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Original Article

Comparative analysis of a bench press using strength methods with and without intra-repetition variable resistance

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Abstract
Background: In line with the recommendations for sustainable development, SDG 3 highlights the importance of working on health and well-being. In this respect, strength training has proven to be highly effective. Improved physical performance in most sports is associated with increased maximum dynamic strength. The existing literature on strength training methods is extensive, varied and has a certain tradition in the scientific field. Therefore, the regulation and optimal treatment of the load/stimulus with which one works in the development of strength is a key point. The analysis and study of the variability in loads or training stimuli is essential since it is modified according to the objective of the training and adapted to the circumstances. The aim of this study was to compare the differences measured in average and maximum strength, rate of force development (RFD) and the perception of effort (RPE) between two training methods (constant resistance (CR) vs. intra-repetition variable resistance (IRVR) in a bench press. **Methods:** Due to the methodological difficulties involved in generating an IRVR, fifteen men executed different percentages of one maximum repetition (40%, 60%, 80% and 100%) with CR and IRVR. The percentage to graduate the selected load was 20% of variable resistance. An intra-subject design was used to compare the acute differences between intra-repetition variable resistance and constant resistance. **Results:** The results showed significant differences in IRVR for maximum force at 1RM ($p = 0.001$). A significant decrease in RPE with IRVR was documented for all percentages evaluated ($p = 0.011$). Less accumulated load during execution with IRVR in the first phases of the range of motion (ROM), provides a greater acceleration of the external load, consequently, in the last phase of the concentric extension a faster speed is produced compared to the traditional method with CR ($p = 0.036$). **Conclusion:** IRVR method requires a lower load accumulated in the first phase of the ROM allows more acceleration of the external load and therefore overcome the sticking point with a higher velocity. The constant adaptations in the pattern of strength production during the ROM cause the muscles to stay closer to their best "length-tension" ratio in the concentric phase; therefore, they can generate higher levels of strength. In addition, the results obtained show that the IRVR method requires less perceived effort. For all these reasons, it should be considered an effective method for developing maximum dynamic force, mainly for sub-maximum and maximum loads.
Keywords: variable resistance, strength training, constant resistance, bench press

Introduction

Improved physical performance in most sports is associated with increased maximum dynamic strength (Bragazzi et al., 2020; Thiele et al., 2020). The existing literature on strength training methods is extensive, varied and has a certain tradition in the scientific field (Buckner et al., 2020; Silva et al., 2015). Background studies provide evidence related to the number of repetitions, planning of training cycles, sequencing of the series, treatment of rest and the magnitude of the load (Scott et al., 2016; Simão et al., 2012). Therefore, the regulation and optimal treatment of the load/stimulus with which one works in the development of strength is a key point (Grgic et al., 2018; Nunes et al., 2020; Schoenfeld et al., 2017). The analysis and study of the variability in loads or training stimuli is essential since it is modified according to the objective of the training and adapted to the circumstances (Schoenfeld et al., 2017). Commonly accepted methods for load variation included chains or elastic bands that increase the external resistance during the execution of a repetition (Gerking, 2018; Godwin et al., 2018; Kashiani & Geok, 2020; Swinton et al., 2011). Traditionally this methodology is known as variable resistance; however, the term is not as precise as intra-repetition variable resistance (IRVR) since resistance variability can occur at various times during a workout (between sets, reps and intra reps) (Chirosa Ríos et al., 2014).

