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EFFECT OF TRAINING HISTORY ON THE NUMBER OF SQUAT REPETITIONS AT MAXIMAL INTENDED VELOCITY UNDER VARYING LOADS

UČINEK TRENIRANOSTI NA ŠTEVILO HITRO IZVEDENIH POČEPOV PRI RAZLIČNIH VELIKOSTIH BREMENA

ABSTRACT

The aim of this study was to compare the number of maximal intended velocity (MIV) barbell squat repetitions performed at different loads (40%, 60%, and 80% 1RM) to a 10% velocity loss threshold between physical education students (n = 26) with endurance- (E-group) and resistance-training (R-group) backgrounds. Mixed-model ANOVA results indicated a significant interaction between load levels and training groups ($p < 0.05$, $\eta^2 = 0.162$) in number of repetitions performed. In the E-group, the number of repetitions decreased as load magnitude increased (10, 6 and 5 at 40%, 60% and 80% 1RM, respectively). Differences between groups were observed only at the 40% 1RM load, where the E-group performed ~50% more repetitions compared to the R-group (10 vs. 5; $p < 0.05$). Training history influences the number of MIV squat repetitions at lower loads. Thus, individual monitoring of repetition velocity is essential to tailor strength and power training programs effectively.

Keywords: Velocity-based training, power, explosive repetitions, velocity-loss threshold, strength

IZVLEČEK

Namen raziskave je bil primerjati število čim hitreje izvedenih počepov v eni seriji do 10 % upada hitrosti izvedbe pri različnih bremenih (40 %, 60 % in 80 % 1RM) med študenti Fakultete za šport (n = 26), ki so se v preteklosti ukvarjali z vzdržljivostnimi športi (E-skupina) ali športi moči (R-skupina). Rezultati analize variance z mešanim načrtom so pokazali statistično značilno interakcijo med bremeni in skupinama ($p < 0,05$, $\eta^2 = 0,162$) v številu izvedenih ponovitev. Pri E-skupini se je število ponovitev zmanjševalo s povečanjem bremena (10, 6 in 5 ponovitev pri 40 %, 60 % in 80 % 1RM). Statistično značilne razlike med skupinama so bile odkrite le pri 40 % 1RM, kjer je E-skupina izvedla približno 50 % več ponovitev kot R-skupina (10 proti 5; $p < 0,05$). Zgodovina trenažnega procesa pomembno vpliva na število hitro izvedenih ponovitev pri nižjih bremenih. Spremljanje hitrosti izvedbe ponovitev na individualni ravni je zato ključno za optimizacijo prilagoditev na vadbo za moč.

Ključne besede: vadba za moč na osnovi hitrosti izvedbe ponovitev, hitra moč, eksplozivnost, upad hitrosti izvedbe, maksimalna moč

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INTRODUCTION

Sports training is a structured process that takes place over a long period of time and aims to improve performance in a specific sport. As a result, the type of sport influences the focus of physical training. For endurance sports, the emphasis is mainly on aerobic processes, which involve sustained low-intensity muscle activity. However, in many other sports, strength and/or power are the key factors. Both the sport itself and the physical training involved play an important role in shaping muscle structure, which in turn affects how muscles function (Hughes et al., 2018).

The training methods we use are largely determined by the specific sport we practice, while the history of muscle development over time influences motor unit (MU) activity (Duchateau et al., 2006; Van Cutsem et al., 1998) and muscle contractile properties (Plotkin et al., 2021; Zierath & Hawley, 2004). The contractile properties can be evaluated by analysing muscle twitch characteristics obtained by electrically-evoked muscle contractions and could also serve as an effective, non-invasive way to estimate muscle fibre composition (Enoka, 2008; Moss, 1991).

In particular, resistance training leads to adaptations in both the muscular and neural systems, resulting in increased strength and power. Muscular adaptations include hypertrophy and possible hyperplasia of slow and fast-twitch fibres and muscle architectural changes (Bandy et al., 1990). Neural adaptations involve improved MU recruitment, higher firing rates, and better synchronization (Bandy et al., 1990; Sale, 1988). These adaptations typically follow a time course where neural changes occur first, followed by muscular adaptations in later phases (Kraemer et al., 1996). Training programs are tailored to specific goals, as adaptations are highly dependent on the type of exercise performed (Gonyea & Sale, 1982; Kraemer et al., 1996).

