"Ido Movement for Culture Journal of Martial Arts Anthropology",
Vol. 24, no. 2 (2024), pp. 50–56
DOI: 10.14589/ido.24.2.6

KINESIOLOGY & COACHING

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Acute impact of exercise order on repetition performance, perceived fatigue, and grip endurance in grapplers

Submission: 08.06.2022; acceptance: 27.10.2022

Key words: Brazilian jiu-jitsu, grappling, resistance training, repetition performance, rating of perceived exertion, grip endurance

Abstract
Background. Grip performance is a fundamental attribute in grappling sports.
Problem and aim. Concurrent training may impact physical function and thus sport-specific training performance. We investigated whether resistance training (RT) exercise order affected repetition performance and rating of perceived exertion (RPE), and quantified the impact of RT on gripping in Brazilian jiu-jitsu (BJJ) grapplers.

For citation – in IPA style:
Belo W.R., Ovretveit K., De Salles B.F., Dos Santos L.G.D., Laginestra F.G., Dias I.B.F., Miarka B., Simao R. (2024), *Acute impact of exercise order on repetition performance, perceived fatigue, and grip endurance in grapplers*, "Ido Movement for Culture Journal of Martial Arts Anthropology", vol. 24, no. 2, pp. 50–56; doi: 10.14589/ido.24.2.6.
In other standard – e.g.:
Belo, W. R., Ovretveit, K., De Salles, B.F., Dos Santos, L. G. D., Laginestra, F. G., Dias, I. B. F., Miarka, B., Simao, R. Acute impact of exercise order on repetition performance, perceived fatigue, and grip endurance in grapplers. *Ido Mov Cult J Martial Arts Anthrop*, 2024, 24 (2): 50–56 DOI: 10.14589/ido.24.2.6

Material and methods. Twelve BJJ athletes completed two RT sessions in a random order. The sessions incorporated the same four exercises in either alternated order (AO) or grouped order (GO). Three sets were performed to failure using a 10-repetition maximum (10RM) load. The maximum number of repetitions (MNR) for each set determined repetition performance, and RPE was used to assess fatigue. Grip performance was measured with a maximum static lift (MSL) at baseline and post RT.
Results. In both protocols, MNR decreased significantly over time, with no significant protocol × set interaction ($p > 0.05$). RPE increased over time, with no protocol × set interaction ($p > 0.05$). Both protocols resulted in reduced MSL ($p < 0.001$), with no difference in magnitude ($p > 0.05$). Total training volume, average RPE, and session perceived load (average RPE × session duration) did not differ between protocols ($p > 0.05$).
Conclusions. Exercise order in short, full-body RT programs did not acutely influence repetition performance or perceptions of fatigue in these athletes. Grip endurance was severely compromised following RT, independent of exercise order. Grapplers doing same-day concurrent training should be mindful of the immediate impact of RT on gripping ability.

Introduction

In Brazilian jiu-jitsu (BJJ), one of the primary objectives is to exert control over a resisting opponent. Although BJJ is a highly technical sport, various physical attributes such as strength, endurance, power, and flexibility can shift the dynamics of a match in favor of the fitter, and at times technically inferior, athlete. Although it can be physically demanding, BJJ training alone appears only to lead to moderate fitness levels [Ovretveit 2018b; Andreato *et al.* 2017]. Consequently, many of these athletes incorporate additional strength and conditioning (S&C) training. Indeed, doing so has been shown to rapidly improve parameters such as force-generating capacity [Ovretveit, Toien 2018] and cardiorespiratory fitness [Ovretveit 2019], which are likely conducive to grappling performance [Ovretveit 2018a].

Since BJJ grappling involves the whole body, compound exercises are commonly recommended [Ovretveit 2020; Ratamess 2011; James 2014]. Still, insight into acute and chronic resistance training (RT) adaptations in this athlete population is limited. Because of the highly technical and strategical nature of BJJ, and the versatility of how it can be practiced, total BJJ-specific training volume is often high among practitioners. This may lead to S&C being performed on the same day as BJJ, which has implications for volume, intensity, and frequency, not only in terms of optimizing training adaptations but also the avoidance of non-functional overreaching and overtraining.