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Training with IRVR is a maximum dynamic strength training method where the external resistance increases during the actual execution of the repetition. This variation in intra-repetition loading produces acute and chronic effects on strength development (Anderson et al., 2008; Wallace et al., 2006, 2018). Longitudinal research has been done comparing the effects of IRVR compared to constant resistance (CR), and the results have been controversial (Cronin et al., 2003; Jones, 2014; Shoepe et al., 2011). However, some benefits have been documented. For example, Joy et al., (2016) showed IRVR develops a higher rate of power and Ariel (1976) demonstrated a significant increase in strength after IRVR but not CR training. Additionally, Anderson et al., (2008) showed significant improvements in 1 repetition-maximum (RM) for both the bench press exercise and squat for groups trained with IRVR over traditional ones. This study was conducted with trained athletes who, at the end of the training period, did not experience an increase in muscle cross-section, suggesting that there were improvements at the neural level caused by this new stimulus or form of training. These adaptations to IRVR can cause the muscle to be stimulated in a different way than usual, thus producing an improvement at the neural level, which ultimately translates into the production of greater maximum strength (Anderson et al., 2008; Bellar et al., 2011; Cronin et al., 2003; Ghigiarelliet al., 2009; McCurdy et al., 2009; Rhea et al., 2009; Shoepe et al., 2011). The acute effect of IRVR has been evaluated in different actions such as squat (Andersen et al., 2016; Cronin et al., 2003; Ebben & Jensen, 2002; Israetel et al., 2010; Mina et al., 2014; Newton et al., 2002; Saeterbakken et al., 2016; Stevenson et al., 2010), snatch (Coker et al., 2006), or deadlift (Galpin et al., 2015; Swinton et al., 2011), However, the acute effect of IRVR on bench press has not been specially studied (Baker & Newton, 2009). There are contradictory results regarding its effectiveness (Wallace et al., 2018). This controversy may be partly caused by the lack of standardization of the methodology related to IRVR (Chirosa Ríos et al., 2014; Frost et al., 2010; Soria-Gila et al., 2015; Wallace et al., 2018). In this methodological standardization, two essential aspects must be considered (Baena-Morales, 2016). On the one hand, the use of different methods to induce load variation, especially elastic bands and chains, produce different tension curves during ROM (Mcmaster et al., 2009; McMaster et al., 2010). The elastic bands generate a higher tension at the end of the gesture, and yet the chains are linear during the complete execution (Baena-Morales, 2016; McMaster et al., 2010; Wilson & Kritz, 2014). Furthermore, the different behavior at the eccentric and concentric levels could explain the higher generation of maximum strength with IRVR. The main difference leads to a reduction of the time under tension in the eccentric phase and an increase of the time under tension in the whole range of concentric motion. About this idea, Wallace et al., (2018) highlights how IRVR produces a higher proportion of overload in the activated muscles, generating a higher production of torque at the maximum peak strength. In addition to the element that causes IRVR, different percentages of IRVR have been used to evaluate it. Previous studies have analyzed IRVR percentages of 5% (Berning et al., 2008; Coker et al., 2006), 10% (Ebben & Jensen, 2002) 20% (Stevenson et al., 2010; Swinton et al., 2011; Wallace et al., 2006), 35% (Galpin et al., 2015; Mina et al., 2014; Wallace et al., 2006) and even, unspecified percentages (Cronin et al., 2003; Newton et al., 2002; Saeterbakken et al., 2016). Consequently, we consider the main error is comparing the variable method with a similar load to the CR methods when the load will only be similar in the maximum extension between both methods. Thus, it is necessary to measure the performance of the strength without considering that IRVR and CR work with the same weight. The reason for this is that, during the execution of the concentric ROM, only at the end of the maximum extension, the external load coincides between the two methods. Therefore, one of the problems detected when implementing protocols with IRVR is the loss of control in the load that is caused by the variability of the load (Chirosa Ríos et al., 2014). This is because, to accurately compare the same percentage of load with constant weight and IRVR, the relative accumulated load applied during ROM will not be similar. In the case of a constant load during the entire ROM, the same weight will be used. However, with IRVR, the load will vary during the ROM and thus, the accumulated load during the movement will not be similar. Consequently, these methods cannot be considered as working with the same load, and therefore the force registers will be different. When we evaluate with encoders or force platforms to measure kinetic variables or strength records, we need to record a reference load, usually expressed in the unit of weight (kilograms or pounds). In the case of CR, this load is the weight that the subject will move. However, when the reference is with IRVR, it would be wrong to establish that same load, since it will only be reached in maximum extension. Therefore, the aim of this study was to compare the differences measured in average and maximum strength, rate of force development (RFD) and the perception of effort (RPE) between two training methods CR vs IRVR in a bench press. We hypothesize that due to the lower load accumulated in the first phases of the ROM during execution with IRVR, a greater acceleration of the load will be produced, which will result in a higher registration of maximum dynamic strength with the IRVR method.