The impact of training history on the number of repetitions performed to failure across different load levels has been extensively studied (Nuzzo et al., 2024). Research shows that the number of repetitions an individual can perform at a given load can vary significantly from person to person. For example, the maximum repetitions at 70% of 1RM for a weightlifter and a marathon runner can differ by as much as 50% (Iguchi et al., 2010; Richens & Cleather, 2014). This may be a result of differing training histories and the corresponding adaptations in muscle contractile characteristics. As a result, it can be speculated that predefined load levels and fixed repetition counts within a set may not effectively optimize training intensity and volume to align with an individual’s current abilities (González-Badilo & Sánchez-Medina, 2010; Marques, 2017).

In addition to the number of repetitions and sets, the speed of contraction plays a key role in power gains during resistance training (Munn et al., 2005). Training with the intention to lift the load as quickly as possible leads to higher MU discharge rates and more frequent brief interspike intervals (doublet discharges), which may explain the enhanced training response (Behm & Sale, 1993). Therefore, not only the load magnitude and number of repetitions matter, but also the speed at which the lifts are performed (slow, moderate, or fast). This aspect can be controlled by monitoring lifting velocity. With this in mind, a new resistance training approach called velocity-based training (VBT) has emerged. In VBT, any load—regardless of its weight—is lifted with maximum effort, resulting in the maximum velocity of the movement; known as maximum intended velocity (MIV). Studies have shown that training with MIV optimizes neuromuscular adaptations across various age groups and exercises (González-Badillo et al., 2014; Gonzalez-Rothi et al., 2015; Iglesias-Soler et al., 2017; Pareja-Blanco et al., 2014; Rojas et al., 2000; Tøien et al., 2023; Yáñez-García et al., 2022).

We found no existing literature that examines the number of MIV squat repetitions performed with different load levels in athletes from various athletic backgrounds. Therefore, the main objective of our study was to investigate the potential influence of training history on the number of MIV squats performed under different relative load conditions, measured at a 10% velocity loss in a single set. The study aimed to determine how many repetitions could be completed with MIV to a 10% velocity loss threshold across various relative load magnitudes (e.g., 40%, 60%, 80% of 1RM) and to assess whether differences exist between endurance-trained and resistance-trained athletes. Due to muscle contractile adaptations that enhance fatigue resistance and the ability to sustain contractions over longer durations, we hypothesized that athletes with endurance training backgrounds would perform more MIV squat repetitions than resistance-trained participants, regardless of the load level.

METHODS

Study design

Cross-sectional design was used. Participants attended the laboratory once. The protocol consisted of a) electrically-evoked contractions of the quadriceps femoris muscle, b) load-velocity 1RM squat measurement procedure and c) MIV squat repetitions to a 10% velocity loss threshold with three different loading conditions (40, 60 and 80% 1RM) (Figure 1).

Relative loading conditions were selected in the randomized order to exclude any possible inter-load fatigue effects. Before the testing, participants performed a standardized 10-min warm-up procedure. This consisted of two minutes of alternating step-ups on a 25-cm high step (80 repetitions per minute); arm, hip, knee and ankle mobility exercises (10 repetitions each); dynamic stretches of hip flexors, knee extensors, knee flexors and ankle extensors (10 repetitions each); and heel raise, squat, crunches resistance exercises (10 repetitions each). After the general warm-up, each participant performed five maximal squat jumps, counter-movement jumps and jump push-ups. The study was approved by the Ethics Committee of the Faculty of Sport, University of Ljubljana (No. 16:2023) and adhered to the principles of Oviedo Convention and the Declaration of Helsinki.

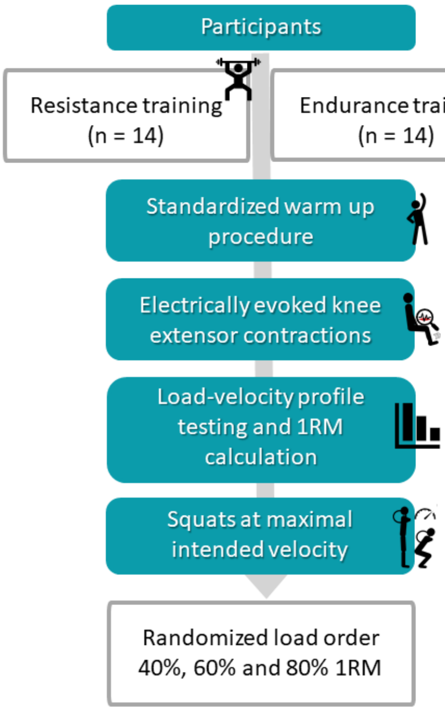


Figure 1. The flow of the testing procedures in the study.

