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# Time under tension and mechanical variables in the bench press exercise at different rest intervals
# Tiempo bajo tensión y variables mecánicas en el ejercicio de press de banca con diferentes intervalos de descanso

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**Abstract.** Purpose: To analyze the behavior of time under tension (TUT), total work (TW), power (PW), mean velocity (MV), and number of repetitions (NR) during the bench press exercise with distinct rest intervals. Methods: Twenty-one wrestling athletes (body mass: 81.27 ± 14.25kg; height: 1.74 ± 0.07m) completed 5 sets, each consisting of a maximum of 10 repetitions, with either a 1-minute rest interval (RI1) or a 3-minute rest interval (RI3). Results: TUT was higher in RI3 when compared to RI1 in set 5 (p<0.001). NR was higher in RI3 compared to RI1 in set 3 (p=0.016), set 4 (p=0.021), and set 5 (p<0.001). TW was higher in RI3 compared to RI1 in set 3 (p=0.005), set 4 (p=0.007), and set 5 (p<0.001). MV was higher in RI3 compared to RI1 in set 4 (p=0.029) and set 5 (p<0.001). PW was higher in RI3 compared to RI1 in set 4 (p=0.044) and set 5 (p<0.001). Conclusion: The behavior of consecutive sets with a similar number of repetitions but with an increase in TUT or sets with a similar TUT but with a lower number of repetitions were found. Third set appears to be a point of performance reduction worth considering depending on the exercise's goal.
**Keywords:** time under tension; number of repetitions; bench press; rest interval between sets; mechanical variables.

**Resumen.** Objetivo: Analizar el comportamiento del tiempo bajo tensión (TBT), trabajo total (TT), potencia (PO), velocidad media (VM) y número de repeticiones (NR) durante el ejercicio de press de banca con distintos intervalos de descanso. Métodos: Veintiún atletas de *wrestling* (masa corporal: 81.27 ± 14.25 kg; altura: 1.74 ± 0.07 m) completaron 5 series, cada una consistente en un máximo de 10 repeticiones, con un intervalo de descanso de 1 minuto (RI1) o un intervalo de descanso de 3 minutos (RI3). Resultados: El TBT fue mayor en RI3 en comparación con RI1 en la serie 5 (p<0.001). El NR fue mayor en RI3 en comparación con RI1 en la serie 3 (p=0.016), serie 4 (p=0.021) y serie 5 (p<0.001). El TT fue mayor en RI3 en comparación con RI1 en la serie 3 (p=0.005), serie 4 (p=0.007) y serie 5 (p<0.001). La VM fue mayor en RI3 en comparación con RI1 en la serie 4 (p=0.029) y serie 5 (p<0.001). La PO fue mayor en RI3 en comparación con RI1 en la serie 4 (p=0.044) y serie 5 (p<0.001). Conclusión: Se encontró un comportamiento de series consecutivas con un número similar de repeticiones, pero con un aumento en el TBT o series con un TBT similar, pero con un menor número de repeticiones. La tercera serie parece ser un punto de reducción del rendimiento que vale la pena considerar según el objetivo del ejercicio.
**Palabras clave:** tiempo bajo tensión; número de repeticiones; press de banca; intervalo de descanso entre series; variables mecánicas.

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## Introduction

Resistance training (RT) is a modality of physical exercise that can improve the capacity of force production and increase the amount of muscle mass (cross-sectional area) of practitioners (Evans, 2019). This modality is practiced by individuals who want to improve the ability to perform activities of daily living (Silva et al., 2018), control health conditions, such as cardiometabolic and musculoskeletal responses, and improve mental health (Bennie et al., 2018). Moreover, RT is also practiced with the aim of improving the performance of athletes in team sports (Nour-Frías; Fernández-Ozcorta; Ramos-Véliz, 2024), or individual sports (Costa et al., 2024), such as wrestling. Athletes in this sport may have their performance influenced by, among other attributes, strength and power production capacity, resulting from RT practice (Francino et al., 2022; Cid-Calfucura et al., 2023).

For an effective RT prescription, it is necessary to manipulate training variables, such as intensity, number of sets and repetitions (volume), selection and order of exercises, rest interval, and movement velocity (Grgic et al., 2018). The manipulation of these variables contributes to the possibility of achieving the intended physiological adaptations (Kneffel et al., 2021). The combination of the load imposed by RT with the volume is recognized as the necessary stimulus to promote adaptations. However, this combination needs to be monitored and quantified (Scott et al., 2016).