Materials & Methods

Experimental approach to the problem An intra-subject research design was used in two situations with repeated measurements to accurately compare strength produced in two strength training methods, with CR and IRVR. Subjects attended the laboratory on three occasions, which included a familiarization session, and two 1RM measurements separated by 72 hours of rest. Subjects were instructed to avoid any fatiguing activity for at least 48 hours before each session.

Subjects

Fifteen healthy males (age = 22 ± 0.44 years, height =179.13 ± 1.75 cm, weight = 75.85 ± 1.51 kg, body-mass index = 23, 64 ± 0.34 kg·m2, fat = 9.05 ± 0.39 %, muscle mass = 50.10 ± 0.40 %) volunteered to participate in the study. All subjects were physically active sport science students (4.0 ± 1.8 years of resistance training experience). The subjects were familiar with weight training and a daily sports routine. Before the investigation, the subjects passed certain selection criteria, such as being male, having at least two years of strength training experience. All participants were informed about the study procedures and signed a written informed consent before the initiation of the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of University of Granada (ref:417).

Experimental Tests: Analysis of the Variables Described in Different Percentages of 1RM Loads

Once the personal 1RM was known for each subject participating in the study, in another session one week later, the experimental tests were carried out with specific percentages of load referring to the 1RM. The reference percentages used to measure the variables described in the study were 40%, 60%, 80% and 100% of the 1RM. For each percentage, a series was standardized with certain repetitions and rest between series. Before the test, the subjects underwent a warm-up similar to that performed in the incremental test. For each repetition, the previously established grips were exhaustively respected. In each of these percentages, the variables studied in this research were measured. The total weight of the bar without the disc was 17.5, so 1.25 kg small dumbbell was attached to each end of the bar to complete the 20 kg reference in the initial load (Figure 1).

Figure 1. Stable platform to transfer the strengths generated in the bench press against the force platform.

The second session consisted of a randomized intrasubject design with repeated measurements in which the differences in the execution of a bench press with the traditional method and with IRVR on different variables of strength (maximum strength, average strength and RFD) and perception (RPE) were compared at a descriptive and inferential level. In turn, all these variables were evaluated and compared on different percentages of execution (40%, 60%, 80% and 100% of 1RM). The percentage to graduate the selected load was 20% of variable resistance. For the measurement of the different variables, a force platform (Kistler, Instrumentation, Winterthur, Switzerland) and the subjective perception scale of the strength (OMNI-RES) were used.

Quantification and individualization of IRVR

To have greater control, the protocol divides the ROM in at least five parts, and thus estimates the behavior of the relative accumulated load with more precision. This implies that, although the weight in maximum extension will always be the same with CR and IRVR, the accumulated load that has been moved during the repetition is not the same (Table 1).

Table 1. Comparison in the relative accumulated load between constant resistance and IRVR with an 80 PCR and 20 PRV in 100 kg for a range of movement of 50 centimeters

ROM	CR	Intra-Repetition Variable Resistance		
	100 (kg)	PRV (20%)	PCR (80%)	Average load (kg)
0-10 cm.	100	0-5	80	82,5
10-20 cm.	100	5-10	80	87,5
20-30 cm.	100	10-15	80	92,5
30-40 cm.	100	15-20	80	97,5
40-50 cm.	100	20	80	100
ALDR	100 (kg)			92 (kg)

PRV, Percentage of variable resistance; CR Constant resistance; PCR Percentage of constant resistance; ALDR, Average load during repetition = Sum of all ROMs divided by the total number of ROMs

A multi-stage process was standardized. In the first phase, chains were used to generate the IRVR, because the quantification of the load inherent to the chain is more stable and simpler. Steel chains were weighed and measured to ensure accuracy in the resistance. The links of the chain were 16 mm thick, which caused an increase in load of 12 kg per 120 cm. Phase two individualized the ROM and divided it into five parts to establish a proportional and linear increase along with the ROM of 20% of the IRVR load. In this phase, small weights were added to the chain. Finally, in the third phase, the set of chains and bar were weighed in the maximum concentric extension to confirm that both methods (IRVR and CR) were similar.