Participants

Twenty-eight physical education students with resistance or endurance training history background were recruited to participate in the study (see Table 1 for details). The inclusion criterion was resistance or endurance training experience defined by a training history that included exercise frequency at least two times per week in the last 5 years and at least 2 times in the past year. The exclusion criteria were: knee injuries (e.g., ligament, meniscus, or cartilage damage), chronic medical conditions (systemic, cardiac, and/or respiratory diseases, and neuromuscular disorders), a history of low back pain, or an acute injury in the past six months that could negatively affect squat performance. The sample size was estimated based on the number of participants recruited in previous studies, analysing different velocity loss thresholds or analysing velocity loss thresholds among different loading conditions (for example: (Weakley, Ramirez-Lopez, et al., 2020) – n = 16; (Pareja-Blanco et al., 2019) – n = 17; (Weakley, Mclaren, et al., 2020) – n = 12; (Pearson et al., 2020) – n = 12). We recruited 14 participants in each training history groups. The adequate sample size was then confirmed by post-hoc statistics power calculation, which was >0.8 for between, within factors and within-between factor interaction. Participants were informed of the possible harmful risks of the experiment and provided written informed consent agreeing to the conditions of the study. They were instructed to avoid any strenuous exercise at least two days before the testing session.

Table 1. Main characteristics of the participants across groups

Group	n	Age (y)	Training history (years)	Height (m)	Body mass (kg)	BMI (kg/m^2)	Training frequency in the past year (/week)
Resistance	14	24.1 (3.2)	9.0 (5.1)	1.82 (9.0)	80.2 (12.2)	24.1 (2.3)	4 (1)
Endurance	14	25.8 (2.9)	11.9 (4.3)	1.79 (10.3)	78.7 (13.8)	24.4 (2.7)	5 (3)
Together	28	24.9 (3.0)	10.4 (4.9)	1.80 (0.10)	79.5 (12.8)	24.3 (2.5)	5 (3)

Notes. Data are mean (SD). Abbreviations: BMI - body mass index; Training history – history of the Resistance/Endurance training in the last five years; Training frequency in the past – frequency of the training sessions per week in the last year in the allocated training history group. Endurance group included four, and resistance group included three women.

Testing procedures

Quadriceps femoris evoked contractions

To determine knee extensor muscles contractile properties, electrically-evoked knee extensions were performed for the preferred push-off leg in isometric knee dynamometer (Figure 2) (S2P, Science to Practice, ltd., Ljubljana, Slovenia) (Šarabon et al., 2013). The knee angle was set to 60° flexion (full knee extension is 0°) and the hip angle to 90° flexion. The flexion-extension knee axis was aligned with the axis of the dynamometer’s lever arm, while the shank was supported at the level two centimetres proximal from the lateral malleolus. Rigid straps tightened over the pelvis ensured good hip fixation. The optimal position for percutaneous electrical stimulation of the femoral nerve and the required intensity were determined while sitting. Stimulation was performed with single square pulses (1 ms) delivered from a constant current stimulator (DS7A; Digitimer, Hertfordshire, UK) to the left femoral nerve via a surface cathode (30 × 24 mm; Kendall, Covidien, Mansfield, TX, USA) manually pressed into the femoral triangle and a 50 × 90 mm anode (Axelgaard Manufacturing Co, LTD, Fallbrook, CA, USA) placed slightly above the gluteal fold. To determine the maximum stimulation intensity individual stimuli were delivered in 30 s intervals gradually at 300 V in 5–10 mA increments until a plateau was reached in the quadriceps twitch torque. Intensity was then increased by 20% to confirm supramaximal stimulation. Twitch was measured two minutes after supramaximal intensity stimulation determination to avoid any post-activation depression response (Xenofondos et al., 2015). Torque signal was captured using the PowerLab system (16/30-ML880/P, ADInstruments) with a sampling frequency of 1000 Hz. Twitch contraction time was defined as the time from the increase of the initial torque above 5% of baseline torque to the time point at the peak twitch torque. Twitch torque signal was recorded and analysed using LabChart8 software (ADInstruments, Bella Vista, Australia). An average of three twitch contraction times was included in the statistical analysis.