In addition to the intricacies of same-day concurrent training in the context of chronic training adaptations, acute perturbations introduced by S&C can impact short-term physiological capacity and thus inhibit subsequent sports performance. For BJJ athletes specifically, the impact of S&C modalities such as RT on crucial physical attributes such as handgrip ability is particularly relevant, as a reduction in handgrip performance prior to BJJ training may impact training quality, such as reducing the quality of technical drilling and sparring performance. Gripping ability is imperative in grappling sports [Ovretveit, Laginestra 2020], and the ability to recover handgrip capacity between matches may influence competition outcome [Kons *et al.* 2018].

The past decade has seen an increasing interest in strength and conditioning strategies for grappling sports [Ovretveit 2020; Ovretveit, Toien 2018; Jones, Ledford 2012; Ratamess 2011; James 2014]. There is, however, a lack of direct comparisons of different RT protocols in the BJJ athlete population [Belo *et al.* 2020], including, to the best of our knowledge, a complete lack of studies exploring the effects of RT on grip performance. In the present study, we investigated the acute impact of exercise order on RT repetition performance, perceived fatigue, training volume, and grip endurance in active BJJ athletes. We hypothesized that an RT program that alternates exercises between body segments results in better repetition performance at the same level of perceived fatigue and consequently greater training volume compared to grouping exercises within the same body segment.

Material and methods

Study design

A group of active BJJ athletes completed two supervised RT sessions in a randomized crossover design. The sessions incorporated the same four exercises: Romanian deadlift (RDL), bench press (BP), leg press (LP), and lat pulldown (PD), in either alternated order (AO) or grouped order (GO). Prior to the RT sessions, all participants completed two familiarization sessions with anthropometric measurements, as well as two testing sessions to determine their 10-repetition maximum (10RM) for each lift. All these sessions were interspersed with 48-72 hours of rest. All familiarization, testing, and training sessions were conducted at the same time of day, between 15:00 and 17:00. In the 72 hours before the training sessions, all participants were told to maintain their regular eating habits and avoid physical exercise. Specific instructions were given to abstain from stimulants such as caffeine, alcohol, and weight loss supplements, as well as chocolate and soda. The participants were given 3-5 days of rest between the training sessions to allow for complete recovery.

Participants

The study sample consisted of 12 male individuals (age: 24.5 ± 3.1 years; height: 175.8 ± 0.1 cm; body mass: 77.1 ± 13.0 kg; body fat: 14.4 ± 5.8 %) with 3.5 ± 2.8 years of BJJ training experience at a current frequency of 2.4 ± 0.5 sessions per week. To mitigate injury risk, all participants were required to have some RT experience, but not be actively engaged in any RT for > six months leading up to the study. The study was approved by the Federal University of Rio de Janeiro Ethics Committee and carried out in accordance with the Declaration of Helsinki. All participants signed written consent forms prior to participation.

Measurement procedures

During the first familiarization session, the participants underwent a body mass assessment with a weight balance scale, a height measurement using a stadiometer (Filizola, Sao Paulo, Brazil), and an estimation of body fat percentage using a skinfold caliper (Sanny, Sao Paulo, Brazil) and Jackson and Pollock's 3-site equation [Jackson, Pollock 1978]. Baseline measurements of the maximum static lift (MSL) [da Silva *et al.* 2012] were performed at both familiarization sessions, as well as 15 minutes after each training protocol to assess RT-induced reductions in grip endurance. In this test, after a grip-specific warm-up, the participants were instructed to hold on to a kimono with maximal flexion in the elbow joint and sustain their body mass in this position until failure. Following the familiarization sessions, each participant completed 10RM tests on all exercises on two separate days with 48-72 hours of rest between to determine the training loads. The tests were conducted using progressively higher loads, aiming to reach 10RM in three attempts, excluding the warm-up. We found excellent test-retest reliability in the range of 0.94 to 0.97 for all four exercises [Belo *et al.* 2020]. The best 10RM performance from the baseline tests was used as a training load.