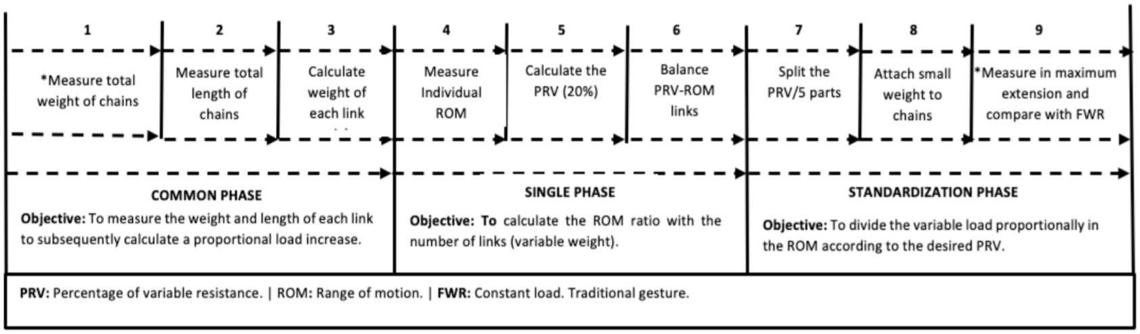

Figure 2. Individualization process of the IRVR for the precise quantification of the workload

Statistical Analyses

Descriptive data are presented as means and standard deviations. The Wilcoxon signed-ranks test was conducted to determine the differences between the strength registers of both methods (CR vs IRVR). The second test consisted of a contrast statistic of the sign test, where through a binomial distribution, we tried to confirm at a qualitative level the possible significant differences detected in the first test. Significance was accepted at $P < 0.05$ in both tests. The statistical analyses were performed using the software package SPSS (IBM SPSS version 22.0, Chicago, IL, USA).

Results

Maximum levels of muscle strength are developed through the IRVR (Table 2). For the maximum strength, there were significant differences in favor of the IRVR method in the percentage 100% ($p = 0.001$). In the case of the RFD, there are differences for all the percentages analyzed: 40% ($p = 0.008$), 60% ($p = 0.005$), 80% ($p = 0.005$) and 100% ($p = 0.036$).

On the other hand, there were significant differences in the average strength when performed with the CR method for the selected percentages of 40% ($p = 0.008$) 60% ($p = 0.005$) and 80% ($p = 0.005$) Finally, no differences appeared for the average strength when working at 100% 1RM, nor for the maximum strength at 40%, 60% and 80% (Table 3).

Table 2. Strength, RFD and RPE of the methods analyzed for a bench press.

Variables	Intensity relative to a percentage of 1RM			
Strength	*40%*	*60%*	*80%*	*100%*
IRVR	658.48 ± 152.32	762.55 ± 158.21	893.74 ± 206.03	996.97 ± 202.67
CR	577.58 ± 122.45	708.28 ± 157.03	825 ± 71.79	880 ± 169.32
IRVR	323.16 ± 57.31	451.02 ± 91.48	564.14 ± 107.81	766.49 ± 144.28
CR	294.58 ± 67.17	465.93 ± 104.34	613.07 ± 138.85	751.93 ± 185.64
IRVR	4606 ± 1104.30	3610 ± 1221.71	2798 ± 1336.15	1528 ± 1073.40
CR	3358 ± 1184.51	2120 ± 1161.40	1584 ±1049.33	735 ± 694.01
Psychological	40%	60%	80%	100%
IRVR	1.30 ± 0.46	3.17 ± 0.98	6.27 ± 0.75	8.57 ± 0.46
CR	2.26 ± 0.56	4.56 ± 0.96	7.03 ± 0.93	9.39 ± 0.59

IRVR, Intra-Repetition Variable Resistance; CR Constant resistance

Table 3. Wilcoxon signed-rank test and contrast statistics to measure the significant difference between the CR and IRVR.

		Intensity relative to a percentage of 1RM			
		40%	60%	80%	100%
Maximum strength	*Wilcoxon*	0.910	0.156	0.088	**0.001***
	Contrast	0.607	0.607	0.607	**0.000***
Average strength	*Wilcoxon*	**0.008***	**0.005***	**0.005***	0.115
	Contrast	**0.035***	**0.035***	**0.001***	0.856
Rate force development	*Wilcoxon*	**0.008***	**0.005***	**0.005***	**0.036***
	Contrast	**0.035***	**0.035***	**0.001***	**0.035***
Rated perceived exertion	*Wilcoxon*	**0.004***	**0.001***	**0.024***	**0.011***
	Contrast	**0.003***	**0.000***	**0.065***	**0.012***