One of the ways to quantify the stimulus performed by RT is to calculate the total work performed, which is a way to quantify the mechanical stimulus performed during a training session. This method considers the force exerted by the individual from the mass of the implement and the displacement that this implement performs (McBride et al., 2009). Furthermore, the velocity at which the implement moves is a variable to be analyzed in the context of RT monitoring, due to its inverse relationship with the overload used, which affects the power production at the moment of the exercise (Balsalobre-Fernández & Kipp, 2021).

In addition to these variables, the execution time of the movement, known as time under tension (TUT), has been studied. TUT has an inverse relationship with velocity (Maszczyk et al., 2020). TUT can be controlled by different cadences for certain phases of the movement (Silva et al., 2023). This can modify post-exercise adaptive responses according to the number of repetitions performed (Wilk et al., 2018).

Another variable related to RT is the rest interval (RI) between sets, which can exert influence over the intensity and volume of training. The RI directly affects the performance of the number of repetitions of the sets to be performed after rest (Maia et al., 2015). In RT sessions, shorter intervals between sets demonstrate greater metabolic, hormonal, and cardiovascular responses (Tibana et al., 2013).

In this sense, an RT program can be prescribed in different ways to potentiate the muscular response. The RT can be based on percentages of the value of one repetition maximum (1RM), with the 1RM test measured before the training session. Also, can be prescribed by multiple repetition ranges with the adjustment of the overload per session or based on the classification of the rating of perceived exertion employed during the performance of the training session (Banyard et al., 2019). The use of different TUT is important for mechanobiological adaptations due to the variation of metabolic responses, recruitment, and firing frequency of motor units. Thus, the behavior of the TUT should be considered when prescribing the training program (Borde; Hortobágyi & Granacher, 2015).

The behavior of TUT, associated with the behavior of other variables and under different conditions, is not yet fully understood for its utilization, both in prescription and in the control and monitoring of RT. Therefore, the present study aimed to analyze the behavior of TUT, total work, power, mean velocity, and number of repetitions in the performance of the bench press exercise with distinct rest intervals. We hypothesize that with the same overload and a fixed rest interval between sets, the number of repetitions across sets will decrease due to the cumulative effect of fatigue. However, this behavior will not be accompanied by a reduction in TUT across sets due to its inverse relationship with the movement velocity. Thus, the power and mean velocity data of each set may more clearly show this relationship. Furthermore, we believe that TUT will present associations with other forms of quantification of training volume, such as the total work performed. This would enable the use of TUT for such a purpose.

## Materials and methods

### *Study design and ethical aspects*

This original descriptive study was approved by the local institutional Ethics Committee for human experiments under the number CAAE: 61911215.3.0000.5259 and followed the ethical standards in Resolution 466/12 of the Brazilian National Health Council. All participants signed an informed consent (Thomas; Nelson & Silverman, 2012).

### *Participants*

The sample consisted of high-performance wrestling athletes from a training center in Rio de Janeiro, Brazil. We included wrestling athletes experienced in RT with the practice of the bench press exercise for at least 6 months, with a minimum training frequency of twice a week. Exclusion criteria were: a) any sign of pain or disorder that could alter the test performance or put the individual at risk; b) to answer positively to at least one question of the Physical Activity Readiness Questionnaire (PAR-Q) (Thomas; Reading & Shephard, 1992).

### *Sample size calculation*

The determination of the required sample size was performed using G*power software, version 3.1.9.4 (Faul et al., 2007). The input data given to the software included: ANOVA with effect size = 0.25, alpha = 0.05, power = 0.80, number of measures = 5, and correlation between measures = 0.5. The power analysis indicated a sample size of 22 individuals. The initial collection was performed with 24 individuals (~10% more) due to the possibility of sample loss during the study (Beck, 2013). Three individuals did not participate in all visits and were discarded from the study. Thus, the final sample was composed of 21 participants.

### *Procedures*

The procedures were split into three separate appointments. During the initial appointment, participants provided informed consent and completed the PAR-Q questionnaire. Following that, they underwent anthropometric measurements for sample characterization and executed the 10-repetition maximal (10RM) bench press exercise test to determine the overload level to be applied during the subsequent visits. In the second and third visits, the participants performed the study intervention.