Training protocols

The RT protocols were designed with the same four exercises, either in an alternating order (AO), which rotated between the upper and lower body (RDL → BP → LP → PD) or grouped (GO) within each body segment (RDL → LP → BP → PD). Following a warm-up set, each exercise was performed for three sets interspersed with two-minute breaks using the previously established 10RM load for as many repetitions as possible. Failure was considered when a repetition could not be performed with a sufficient range of motion. Participants were supervised and verbally encouraged by an experienced coach throughout every set. The maximum number of repetitions (MNR) for each set was recorded and used to quantify exercise performance. Additionally, the participants were asked to give their rating of perceived exertion (RPE) on the Adult OMNI Perceived Exertion Scale for Resistance Exercise [Lagally, Robertson 2006] following each set. Training volume was calculated as sets (n) × repetitions (n) × load (kg).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 25 (Chicago, IL, USA). Figures were made with GraphPad Prism 6 (San Diego, CA, USA). A two-way repeated measures ANOVA (protocol × set) was used to detect differences in MNR and RPE between protocols. If a significant interaction was found, pairwise differences were identified using Sidak post-hoc test correction for multiple comparisons. If the sphericity assumption was violated, the Greenhouse-Geisser correction coefficient was reported. Data normality for variables used in pairwise comparisons was assessed with the Shapiro-Wilk test, with a two-tailed paired samples t-test being applied to compare differences in grip endurance, session time, and total training volume between protocols. The data are presented as mean ± standard deviation. A p-value ≤ 0.05 was considered statistically significant.

Results

All measurements, testing, and training were completed by all participants, resulting in no missing data. No serious injury was observed during the study. However, due to the high-intensity nature of the training sessions, some participants experienced transient dizziness and nausea.

Overall, repetition performance decreased over time, with no between-protocol differences in MNR being observed ($p > 0.05$). This reduction in MNR was observed for RDL ($F_{2,22}$ = 28.5, = 0.72, p < 0.01; protocol × set interaction: $F_{2,22}$ = 2.34, = 0.18, p = 0.12), BP ($F_{2,22}$ = 41.0, = 0.79, p < 0.01; protocol × set interaction: $F_{2,22}$ = 0.3, = 0.03, p = 0.73), LP ($F_{2,22}$ = 9.6, = 0.47, p < 0.01; protocol × set interaction: $F_{2,22}$ = 1.8, = 0.14, p = 0.19), and PD ($F_{1.4,15.1}$ = 1.7, = 0.76, p < 0.01; protocol × set interaction: $F_{1.3,14.1}$ = 1.7, = 0.13, p = 0.21) (figure 1).

Both protocols elicited increases in RPE over time, but no protocol × set interaction was found ($p > 0.05$). Specifically, increased RPE was found for RDL ($F_{2,22}$ = 30.0, = 0.73, p < 0.01; protocol × set interaction: $F_{2,22}$ = 0.7, = 0.06, p = 0.52), LP ($F_{2,22}$ = 7.7, = 0.41, p < 0.01; protocol × set: $F_{2,22}$ = 0.2, = 0.02, p = 0.79), and PD ($F_{2,22}$ = 13.5, = 0.55, p < 0.01; protocol × set interaction: $F_{2,22}$ = 0.6, = 0.05, p = 0.55). Despite no interaction for BP ($F_{2,22}$ = 0.2, = 0.02, p = 0.79), we found that AO elicited significantly higher RPE values compared to GO ($F_{1,11}$ = 6.4, = 0.37, p = 0.03) in both the second (p = 0.05) and third set (p = 0.02), with a trend for the first set (p = 0.09) (fig. 1). Neither the average RPE nor the session perceived load (average RPE × duration) differed between protocols (ΔRPE: 0.26 ± 0.65, t_{11} = -0.6, p = 0.20, 95% CI = -0.16, 0.67; Δsession perceived load: 527.7 ± 1337.7, t_{11} = -1.4, p = 0.20, 95% CI = -322.2, 1377.6).