The number in bold indicates significant differences. *$p < 0.05$

Discussion

This study was designed to compare the differences measured in average and maximum strength, rate of force development (RFD) and the perception of effort (RPE) between two training methods CR vs IRVR in a bench press. The main findings in this study are that the IRVR method, despite having a lower cumulative load during the execution of the concentric ROM, produces a higher maximum dynamic force than in 80% and 100% of the 1RM and lower subjective perception of the effort. Our hypothesis was confirmed since the lower accumulated load in the first phases of the ROM with IRVR generates a greater acceleration of the load, which means higher production of the maximum dynamic strength with sub-maximum loads. These results indicate that the effect of varying the load during the repetition itself could be an optimal method of training maximum dynamic strength when working with maximum and sub-maximum loads. The importance of knowing the performance of the strength at different intensities of these methods will allow a more in-depth understanding of the acute effects of IRVR.

Load percentages close to 1RM executed with IRVR produce a higher maximum dynamic strength generation than similar loads with constant resistance. These results coincide with other investigations carried out in bench presses, where IRVR develops a higher concentric peak of force (Baker & Newton, 2009). Other research that evaluated the acute effect, using the same percentage as our research (80%), obtained a higher level of strength, power, and muscle activity with IRVR in early eccentric and late concentric phases (Israetel et al., 2010).

Our results for maximum strength, show significant differences ($p = 0.01$) from IRVR methods in execution 1RM, even though the accumulated load during repetition is lower. Also, though there are no significant differences for the other percentages, they have higher maximum strength values in the IRVR method. These results coincide in part with those presented in other descriptive research (Newton et al., 2002; Stevenson et al., 2010; Swinton et al., 2011). Additionally, our results are similar to other study where the group that performed the squat with IRVR obtained significantly greater differences during the first 25% of the eccentric phase and the last 10% of the concentric phase. Also, more accentuated neuromuscular adaptations were registered along with greater recruitment of type II fibers in training with IRVR (Anderson et al., 2008).

IRVR methods seem to obtain more significant differences in high loads (Wallace et al., 2018). Several reasons could explain these significant differences. Firstly, IRVR allows the sticking point to be passed at a higher velocity (Chirosa Ríos et al., 2014) and allows greater initial acceleration to the load, which leads to increased muscle recruitment (Mcmaster et al., 2009). The initial load is lower with IRVR so that the start of the gesture is softened. At the same time, during the stretch-shortening cycle, this means an increase in velocity and levels of strength and power during repetition in its concentric phase (Baker & Newton, 2009; Galpin et al., 2015; Mcmaster et al., 2009; Rhea et al., 2009).

Second, the relationship between length and stress manifests itself differently in IRVR methods compared to CR, as a result of the adhesion of a rubber band or a chain (McMaster et al., 2010; Wallace et al., 2018). This could cause an increase in stress at specific joint angles where the production of strength is more advantageous (Elliott et al., 1989) Also, Bellar et al., (2011) note that if a variable resistance produces this added stress, it will result in a change in the pattern of strength production during execution. Also, there is an increase in muscle tension in the biomechanically more favorable areas of the ROM, accompanied by a decrease in external resistance at the sticking point (Elliott et al., 1989). Therefore, as Wallace et al., (2006) commented, muscles will stay closer to their best "length-tension" ratio in the concentric phase and therefore have a greater capacity to generate higher records in maximum strength. This would allow a greater load to be overcome in the last part of the concentric extension, an aspect which is directly related to the joint kinematics in the production of strength (Shoepe et al., 2011). As a result, there will be a higher velocity in the stretch-shorten cycle and therefore, when faced with the same load (IRVR = CR), higher production of maximum strength (Baker & Newton, 2009), a 5% higher strength rate at the beginning of the concentric phase and end of the eccentric for the group that did not use IRVR (Israetel et al., 2010).

Therefore, IRVR methods seem to cause a higher acceleration in the eccentric phase, mainly causing a higher velocity in the last part of the eccentric phase. These results are in line with those obtained by other studies (Israetel et al., 2010; Swinton et al., 2011; Wallace et al., 2006) where significant differences were found in the strength and kinetic values analyzed in favor of IRVR methods. At the same time, the fact that the deceleration phase with IRVR decreases, leading to a higher amount of time near the maximum velocity, stands out as an indicator that the muscles work at maximum capacity for longer (Wallace et al., 2018).