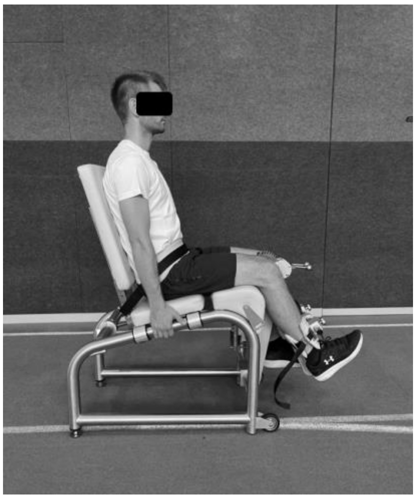


Figure 2. Placement of the participant into isometric dynamometer for electrically-evoked knee extensor contractions test.

Squat one repetition maximum estimation and relative loads calculation

After the quadriceps femoris evoked contractions, participants underwent an incremental loading squat testing procedure to estimate their 1RM based on movement velocity, following the protocols outlined in the literature (Pérez-Castilla et al., 2019). During the squat executions (Figure 3), the average velocity in the propulsive phase of the concentric movement was measured using a linear position transducer (Chronojump, Boscosystem, Barcelona, Spain). The propulsive phase was defined as the portion of the concentric phase in which barbell acceleration exceeded that of gravity. A cable from the linear transducer was attached to the barbell, which rested on the participants' shoulders. Velocity was derived from the recorded displacement-time data using an inverse dynamic approach as defined by the manufacturer's data processing and filtering system software (Software Chronojump 2.3.0-63, Boscosystem, Barcelona, Spain).

Squat execution was determined from the lowest point (approximately 90° knee angle) to full knee extension (approximately 0° knee angle). Participants placed their arms on the barbell, and lifting their heels off the floor was not permitted. The initial loading condition included body mass (BM) plus a 40 kg barbell. Subsequently, an additional 10 kg were progressively added, up to a total of 70 kg. Participants were instructed to lower themselves slowly from a standing position to a crouched position. There, they were required to hold still for two seconds before receiving a start signal from a researcher to lift the barbell as rapidly and forcefully as possible (i.e., at maximal intended velocity [MIV]). The researcher visually inspected the starting position to ensure a 90° knee and hip angle and a stable, non-moving posture. Three MIV squats were performed for each loading condition. Rest periods between squats were 60 seconds, and rests between different loading conditions were three minutes to allow participants to recover adequately and perform maximal squat executions. Researchers provided verbal encouragement during testing.

Subsequently, the velocity-load relationship was calculated. Only the best repetition at each of the four loads, determined by the fastest mean propulsive velocity, was considered for subsequent analysis. A least-square linear regression model was used to establish individualized load-velocity relationships (Pérez-Castilla et al., 2021). Squat 1RM was then calculated as the intercept of the load-axis at the velocity corresponding to 1 RM (i.e., 0.3 m/s), following guidelines from the literature (Weakley et al., 2021). This indirect method of determining 1RM was chosen to minimize the impact of testing-induced fatigue on the final results. Subsequently, 40%, 60%, and 80% of 1RM were calculated and used in the subsequent testing procedures.