### *Anthropometric data*

The collection of total body mass and height were performed using a mechanical scale with a stadiometer (Filizola® PL – 150 n° 8346/97, São Paulo, Brazil) and the armspan was collected using a flexible anthropometric tape (CESCORF, Brazil). An experienced evaluator (ICC > 0.92) performed the measurements of all study subjects (Marfell-Jones; Stewart & Ridder, 2012).

### *10-repetition maximum test*

The 10RM test was performed in the bench press exercise. The warm-up consisted of a set of 15 repetitions with 40% of the estimated overload and a set of 12 repetitions with 50% of the estimated overload, separated by 1 minute of passive rest interval. After the warm-up, a 3-minute rest interval was determined for the first attempt of the 10RM test. The test allows up to three attempts to reach the final overload value, with 5 minutes of rest interval between attempts. If at the end of the three trials, it was not possible to determine the overload for 10RM, the test would be performed again 48 hours apart. The final overload was recorded according to the maximum value obtained in the performance of 10RM, with the unsuccessful attempt of the eleventh repetition (Baechle & Earle, 2000).

### *Intervention*

During the second visit, 48 hours following the 10RM test, the athletes underwent the intervention in the bench press exercise. The intervention consisted of 5 sets of up to 10 repetitions with the value obtained in the 10RM test, under conditions of 1-minute (RI1) or 3 (RI3) minutes of the rest interval. The first set performed by everyone on each visit needed to necessarily have 10 maximum repetitions to validate the previously conducted 10RM test. If this did not occur, a new 10RM test was scheduled to confirm the overload to be used. The entry of the individuals occurred in a randomized manner (random function; Microsoft Excel version 2211, USA). After 48 hours from the second visit, the third visit was conducted, during which the intervention was repeated, however, a different rest interval between sets was implemented compared to the one used in the second visit. Figure 1 shows the flow followed for the data collection of the study.


Figure 1. Data collection flow.

The pattern of the bench press exercise was as follows: the individual started in the supine position on the bench without inclination, with the knees flexed, feet on the floor, and head and hip in contact with the bench during the entire execution of the movement. The movement began with the removal of the bar from the support and maintenance of the elbows in full extension with the bar in the direction of the pectoral. In the eccentric phase, the individuals performed elbow flexion and shoulder abduction until the bar touched the lateral elastic band placed to control the range of motion at 90° of the elbows. In the concentric phase, the individuals performed the opposite movement at the highest possible velocity until returning to the initial position. The whole movement was performed at the highest possible velocity. Two trained instructors were positioned on each side of the bar to ensure safety in possible concentric failures (Padulo et al., 2015).

### *Mechanical variables*

The data on power, total work, and mean velocity were collected by using the Iload application. This application combines information like execution time, overload (10RM), distance (collected from the measurement, in meters, of the space traveled by the bar between the amplitude limiters) and number of repetitions (entered at the end of the performed set) to calculate the data in real time of a exercise's set. (Pérez-Castilla; Boullosa & García-Ramos, 2021; Sá et al., 2019).

### *Time under tension*

The capture of images to analyze the time under tension (TUT) of each set was performed using retro-reflective markers (Noraxon Inc., USA) with about 19 mm of diameter, placed at the reference points (wrists, elbows, and shoulders) to facilitate accuracy in finding the initial and final moment of each movement. The entire intervention was recorded by a smartphone supported on a tripod, positioned perpendicular and three meters away from the bench support so that it was possible to capture all the movement. The captured images were analyzed by the Kinovea software version 0.8.27, and from the recordings, it was possible to accurately account and register the time under tension of each set. This tool has precision in the angular and linear digital measurements of the X and Y axes (Silva et al., 2017).

### *Statistical analysis*

Data were presented as mean, standard deviation, and minimum and maximum values. The Shapiro-Wilk and Levene tests were used to verify the normality and homogeneity of the data. Factorial analysis of variance (ANOVA) (condition *vs.* sets) was performed, followed by Bonferroni's post-hoc analysis to analyze the possible differences in the TUT variables, total work, power, mean velocity, and number of repetitions throughout the sets under RI1 and RI3 conditions. Pearson's correlation test was performed to analyze the associations between the study variables. A p-value $< 0.05$ was adopted for statistical significance. The analysis of data was carried out utilizing the IBM SPSS Statistics 25 software.

## Results

Table I presents the characterization of the sample with mean, standard deviation, and minimum and maximum values of each variable. Data on age, height, body mass, armspan, overload used, and distance between the initial and final position that the bar covered were collected.