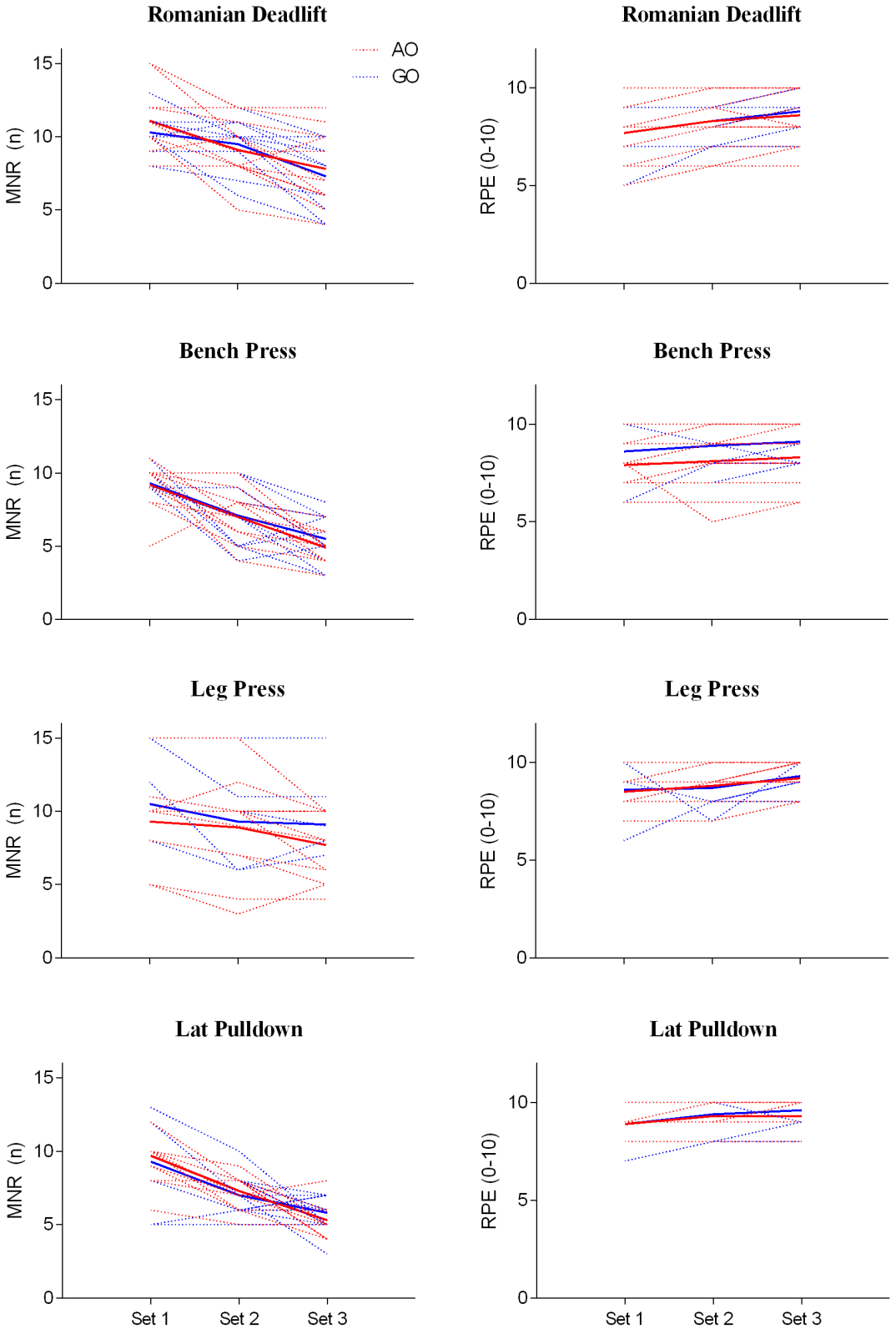

Fig. 1. Comparison of individual repetition performance between protocols. *AO, alternated order; GO, grouped order; MNR, maximum number of repetitions; RPE, rating of perceived exertion*

Grip performance measured as MSL was equally diminished following both AO and GO, with no difference between protocols (AO: 48 ± 19 to 24 ± 10 s; GO: 48 ± 19 to 25 ± 10 s, t_{11} = 0.6, p = 0.56, 95% CI = -2.6 ± 4.6 s; fig. 2). Total training volume was not different between protocols (AO: 9873 ± 2432 kg; GO: 10617 ± 2741 kg, t_{11} = -1.2, p = 0.26, 95% CI = -2128, 638). When considering the individual volume for each exercise, the protocol × exercise interaction showed no significant difference ($F_{1.0,11.5}$ = 1.3, = 0.11, p = 0.28).