Number of repetitions to a 10% velocity loss threshold

After applying a relative load, subjects were given a five-minute recovery period and then completed repetitions of the back squat to a 10% velocity loss threshold, using either 40%, 60%, or 80% of their 1RM. Rest periods between different loading conditions were set at 10 minutes, ensuring that participants had time to recover and maintain maximal squat execution. Furthermore, the loading conditions were applied in a randomized order to eliminate any potential inter-load effects on the final results. The squat execution was defined as the movement from the lowest point, which was approximately a 90° knee angle, to full knee extension, approximately 0° knee angle. Participants placed their arms on the barbell, and lifting their heels from the floor was not allowed. Squats began with subjects in an upright position, knees and hips fully extended, with feet parallel and approximately shoulder-width apart. The barbell rested across the back at the level of the acromion. Participants descended in a continuous motion until they reached approximately 90° knee flexion, as determined by visual inspection from a researcher. At this point, they stabilized themselves in a 90-90° crouch position and then reversed the motion, raising back to the upright position with the intention of extending their legs as forcefully and rapidly as possible. Participants were instructed to follow the beat of a metronome set at 60 beats per minute, with approximately 3 seconds for the eccentric phase and approximately one second for the concentric phase. The tempo was selected during pilot testing. Throughout the testing, participants received verbal encouragement from the researchers. The number of repetitions performed with MIV just before exceeding the 10% velocity loss threshold was recorded for further analysis.

Notes. A linear position transducer pulling wire was mounted perpendicular to the ground and in the direction of the barbell's vertical displacement, laterally to the center of the standing surface of the subject.

Figure 3. Squat testing setup.

Statistical analyses

Differences between group characteristics (mass, height, BMI, muscle twitch contraction time, 1RM and velocities at 40%, 60% and 80% 1RM) were checked using independent samples t-test. Then, a two-way mixed-effects ANOVA (Group [Endurance, Resistance] * Load [40%, 60% and 80% 1RM]) was used to compare the differences in the number of repetitions across the loading conditions and between groups. The assumption of normality distribution of data within subgroups (Groups * Loads) has been violated in 50% of the cases. Nevertheless, we continued with the mixed model repeated measures ANOVA, which is fairly robust for violation of normality within subgroups when group sizes are equal. Equality of variances between groups were confirmed using Levene's test ($p > 0,05$). In the event that the assumption of sphericity was violated (Mauchly's Test of Sphericity < 0,05), the Greenhouse–Geisser correction was applied. The reported effect size (ES) from the univariate model for the comparisons was Partial eta squared (η^2), where the criteria for ES were small (ES = 0,010), medium (ES = 0,059) and large (ES = 0,138) (Kotrlik & Williams, 2003). Statistical analyses were performed in SPSS (Version 28, IBM, Armonk, NY, USA). For all analyses, the level of significance was set at $p < 0.05$.

RESULTS

Using independent samples t-test, we found no statistically significant differences between the two different sport history groups for mass, height, BMI (Table 1) and muscle twitch contraction time, 1RM, 40% 1RM, 60% 1RM, 80% 1RM and average velocity at 40%, 60% and 80% 1RM ($p > 0.05$) (Table 2).

Table 2. Twitch contraction time, one repetition maximum, relative load magnitudes and squat movement velocity results among groups.

Group	Twitch contraction time (ms)	1RM (kg)	40% 1RM (kg)	60% 1RM (kg)	80% 1RM (kg)	*v* 40% 1RM (m/s)	*v* 60% 1RM (m/s)	*v* 80% 1RM (m/s)
Resistance	78.3 (14.6)	162.7 (37.4)	65.1 (22.9)	97.6 (34.4)	130.2 (45.9)	0.87 (0.12)	0.66 (0.11)	0.52 (0.14)
Endurance	75.7 (13.5)	138.2 (34.8)	55.3 (13.9)	82.9 (20.9)	110.6 (27.8)	0.81 (0.11)	0.62 (0.10)	0.47 (0.08)
Together	75.8 (15.0)	150.5 (48.2)	60.2 (19.3)	90.3 (28.9)	120.4 (38.5)	0.84 (0.12)	0.64 (0.11)	0.50 (0.12)