Table I.
Characteristics of the sample, overload used, and distance covered by the bar. (n = 21).

| Variables | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Age (years) | 23.42 | 5.05 | 19 | 35 |
| Body mass (kg) | 81.27 | 14.25 | 58.1 | 111.7 |
| Height (m) | 1.74 | 0.07 | 1.56 | 1.83 |
| Armspan (m) | 1.79 | 0.07 | 1.64 | 1.9 |
| 10RM overload (kg) | 83.62 | 13.95 | 60 | 110 |
| Distance (m) | 0.29 | 0.03 | 0.25 | 0.35 |

kg: kilogram; m: meter; SD: standard deviation.

ANOVA showed an effect of the interaction of the 5 sets in the bench press exercise on RI1 and RI3 on the TUT variables [$F(4;160) = 21.259$; $p<0.001$], total work [$F(4;160) = 79.956$; $p<0.001$], power [$F(4;160) = 97.549$; $p<0.001$], mean velocity [$F(4;160) = 99.320$; $p<0.001$], and number of repetitions [$F(4;160) = 90.657$; $p<0.001$].

Figure 2 shows the results of the TUT and the number of repetitions under the analyzed conditions. TUT was higher in RI3 when compared to RI1 in set 5 ($p<0.001$), but there was no difference in the other 4 sets. RI1 showed a reduction in TUT in sets 3, 4, and 5 compared to sets 1 ($p=0.001$; $p=0.010$; $p<0.001$) and 2 ($p<0.001$; $p=0.001$; $p<0.001$). RI3 showed lower TUT in sets 3 ($p=0.001$) and

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5 (p=0.049) compared to set 1. RI3 also showed lower TUT in set 3 compared to set 2 (p=0.005).

The number of repetitions was higher in RI3 compared to RI1 in set 3 (p=0.016), set 4 (p=0.021), and set 5 (p<0.001). However, no substantial distinction was observed in sets 1 and 2. In RI1, there was a decrease in the number of repetitions in sets 2, 3, 4, and 5 as compared to set 1. (p=0.002; p<0.001; p<0.001; p<0.001). We also found a lower result of the number of repetitions in sets 3, 4, and 5 compared to set 2 (p<0.001; p<0.001; p<0.001) and in set 5 compared to set 3 (p=0.001) and set 4 (p=0.004). In RI3, a lower result of the number of repetitions was found in sets 2, 3, 4, and 5 compared to set 1 (p=0.035; p<0.001; p<0.001; p<0.001) and in sets 3, 4, and 5 compared to set 2 (p=0.025; p<0.001; p<0.001).

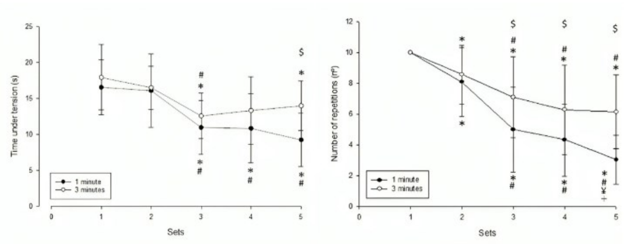


Figure 2. Result of TUT analysis and number of repetitions in the different recovery intervals.

The total work was higher in RI3 when compared to RI1 for the results of set 3 (p=0.005), set 4 (p=0.007), and set 5 (p<0.001). No significant differences were found between sets 1 and 2. In RI1, the total work was lower in sets 2, 3, 4, and 5 compared to set 1 (p=0.004; p<0.001; p<0.001; p<0.001). Lower results were also found in sets 3, 4, and 5 compared to set 2 (p<0.001; p<0.001; p<0.001) and in set 5 compared to set 3 (p=0.003) and set 4 (p=0.006). In RI3, lower results were found in sets 2, 3, 4, and 5 compared to set 1 (p=0.031; p<0.001; p<0.001; p<0.001). Total work was also lower in sets 3, 4, and 5 when compared to set 2 (p=0.029; p<0.001; p<0.001).

The mean velocity was higher in RI3 compared to RI1 in set 4 (p=0.029) and set 5 (p<0.001). There were no significant differences for sets 1, 2, and 3. RI1 presented lower mean velocity in sets 2, 3, 4, and 5 compared to set 1 (p<0.001; p<0.001; p<0.001; p<0.001). Sets 3, 4, and 5 showed lower velocities when compared to set 2 (p<0.001; p<0.001; p<0.001) in addition to set 5, which presented lower results than sets 3 (p=0.001) and 4 (p=0.026). In RI3, lower velocities were found in sets 2, 3, 4, and 5 compared to set 1 (p<0.001; p<0.001; p<0.001; p<0.001) and in sets 3, 4, and 5 compared to set 2 (p=0.045; p<0.001; p=0.001).

