigue due to the technical level of each volunteer. Figure 1 presents the experimental design.

The same procedure was performed twice, one week apart, so that on each day volunteers performed the protocol in one of the two conditions: 1) with “hand guard”, or 2) without “hand guard”, and the order of these conditions was randomized. For this study we used a Skyhill® hand guard (Florianópolis, SC, Brazil) developed to practice gymnastic exercises applied to HIFT (Figure 2). During the task execution, the use of magnesium was allowed, since its protective effect on the hands has been demonstrated by Pušnik & Čuk (2014).

Prior to and immediately after the exercise protocol used to induce fatigue of the forearm flexor and extensor muscles, maximal voluntary handgrip isometric contractions (MVIC) and the perception of pain and exertion were recorded.

Prior to the exercise protocol, volunteers were familiarized with the pain perception scale, which consists of a 100 mm line representing "no pain" at the left limit (0 mm) and "very, very painful" at the right limit (100 mm), as used by Borges, Cerqueira, Rocha, Conrado, Machado, Pereira & Neto (2014). In the present study, the volunteers were instructed to consider the perception of hand and wrist pain to indicate the level of pain on the line. Volunteers were also asked if pain perception was located in the hand (palm), wrist or both regions. Similarly, volunteers were previously instructed regarding the assessment of perception of exertion from the forearm muscles during the task. The Borg CR10 effort perception scale was used to assess the perception of exertion during the task, as used by McGorry, Lin, Dempsey, & Casey (2010).

The volunteers underwent 4 maximal voluntary handgrip isometric contractions (MVIC) (two with each hand) with a strain gauge-based force transducer (EMG System, São José dos Campos, SP, Brazil). To perform the MVIC, the volunteers stood in an orthostatic position, and were instructed to position the arm at 90° of elbow flexion with their forearm in the neutral position. The device's handle was fit into their palm with the fingers at 90° flexion at the proximal and distal interphalangeal joints with the thumb in 90° abduction. Two handgrip maximal isometric force attempts with an inter-attempt rest interval of 30 seconds were performed for each arm (right and left), and the maximum handgrip force of each trial was identified. The order of tested hand (i.e., right and left) was random. Subjects were carefully instructed to contract "as fast and forcefully as possible" after the command "go," sustaining the contraction for 3 seconds when the command "stop" was given. Verbal encouragement was given by the evaluator during the maintenance of the MVIC and the best attempt at each moment (i.e., before and immediately after the fatigue protocol) was used for analysis purposes. The sampling rate from force transducer was set at 2 kHz, as performed by Schettino, Luz, Oliveira, Assunção, Coqueiro, Fernandes, Brown, Machado & Pereira (2014) and Borges, Fernandes, Schettino, Coqueiro & Pereira (2015).

The force-time curves were analyzed to obtain the rate force development (RFD) in the first 200 milliseconds of MVIC. Briefly, the force-time curves were smoothed by a digital fourth-order, zero-lag Butterworth filter, with a cutoff frequency of 15 Hz, as proposed by Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen (2002). The Δ force / Δ time ratio was measured at time intervals of 30, 50, 100, 150 and 200 ms after the onset of MVIC. Likewise, the area under the force-time curve was calculated at the same time intervals as mentioned above, obtaining the contractile impulse (CI) parameter (Aagaard et al., 2002). Both CI and RFD measure explosive force, however, they use distinct but complementary methods. The CI measures accumulated area under the force–time curve which reflects the entire time period of contraction, including the overall influence of the various time-related RFD parameters (Aagaard et al., 2002; Schettino et al., 2014).

The onset of muscle contraction was defined as the time point at which the force curve exceeded the baseline by 2.5% of the difference between baseline force and the maximum voluntary contraction (i.e., maximum handgrip force), as proposed by Aagaard et al. (2002) and Schettino et al. (2014). All analyses were conducted using specific algorithms developed in MATLAB®.