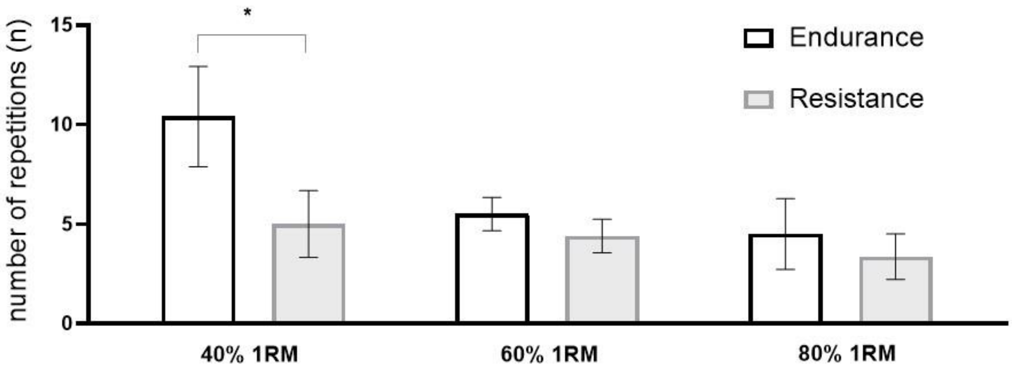
Notes. Data are mean (SD). *v* – average propulsive concentric phase velocity; 1RM - one repetition maximum.

We found a statistically significant interaction between loading conditions (40%, 60% and 80% 1RM) and training history groups (Endurance vs. Resistance) ($p < 0.05$, $\eta^2 = 0.16$) (Table 3). Moreover, statistically significant main effects of Load and Group were observed ($p < 0.05$, η^2 = 0.25-0.33). Pairwise comparisons revealed statistically significant differences in the number of repetitions performed between 40% and 80% 1RM ($p < 0.05$), 40% and 60% 1RM ($p < 0.01$), but not between 60% and 80% 1RM conditions ($p = 0.44$). More specifically, only athletes with endurance training history performed statistically significantly higher number of repetitions to a 10% velocity loss threshold at the 40% 1RM in comparison to 60% and 80% 1RM conditions ($p < 0.01$). Finally, statistically significant difference in number of repetitions performed between both sport history groups was only found at 40% 1RM loading condition ($p < 0.01$) (Figure 4).

Table 3. Differences in the number of repetitions performed between different loading conditions based on training history.

Group	**40% 1RM**	**60% 1RM**	**80% 1RM**	**ANOVA**								
				Main Effect of Load			**Main Effect of Group**			**Load*Group Interaction**		
				F-ratio	***p*-value**	***η²***	**F-ratio**	***p*-value**	***η²***	**F-ratio**	***p*-value**	***η²***
Resistance	5.0 (3.2)	4.4 (1.6)	3.4 (2.2)	12.53	**<0.01**	0.33	8.46	**<0.05**	0.25	5.03	**<0.05**	0.16
Endurance	10.4 (4.9)	5.5 (3.5)	4.5 (3.4)									
Together	7.7 (4.9)	5.0 (2.7)	3.9 (2.9)									

Notes. Data are mean (SD). 1RM – one repetition maximum load; ANOVA - analysis of variance; η^2 - eta squared.



Notes. 1RM – one repetition maximum load. Plots are means and vertical lines are 95% confidence intervals for means.

Figure 4. Differences in the mean number of repetitions performed for each group across different loading conditions and training history.

DISCUSSION

The primary aim of this study was to compare the number of MIV squat repetitions performed at different loads (low - 40% 1RM, moderate - 60% 1RM, high - 80% 1RM) to a 10% velocity loss threshold between athletes with different training backgrounds. We observed a significant interaction between loading conditions and training history groups (endurance vs. resistance) ($p < 0.05$, $\eta^2 = 0.16$). Notably, only athletes with an endurance training background performed fewer repetitions at 40% 1RM compared to 60% and 80% 1RM loads ($p < 0.01$). Additionally, a significant difference in the number of repetitions between the two groups was found only at the 40% 1RM load ($p < 0.01$) (Figure 4), with the endurance group performing approximately 50% more repetitions than the resistance group (10 vs. 5; $p < 0.05$). In line with our hypothesis, endurance-trained athletes completed more repetitions with MIV, but only at the lowest load. This outcome is likely influenced by their training history rather than muscle contractile properties, as no differences in twitch contraction time were observed between the groups.

The specification of training intensity and volume are critical factors in designing effective strength and power training programs. One common approach is to base these specifications on the number of repetitions at a certain percentage of the 1RM, as there is a known correlation between these two variables. However, previous research has questioned the accuracy of this method, as the number of repetitions performed at different percentages of 1RM can vary depending on an athlete's individual characteristics. In our study, which primarily focuses on the power aspect of resistance training, we introduced a new parameter by limiting the number of repetitions to a 10% velocity loss threshold. Consequently, the aim of our study was to evaluate the effects of an athlete's training background on the relationship between the magnitude of the load lifted and the number of repetitions performed until a predetermined velocity loss.