For power, RI3 presented higher results compared to RI1 in sets 4 (p=0.044) and 5 (p<0.001), without significant differences for sets 1, 2, and 3. RI1 showed lower results in sets 2, 3, 4, and 5 compared to set 1 (p<0.001; p<0.001; p<0.001; p<0.001). Power was also lower in sets 3, 4, and 5 compared to set 2 (p<0.001; p<0.001; p<0.001) and in set 5 compared to set 3 (p=0.001) and set 4 (p=0.015). In RI3, lower results were found in sets 2, 3, 4, and 5 compared to set 1 (p<0.001; p<0.001; p<0.001; p<0.001) and in sets 4 and 5 compared to set 2 (p=0.001; p=0.002).

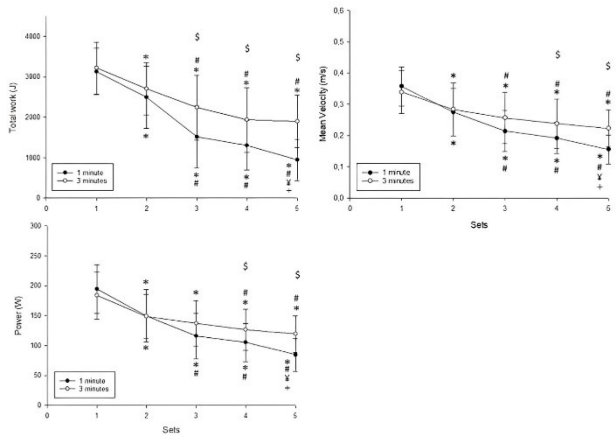


Figure 3. Result of the analysis of the total work, mean velocity, and power in the different recovery intervals.

The results of the associations of the mean of the variables studied in RI1 and RI3 are shown in tables 2 and 3, respectively.

Table II.
Analysis of the associations between the mean of the study variables in RI1. Table II. Analysis of the associations between the mean of the study variables in RI1.

| | | Armspan | Distance | Load | TUT | Work | Power | Velocity |
|---|---|---|---|---|---|---|---|---|
| Distance | r | 0.367 | | | | | | |
| | p-value | 0.102 | | | | | | |
| Load | r | 0.193 | -0.299 | | | | | |
| | p-value | 0.402 | 0.187 | | | | | |
| TUT | r | 0.004 | -0.169 | 0.009 | | | | |
| | p-value | 0.988 | 0.463 | 0.969 | | | | |
| Work | r | 0.382 | -0.221 | 0.137 | 0.584 | | | |
| | p-value | 0.088 | 0.337 | 0.554 | 0.005* | | | |
| Power | r | 0.459 | -0.229 | 0.390 | 0.292 | 0.859 | | |
| | p-value | 0.036* | 0.318 | 0.081 | 0.199 | <0.001* | | |
| Velocity | r | 0.326 | -0.140 | -0.186 | 0.334 | 0.848 | 0.822 | |
| | p-value | 0.149 | 0.544 | 0.420 | 0.139 | <0.001* | <0.001* | |
| Repetitions | r | 0.163 | -0.366 | -0.178 | 0.593 | 0.899 | 0.687 | 0.877 |
| | p-value | 0.480 | 0.103 | 0.440 | 0.005* | <0.001* | 0.001* | <0.001* |

TUT: time under tension; r: correlation value; p-value: significance value; *: p<0.05.

In table II, RI1 showed positive correlations between total work and power, total work and mean velocity and total work and number of repetitions. This means that the higher the total work performed, the higher the power output, mean velocity achieved, and the number of repetitions performed. Positive correlations were also found between mean velocity and power and mean velocity and number of repetitions. This demonstrates that the higher the mean velocity achieved, the greater the power produced, and the number of repetitions performed. Moreover, positive correlations were found between TUT and total work, TUT and number of repetitions, power and number of repetitions, and power and armspan. This indicates that as the TUT increases, both the total work accomplished, and the number of repetitions executed rise. Furthermore, as the power output increases, so does the number of repetitions executed and the value of armspan.