For descriptive purposes, the explosive force data (i.e., RFD and CI) obtained immediately after the fatigue protocol were normalized by the measurements obtained before the fatigue protocol (Δ (%) = [POS / PRE] * 100) for each arm (i.e., right and left). For statistical analysis, Δ POS / PRE from the right and left arm were grouped, so that comparisons between the experimental conditions with and without hand guard were made considering the mean ΔPOS / PRE (%) from the right and left arms. Figure 3 illustrates the data analysis and grouping procedure for statistical analysis.

Student's t-test was used to compare pain and effort perception in the task performed with and without hand guard. Similarly, ΔRFD and ΔCI from each experimental condition (i.e., with and without HG) were compared with Student's t-test. For all comparisons, the significance level of $p \leq 0.05$ was used, and all statistical analyses were performed using

SPSS 21.0 software (IBM Corp., Chicago, IL, USA). The effect size was calculated to obtain Cohen's *d*-index as proposed by Cohen (1988). The following interpretation was considered: small (d = 0.2), medium (d = 0.5), and large effect size (d = 0.8). Data are presented as mean ± standard deviation.

Figure 1. Experimental design.

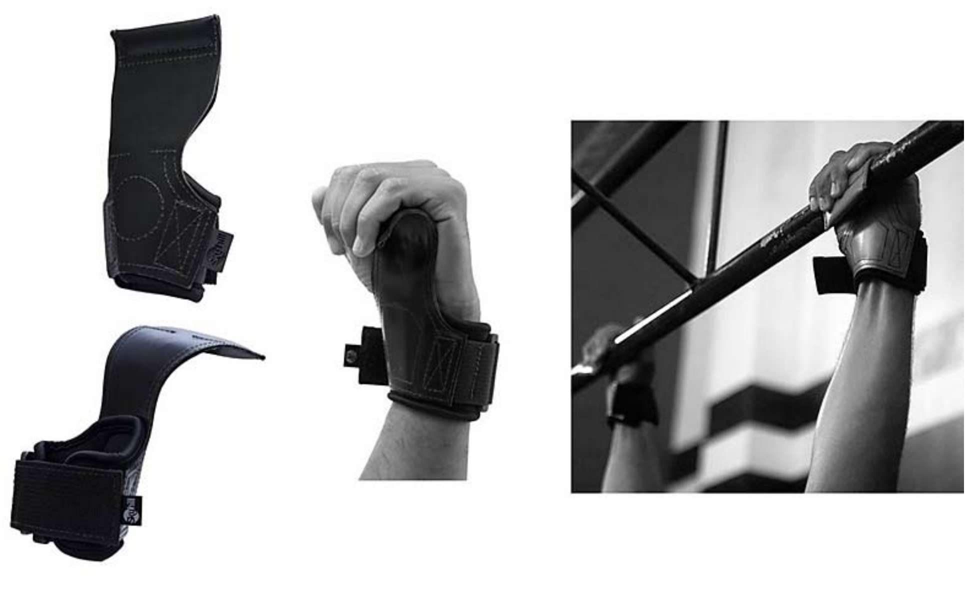

*Figure 2***.** “Hand guard” used, and its proper use mode.