Endurance training typically focuses on enhancing cardiovascular function and aerobic metabolism, while athletes involved in sports games often incorporate some form of resistance training. In our study, participants assigned to the endurance group had not included strength or power training in their training regimens (predominantly runners), whereas those in the resistance group had completed at least two strength or power resistance training sessions per week over the past year. As we expected, we found that the resistance group had an 18% higher 1RM for squats (Table 2). However, we also anticipated that the resistance group would exhibit shorter contraction times compared to the endurance group, indicating greater recruitment of fast MU due to their training history. Contrary to our expectations, we found no significant differences in contraction times between the two groups. According to established literature on exercise physiology, the average contraction times of our two groups (78.3 ± 14 ms for the resistance group and 75.7 ± 13.5 ms for the endurance group) align with fast-twitch fibers (50-80 ms), while contraction times of 100 ms or more are characteristic of slow-twitch fibers (Radak, 2019). Additionally, Hamada et al. (2000) reported an average peak contraction time of 73.5 ± 10.8 ms for a sample of 20 male subjects who trained 3–4 times per week, which is also consistent with our findings. From another perspective, the absence of differences in twitch contraction time between the groups allowed us to conclude that training history, rather than MU characteristics, was the primary factor influencing the decrease in lifting velocity. This suggests that the adaptations resulting from an athlete's training background play a more significant role in performance outcomes than inherent differences in muscle fiber properties.

We observed the most pronounced differences at 40% 1RM, where the average number of repetitions performed to a 10% velocity loss was significantly higher in the endurance group compared to the resistance group. This suggests that certain mechanisms enhanced by endurance training contributed to this difference. It is well-established that skeletal muscle exhibits considerable plasticity based on its use, showing consistent changes in response to various physiological stimuli, including resistance and endurance training (Hoppeler, 1987). While high-load resistance exercise (strength training) leads to neural adaptations and muscle fiber growth—resulting in an increase in contractile proteins, low-load endurance-type exercise induces qualitative changes in muscle tissue. These changes are characterized by an increase in structures that support oxygen supply and consumption, such as capillaries and mitochondria, as well as enhanced enzyme activity and improved aerobic power output (Hoppeler, 2016; Taylor & Bachman, 1999). Such adaptations may enhance muscle endurance and delay fatigue but typically do not significantly impact maximal muscle strength (Grandys et al., 2008). In our study, these adaptations likely resulted in a greater number of repetitions executed when lifting low loads (40% 1RM) among participants engaged in endurance sports. Throughout their training, the endurance group consistently activates and trains smaller, slower MU, making them increasingly efficient over time.

The activation level of MUs could be another factor contributing to the differences observed between the groups. Larger MUs are typically not engaged during endurance training, leading to a generally low level of muscle activation. This adaptation may result in a lower 1RM, as participants are unable to effectively recruit fast-twitch MUs, with slow-twitch MUs primarily contributing to their 1RM. Consequently, the 1RM load (and, by extension, all testing loads) for the endurance may have been underestimated, allowing them to perform more repetitions at a 40% 1RM load. Our findings align with those of Richens & Cleather (2014) who reported similar discrepancies in 1RM evaluations between endurance and resistance-trained participants. They suggested that the endurance group's lack of experience with heavier loads prevented them from achieving the necessary level of arousal to lift maximum weights effectively. Furthermore, when lifting at 40% 1RM, slow MUs contribute more significantly to completing the lift compared to higher loads (60% and 80% 1RM). Since slow MUs are more fatigue-resistant than fast MUs, participants in the endurance group experienced less fatigue than those in the resistance group, enabling them to perform more repetitions. Additionally, the repetitive nature of the lifting task leads to both local muscle fatigue and some degree of cardiovascular fatigue. It is possible that cardiovascular fatigue had a more significant impact during the low-load sets. It could be speculated that endurance group managed these conditions more effectively, enabling them to sustain their performance despite the fatigue.