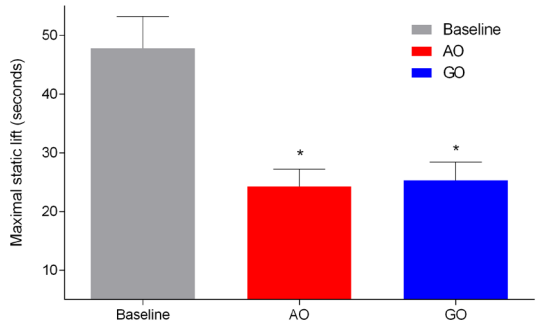

Fig. 2. Grip endurance at baseline and following resistance training. *Data presented as mean ± standard error. Duration of maximum static lift following either an alternating (AO) or grouping (GO) resistance training session; * p < 0.001 compared to baseline.*

Discussion

The main aim of this study was to investigate whether exercise order acutely affected repetition performance and perception of fatigue in grapplers. Secondarily, we sought to quantify the impact of RT on grip endurance, an important determinant of competition success in grappling sports, but also integral to the quality of grappling-specific training. Contrary to our hypothesis, the main finding was that exercise order did not appear to affect repetition performance in a single RT session when correcting for repeated measures. Expectedly, both protocols resulted in a significantly compromised grip, with a ~50% reduction in MSL following a total of 12 working RT sets.

The similar repetition performance observed across protocols suggests that exercise order has little impact on this parameter, which is in disagreement with previous findings [Simao *et al.* 2012; Nunes *et al.* 2020]. There are several possible explanations for this. First, the only difference between protocols is the placement of BP and LP, which resulted in a limited exposure contrast between conditions. Additionally, exercise order may also be less impactful in full-body RT programs, particularly when fewer exercises are incorporated. When the number of exercises per body segment increases, work capacity progressively declines, which reduces performance towards the end of the session [Simao *et al.* 2005]. Furthermore, the two-minute interset rest periods may have allowed for sufficient recovery between exercises, restoring work capacity to the extent that exercise order did not significantly affect MNR. Lastly, our sample size may not have been large enough to detect small effects, and the lack of difference between protocols should not be interpreted as a general lack of influence on exercise order, both in terms of acute and chronic adaptations; in RT program design, exercise order should be informed by athletic goals [Simao *et al.* 2010; Nunes *et al.* 2020; Simao *et al.* 2012].

The immediate recovery demands of RT are related to both volume and intensity, with maximal effort training requiring longer recovery times than moderate intensity [Raastad, Hallen 2000]. Heavy RT is a well-established approach to improvements in force-generating capacity without an increase in body mass [Heggelund *et al.* 2013; Hoff, Berdahl, Braten 2001], an observation also made in BJJ athletes [Ovretveit, Toien 2018]. Athletes in the present study trained to failure in every set using a moderately heavy 10RM load, which, although not generally a recommended RT approach, can be used as a method to assess differences in capacity, i.e., how much work the athlete is able to perform over the course of a training session. Chronic RT adaptations such as maximal strength and hypertrophy appear to favor longer interset rest periods [Schoenfeld *et al.* 2015]. Although longer breaks are conducive to more intra-session work and thus potentially greater stimuli and subsequent adaptations, it could be speculated that post-session fatigue may be comparable or even more pronounced compared to shorter breaks. It was recently shown that less rest during RT results in greater acute metabolic and perceptual fatigue in grapplers, but the cumulative fatigue, i.e., following multiple sessions, was not assessed [Belo *et al.* 2020]. Thus, in the context of same-day concurrent training, aiming to both space out RT and sport training, as well as incorporate longer rest periods during RT training, may benefit both acute fatigue and long-term adaptations. We stress the importance of appropriate programming for both progression and fatigue management, which should include monitoring of markers for each outcome.