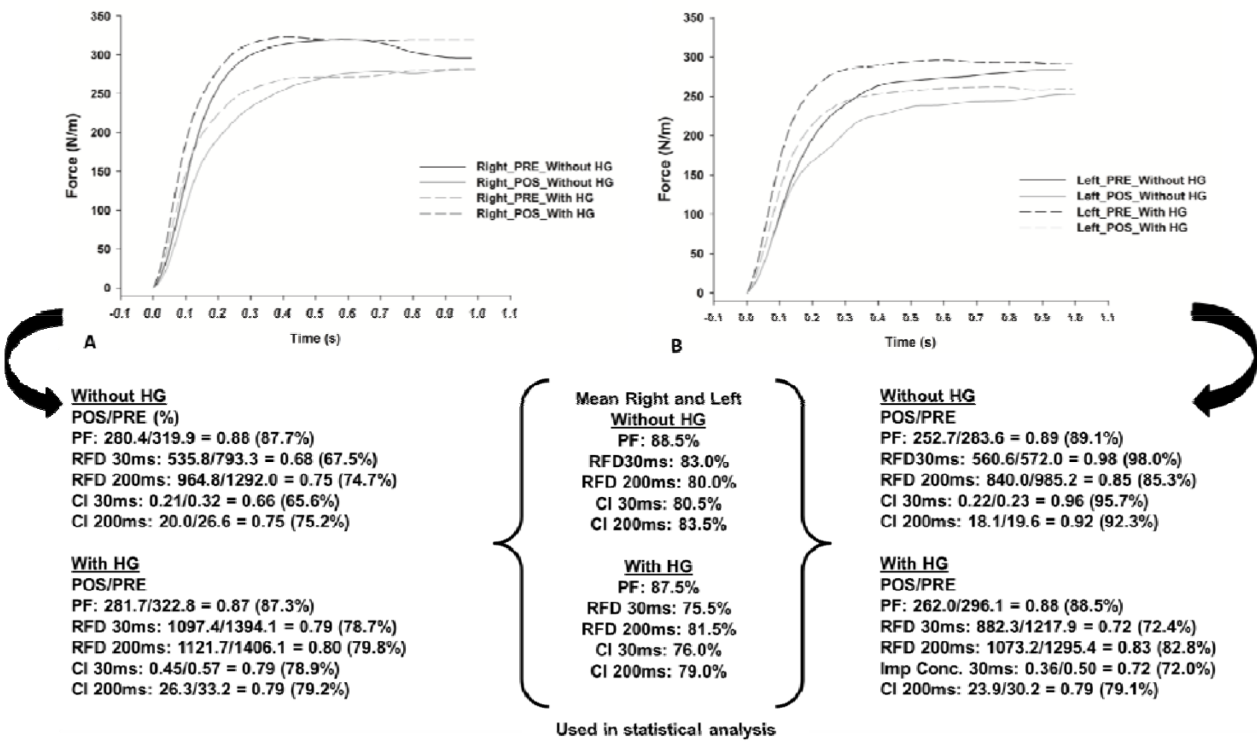

*Figure 3***.** Force / time curves of the right (A) and left (B) arms, before (PRE) and after (POS) the task for fatigue induction without and with hand guard (HG). Peak Force (PF), rate of force development at 30 (RFD 30ms) and 200 ms (RFD 200ms), Contractile Impulse at 30 (CI 30ms) and 200 ms (CI 200ms) values are presented in absolute and normalized values (POS / PRE). The central column shows the mean of the right and left arms in studied conditions (i.e., without and with HG).

Table 1
Perception of pain and exertion during the proposed task without and with hand guard.

	Without HG	With HG	P value	Mean difference [95% Conf. Int.]	Effect size
Perception of Pain (mm)	5.5±0.5	4.1±0.6	0.038*	1.40 [0.09 to 2.71]	0.52
Perception of exertion (A.U.)	7.5±0.5	7.1±0.5	0.290	0.46 [-0.44 to 1.38]	0.28

Table 2
Mean ± standard deviation from the difference (Δ POS / PRE (%)) of the peak force and the right and left arms explosive force parameters under experimental conditions with and without hand guard (HG). P values, mean difference and effect size of comparisons between experimental conditions are also presented.