Recently, Nuzzo et al. (2024) reviewed the maximum number of repetitions at various percentages of the one-repetition maximum and concluded that their findings can serve as a guide for resistance exercise prescriptions for all individuals and for most exercises. Their analysis considered factors such as gender, age, and the specific body part involved, noting that the tables differed for bench press and lower body exercises. However, it is important to highlight that all repetitions observed in their study were performed in hypertrophic mode, and the velocity of the repetitions (tempo) was not controlled. Our study emphasizes that repetition velocity should also be taken into account, as an athlete's training history—whether resistance or endurance-oriented—can influence the number of lifts performed to a predetermined velocity loss, particularly at lower loads. We did not observe any differences at higher loads, likely because the number of repetitions performed at a 10% velocity loss is more dependent on fast motor units, which fatigued at similar rates in both the endurance and resistance trained groups.

Our study has several limitations that should be taken into account. Participants were selected based on their training history in endurance and resistance training, after which we measured the mechanical properties of muscle twitches. Contrary to our initial hypotheses, we found no differences in contraction time. It is possible that the results might have differed if we had first assessed twitch characteristics and then divided the participants into two groups. However, by equalizing these characteristics, we were able to focus exclusively on how history of physical training influenced muscle characteristics. Additionally, the lowering phase from the starting position (eccentric contraction) and the pause in the isometric half-squat position before each repetition (isometric contraction) may have contributed to better tolerance to overall fatigue in the endurance group. This issue could potentially be addressed by supporting the bar (load) in the eccentric and isometric positions before executing the MIV concentric action. However, this approach is impractical and not commonly used in resistance training, which would limit the applicability of our findings. Another limitation of our study is the inconsistent control over the resistance training practices of the participants in the resistance group, as they came from various sports and disciplines (e.g., track and field, team sports). Their resistance training could have been sport-specific, leading to variations in focus on hypertrophy, power, or maximum strength. While our sample size was sufficient for statistical analysis, achieving a power greater than 0.8 for all analyzed variables, the inclusion of participants from various sports and disciplines within the resistance and endurance groups may limit the generalizability of the findings to specific sport populations. Therefore, future studies are warranted to confirm our results in specific sports.

In practice, despite endurance-trained athletes being able to perform more than ten repetitions before a noticeable decrease in lifting velocity when using low loads, such a high number of repetitions performed across several sets could also be counterproductive. A high number of MIV repetitions can lead to metabolic acidosis (Sanchez-Medina & González-Suárez, 2009), which impairs protein synthesis, promotes protein degradation, and hinders mitochondrial function by inhibiting oxidative phosphorylation. Most importantly, it reduces the excitability and recruitment of motor neurons and muscle fibers, leading to a diminished ability to generate force and performance at high intensities (Ho & Abramowitz, 2022; Jubrias et al., 2003) which is essential when training to improve power performance (Behm & Sale, 1993). Additionally, metabolic acidosis activate III and IV afferent fibers, significantly inhibiting alpha and gamma motoneurons, as well as the sympathetic nervous system (Kaufman et al., 2002). It could be speculated that endurance athletes are more tolerant of acidosis-induced fatigue, but considering all the detrimental effects on neural components, we question whether endurance athletes performing low-load exercises for power development should adopt a different velocity loss threshold to avoid negative effects of metabolic acidosis; possibly aiming for a 5% decrease instead of the standard 10%. This adjustment could optimize strength and power training adaptations and enhance performance.

CONCLUSION

To our knowledge, this study is the first to examine the number of repetitions performed at a predefined velocity loss threshold with MIV and to compare these repetitions between resistance-trained and endurance-trained athletes. According to our data, there were no differences in the number of repetitions leading to a noticeable decrease in lifting velocity between athletes with predominantly endurance or resistance-oriented backgrounds when moderate and high loads were applied, resulting in 5 to 7 repetitions. In contrast, when low loads were lifted with MIV, athletes with an endurance-oriented training background were able to complete 50% more repetitions before experiencing a 10% decrease in lifting velocity. This study therefore highlights the importance of tailoring training protocols to individual backgrounds to maximize performance and prevent overtraining. Future practice should prioritize monitoring repetition velocity to optimize strength and power training adaptations at the individual level. Specifically, endurance athletes may benefit from a lower velocity loss threshold (e.g., 5%) to avoid potential counterproductive adaptations associated with performing a higher number of repetitions within a set, which could hinder strength and power development.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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