As expected, both protocols resulted in a significantly reduced grip endurance, as determined by MSL. This reduction may negatively impact subsequent grappling training by compromising the ability to perform certain techniques and control the opponent during sparring. However, although briefly detrimental to grappling performance, this reduction likely reflects a stimulus that improves grip performance long-term, a key attribute for grapplers [da Silva *et al.* 2012; Chaabene *et al.* 2017]. Since the reliance on gripping is both athlete and style-dependent, individual RT programming is crucial for BJJ athletes, especially those who routinely perform two-a-day (RT + BJJ). In some cases, the use of training equipment such as straps to preserve gripping ability following RT may be appropriate. In other cases, grappling in a compromised physical state may be actively sought out as a training modality [Ovretveit, Laginestra 2020].

There were several limitations to this investigation. The study design did not allow for inferences regarding long-term differences in training stimuli and adaptations. Additionally, the single measurement of grip performance only characterizes one aspect of gripping, of which there are many [Ovretveit, Laginestra 2020]. We also did not quantify the practical implications of a compromised

grip during BJJ training, which reduces the ecological validity of the grip performance test results. The limited sample size also poses a risk of false negatives.

Conclusions

Observations from the present study suggest that exercise order in short, full-body RT programs does not acutely influence repetition performance when training to failure in BJJ athletes with limited RT experience. Similarly, perceptions of fatigue generally did not differ between the protocols, although some differences in RPE were indicated in one of the exercises. Grip endurance was severely compromised following RT, independent of exercise order. Grapplers, particularly those doing same-day concurrent training, should be mindful of the immediate impact of RT on gripping ability.

Acknowledgments

This investigation was supported by the Coordination for the Improvement of Higher Education Personnel (CAPES). We would like to thank the athletes from the Federal Brazilian Jiu-jitsu School (Team Minerva) at the Federal University of Rio de Janeiro (UFRJ) who participated in this study. The study procedures complied with the current laws of the country in which they were performed.

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Znaczący wpływ kolejności ćwiczeń na wydajność powtórzeń, postrzegane zmęczenie i wytrzymałość chwytu u grapplerów

Słowa kluczowe: Brazylijskie jiu-jitsu, grappling, trening oporowy, wydajność powtórzeń, ocena odczuwanego wysiłku, wytrzymałość chwytu

Streszczenie.

Tło. Wydajność chwytu jest podstawowym atrybutem w sportach grapplingowych.

Problem i cel. Równoczesny trening może wpływać na funkcje fizyczne, a tym samym na wyniki treningu sportowego. Autorzy zbadali, czy kolejność ćwiczeń treningu oporowego (RT) wpływa na wydajność powtórzeń i ocenę odczuwanego wysiłku (RPE) oraz określili ilościowo wpływ RT na chwytanie u brazylijskich grapplerów jiu-jitsu (BJJ).

Materiał i metody. Dwunastu zawodników BJJ ukończyło dwie sesje RT w losowej kolejności. Sesje obejmowały te same cztery ćwiczenia w kolejności naprzemiennej (AO) lub grupowej (GO). Trzy zestawy zostały wykonane do czasu porażki przy użyciu maksymalnego obciążenia 10 powtórzeń (10RM). Maksymalna liczba powtórzeń (MNR) dla każdego zestawu określała wydajność powtórzeń, a RPE wykorzystano do oceny zmęczenia. Wydajność chwytu została zmierzona za pomocą maksymalnego statycznego uniesienia (MSL) na początku i po RT.

Wyniki. W obu protokołach MNR zmniejszał się znacząco w czasie, bez znaczącej interakcji protokół × zestaw ($p > 0,05$). RPE wzrastał z czasem, bez interakcji protokół × zestaw ($p > 0,05$). Oba protokoły spowodowały zmniejszenie MSL ($p < 0,001$), bez różnicy w wielkości ($p > 0,05$). Całkowita objętość treningu, średnie RPE i postrzegane obciążenie sesji (średnie RPE × czas trwania sesji) nie różniły się między protokołami ($p > 0,05$).

Wnioski. Kolejność ćwiczeń w krótkich, pełnych programach RT nie miała znaczącego wpływu na wydajność powtórzeń lub postrzeganie zmęczenia u badanych sportowców. Wytrzymałość chwytu była poważnie obniżona po RT, niezależnie od kolejności ćwiczeń. Grapplerzy wykonujący jednoczesny trening tego samego dnia powinni pamiętać o bezpośrednim wpływie RT na zdolność chwytania.