	Without HG			With HG			P value	Mean difference	Effect
	Right	Left	Mean	D	E	Mean		[95% Conf. Int.]	size
Peak Force	88.8±16.6	86.6±16.5	87.7±14.8	86.9±22.0	80.3±19.1	83.6±18.8	0.520	4.1 [-9.2 to 17.4]	0.17
RFD 200ms	75.5±19.5	71.6±17.8	73.5±17.0	68.2±22.0	62.1±18.1	65.2±19.2	0.163	8.4 [-3.8 to 20.5]	0.37
RFD 150ms	74.8±20.1	70.2±19.4	72.5±18.0	67.9±26.6	59.1±19.9	63.5±22.0	0.197	9.0 [-5. 3 to 23.3]	0.34
RFD 100ms	76.1±23.0	70.0±21.7	73.0±20.4	69.2±33.2	58.3±22.5	63.8±26.0	0.270	9.3 [-8.0 to 26.6]	0.29
RFD 50ms	79.0±27.6	73.6±26.1	76.3±24.5	71.0±35.5	60.9±26.3	66.0±28.6	0.281	10.3 [-9.4 to 30.1]	0.29
RFD 30ms	80.7±29.1	75.5±28.1	78.1±26.1	71.9±34.7	63.8±29.1	67.8±29.5	0.299	10.3 [-10.2 to 30.7]	0.28
CI 200ms	75.7±21.2	70.4±19.6	73.0±18.7	68.1±27.1	59.6±20.3	63.9±22.3	0.194	9.2 [-5.2 to 23.6]	0.34
CI 150ms	76.3±22.7	70.4±21.3	73.3±20.1	68.9±31.2	58.9±22.0	63.9±24.9	0.238	9.4 [-7.0 to 25.8]	0.31
CI 100ms	77.8±25.4	71.7±23.9	74.8±22.6	70.2±34.4	59.8±24.3	65.0±27.3	0.275	9.8 [-8.7 to 28.2]	0.29
CI 50ms	80.2±28.6	74.9±27.4	77.5±25.5	71.5±34.6	63.2±28.1	67.4±29.0	0.295	10.2 [-9.9 to 30.2]	0.28
CI 30ms	81.3±29.6	76.6±28.5	79.0±26.5	72.5±34.1	65.5±30.8	69.0±30.0	0.314	10.0 [-10.5 to 30.5]	0.27

RFD = Rate of Force Development; CI = Contractile Impulse

RESULTS

All volunteers completed the proposed exercise protocol in both experimental sessions. Pain perception reported immediately after the experimental session was significantly lower in the experimental session with the use of hand guard ($p < 0.05$), and the observed effect size was classified as medium to large ($d = 0.52$). All volunteers reported pain at the end of the task performed without a hand guard. From 15 volunteers, 14 (93.3%) reported hand (palm) pain and only 1 (6.7%) reported wrist pain at the experimental session without HG. When the HG was used 6 volunteers (40%) did not report pain, 8 (53.3%) reported hand (palm) pain and only 1 (6.7%) reported wrist pain.

The perception of exertion during the task was not different between experimental sessions ($p > 0.05$). The results from perception of pain and exertion during the task are presented in table 1.

The peak force and explosive force parameters decreased by about 13 to 37% after the induced fatigue by the used hang holding task (see table 2). The peak force and the explosive force parameters decline did not differ significantly between experimental conditions with and without hand guard ($p > 0.05$), as shown in table 2.

DISCUSSION

The present study aimed to investigate whether the use of HG influences the perception of pain and exertion during a standardized task to induce forearm muscles fatigue as well as a decline in peak force and explosive force after the applied task. Our results showed that the use of HG significantly attenuates pain perception, with a moderate to large effect size, but did not attenuate the perception of exertion during the task, as well as the ability to produce maximum force and explosive force immediately after the task.

HG are proposed as protective equipment to perform gymnastic exercises on the bar (Neal et al., 1995; Wettstone, 1941) and our results corroborate this proposal, since HG attenuated pain perception during a standardized task sustaining the body weight on high bar. The compression and friction generated on the palm during this task generates pain and may therefore be a limiting factor for the practice of higher volumes of exercises on high bar. Our results indicate that the use of HG may effectively enable a greater volume of training in the same session, even though factors other than pain may limit the session volume.

Despite the lower pain perception in the palm and wrist, HG did not attenuate the perception of exertion during the task. This may be due to the fact that this model of HG does not attach to the bar (see figure 1), requiring maintenance of the contraction of forearm and fingers flexor muscles to sustain the hold. McGorry et al. (2010) demonstrated that the measure of perceived exertion involving forearm muscles, as used in our study, has a direct relationship with the handgrip strength demand.