Thirdly, IRVR methods seem to indicate different records in muscle activation than traditional methods with constant resistance (Andersen et al., 2016). IRVR methods imply a continuous correction of the external load, so the muscles involved are encouraged to perform a greater muscle activation during the entire ROM (Baker & Newton, 2009). In turn, IRVR methods seem to provide greater muscle activation throughout the repetition, creating higher muscle demand and greater strength production at the end of the repetition (Coker et al., 2006; Mcmaster et al., 2009). In the study conducted by Ghigiarelliet al., (2009) significant increases in strength were observed in the group that trained with IRVR compared to traditional training. At the same time, it appears that when using IRVR methods in the eccentric phase, there will also be different muscle demands and activation than when working exclusively with CR. This muscle demand will be higher in the first third of the eccentric phase, mainly during the first 10% because the elastic tension of the bands or the sum of strengths produced by the adhesion of chains occurs when the greatest amount of resistance is produced (Anderson et al., 2008).

Finally, concerning RFD, the results show significant differences ($p \leq 0{,}01$) for all the percentages analyzed. This difference denotes a higher RFD for IRVR methods concerning traditional constant resistance methods. The studies evaluated to date support that RFD can be improved through IRVR training using IRVR (Anderson et al., 2008; Cronin et al., 2003; Ebben & Jensen, 2002; Ghigiarelliet al., 2009). The data obtained in previous studies that analyzed RFD among its variables show contradictory results mainly due to differences when setting up the IRVR. Some studies share results with those obtained by this research (Baker & Newton, 2009; Israetel et al., 2010; Stevenson et al., 2010). In contradiction to these results, some studies do not find significant differences (Wallace et al., 2006) and even differences in favor of methods with constant resistance (Swinton et al., 2011). From this data, we could conclude that, by optimizing the stretching-shortening cycle phase, IRVR methods produce greater activation due to higher storage of elastic energy in their muscles, which in turn translates into greater RFD (Rhea et al., 2009). Wallace et al. (Wallace et al., 2006) suggested that RFD could be increased as a result of the phase in which peak velocity is reached with IRVR training because resistance increases as the mechanical advantage increases since the athlete is theoretically able to generate the highest levels of strength during the concentric (van den Tillaar & Ettema, 2010).

The main limitation of the current study was the indirect determination of 1RM strength. We know that the subjects were used to training with high weights, but the direct method for calculating the 1RM in the bench press is not sufficiently precise (Ritti-Dias et al., 2011) In addition, the incremental protocol may produce muscle damage. An attempt was made to overcome this problem by leaving enough rest time between measurements.

Conclusions

To summarize, the lower load accumulated in the first phase of the ROM allows more acceleration of the external load and therefore overcome the sticking point with a higher velocity. The constant adaptations in the pattern of strength production during the ROM cause the muscles to stay closer to their best "length-tension" ratio in the concentric phase; therefore, they can generate higher levels of strength. Consequently, working with loads over 80% using the IRVR method permits generating higher levels of maximum force than the CR method. The individualization protocol used in this study is effective in ensuring a linear load increase throughout the ROM. This protocol allows greater control in the distribution of the load in the evaluated methods, assuring similar work in the last fifth part of the ROM. Additionally, the IRVR proposed in this study (20%) seems to be sufficient to cause an acute differentiating effect with CR. Future studies should investigate the differences between the 1RM with CR and IRVR. It is possible to formulate hypotheses that support the idea that with IRVR, a new supra-maximal RM could be established, given that it allows the last concentric phase of the ROM to be reached at a higher velocity and therefore exceed 1RM.

The IRVR method can be used as an efficient training tool to develop maximum dynamic strength. Additionally, it is assumed that this method implies less joint damage as a result of less accumulated load during repetition, concretely at the moment with the greatest biomechanical disadvantage. Therefore, IRVR could be an ideal training method in phases before maximum strength exercise or untrained subjects. Also, the standardization protocol presented in this study will allow a more controlled quantification of external load behavior with the IRVR method. Therefore, future research may consider this protocol to improve the methodological problems previously documented partially.

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