Many HG models are used by gymnasts, with differing models suited to various gymnastic movements. In the present study we examined the model where the HG is fixed to the wrist but not fixed to the bar. Our results indicate that the used HG model does reduce the demands of the forearm muscles. Previous research by Neal et al. (1995), compared the forces applied to the bar and the electromyographic activity (EMG) of the forearm muscles of gymnasts during the execution of 3 giant swings on the high bar with and without the use of HG (2 typical models – webbing loops and dowelled hand guards, used for gymnastics). EMG activity was equal during the performance of the movements under conditions with and without both HG models.

Neal et al. (1995) submitted 10 gymnasts to a movement typically used in artistic gymnastic competitions, which is not directly applicable to HIFT-based workouts. Despite the differences in movement analyzed (giant swing vs. static support) and HG style, our results are in line with the cited study, leading us to infer that the used HG model in our study meets the criteria of hand protection, but does not alter muscular demand when sustaining the body on high bar, which was confirmed by the force measurements before and immediately after the proposed task. In fact, the ability to generate maximum force and explosive force were not different in studied experimental conditions (i.e., with and without HG).

It is important to note that the explosive force analysis applied in our study permits the differentiation of influence of neural factors (i.e., the ability to recruit motor units and its recruitment pattern) and muscular factors (i.e., the contractile apparatus characteristic and availability of energy substrates), since the ability to increase force within the first 100 ms of a MVIC is directly related to neural factors, while the ability to increase strength from 100 to 200 ms is directly related to muscle factors (Cerqueira, Pereira, de Mesquita, Rocha, & de Moura Filho, 2019; Maffiuletti, Aagaard, Blazevich, Folland, Tillin, & Duchateau, 2016; Oliveira, Corvino, Caputo, Aagaard, & Denadai, 2016).

Perception of palm pain has been found to directly influence the descending command pattern of the central nervous system to the muscles involved in the handgrip task (Tokimura, Di Lazzaro, Tokimura, Oliviero, Profice, Insola, Mazzone, Tonali, & Rothwell, 2000) and consequently in the ability to produce muscle force. Despite this, the present results did not show any advantage in the use of HG in regards to force production, as there were no observed differences between conditions in the force measurements in the first 100 ms of the MVIC after the applied task. However, it is important to emphasize that we used a time-limited task, where all subjects were able to complete the task, regardless of the use of HG. Thus, we cannot infer whether the use of HG would enable one to sustain the task for a longer time period before the onset of fatigue. The effect of HG on time to exhaustion during static holds could be investigated in future studies, since the current experimental design was directed to investigate the neural and mechanical factors involving the use of HG during a time-limited task.

The results of this study shed light on aspects related to the mechanisms involved in the use of HG in a time-limited task, while future studies should investigate how the use of HG influences the performance-limited tasks (i.e., the maximum time sustaining the body weight or recording the maximum pull-ups, toes-to-bar or bar muscle ups repetitions), which would require good control of technical variables during the movement execution.

The practical implications of these results may affect athletes and coaches in the area of HIFT or related modalities where gymnastic exercises, such as pull ups, toes-to-bar and bar muscle ups are applied. In this context, our results indicate that athletes and coaches should choose whether or not to use HG on the basis of pain perception rather than the possible mechanical advantage of using this accessory. Additionally, it is possible to hypothesize that in typical HIFT workouts, where weightlifting exercises (e.g., clean, snatch) can be performed immediately after gymnastic exercises on high bar, the use of HG would not favour a higher grip strength and would lend no advantages.

CONCLUSION

In conclusion, the results of this study suggest that the use of HG reduces the perception of local pain (palm). However, it does not provide any mechanical advantage for the applied task, since it does not reduce the perception of exertion during the task nor the ability to develop force based on neural and/or muscular aspects immediately after the proposed task. When deciding whether to use HG for HIFT-based workouts, athletes and coaches should be aware that this is protective equipment and there is no evidence that it offers any mechanical advantage.

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