Table III.
Analysis of the associations between the mean of the study variables in RI3.

| | | Armspan | Distance | Load | TUT | Work | Power | Velocity |
|---|---|---|---|---|---|---|---|---|
| Distance | r | 0.367 | | | | | | |
| | p-value | 0.102 | | | | | | |
| Load | r | 0.193 | -0.299 | | | | | |
| | p-value | 0.402 | 0.187 | | | | | |
| TUT | r | -0.033 | -0.016 | 0.260 | | | | |
| | p-value | 0.887 | 0.946 | 0.256 | | | | |
| Work | r | -0.040 | -0.050 | 0.238 | 0.579 | | | |
| | p-value | 0.864 | 0.829 | 0.298 | 0.006* | | | |
| Power | r | -0.093 | -0.173 | 0.042 | 0.402 | 0.854 | | |
| | p-value | 0.688 | 0.452 | 0.857 | 0.071 | <0.001* | | |
| Velocity | r | -0.212 | 0.032 | -0.602 | 0.214 | 0.495 | 0.747 | |
| | p-value | 0.356 | 0.889 | 0.004* | 0.353 | 0.023* | <0.001* | |
| Repetitions | r | -0.300 | -0.210 | -0.325 | 0.421 | 0.722 | 0.828 | 0.860 |
| | p-value | 0.187 | 0.362 | 0.150 | 0.057 | <0.001* | <0.001* | <0.001* |

TUT: time under tension; r: correlation value; p-value: significance value; *: $p<0.05$.

Table III shows a negative correlation between overload and mean velocity. This demonstrates that the higher the overload used, the lower the mean velocity achieved. There were positive correlations between total work and power, total work and number of repetitions, and total work and mean velocity. This means that the higher the total work performed, the higher the power output, number of repetitions, and mean velocity achieved. In addition to these, positive correlations were found between power and mean velocity, power and number of repetitions, and mean velocity and number of repetitions. This demonstrates that the higher the power production, the higher the mean velocity achieved, and the number of repetitions performed. Additionally, the higher the mean velocity achieved, there is a corresponding increase in the number of repetitions executed. A positive correlation was also demonstrated between TUT and total work, which shows that the higher the TUT, the higher the total work.

## Discussion

The goal of the present study was to analyze the TUT behavior, total work, power, mean velocity, and number of repetitions in the performance of the bench press exercise with distinct rest intervals. The results showed that TUT was higher for RI3 compared to RI1 only in fifth set. Both RI1 and RI3 showed a reduction in TUT from first to third set. In RI1, there was no difference in TUT starting from third set onwards, which demonstrates that the last three sets had a similar TUT. However, in RI3, the fifth set showed a TUT greater than the third set but not enough to be similar to the first set. The results show that different rest intervals may affect the TUT of the next set to be performed in different ways, especially from the middle to the end of a session comprising five sets. Using the same overload and the highest intentional execution velocity, longer rest intervals showed a smaller reduction in TUT over the sets. Thus, longer intervals may contribute to the response to the mechanical stimulus derived from the RT (Jambassi Filho et al., 2013).

For both RI1 and RI3, the number of repetitions decreased throughout the completion of the sets. In RI1, the number of repetitions decreased up to fifth set, in which it showed a lower value than all the previous sets. In RI3, the number of repetitions decreased until the third set and remained similar until the fifth set. This is evidenced in the difference between the conditions with RI1 presenting a lower number of repetitions in third, fourth and fifth sets compared to RI3. Millender et al. (Millender et al., 2021) compared the effect of short and long intervals (1 minute *vs*. 3 minutes) on the number of repetitions in the bench press and squat exercises in four sets up to concentric failure with 75% of 1RM in athletes with experience in RT. They found a higher number of repetitions in the last three sets for the two exercises in the condition with a longer rest interval, which corroborates the results of the present study. In this sense, during RT, if the goal is to keep the training volume high, longer intervals are beneficial (Hernandez et al., 2021).

There is a discrepancy in the behavior of the TUT and the number of repetitions when placed in the same circumstance (RI1 or RI3). In RI1, while the TUT decreased in the third set and remained similar from third until the last set, the number of repetitions decreased in the second set, in the third set and again in the fifth set. In RI3, the TUT decreased in third set and from then demonstrated an increasing behavior again. The number of repetitions decreased from the first to the third set and remained similar until the fifth set. This decrease in the number of repetitions for the similar execution time may demonstrate that the repetitions were becoming slower throughout the sets. The same may have happened when TUT increased, but the number of repetitions remained similar. The results of mean velocity and power possibly may explain these findings. In the RI1 condition, a reduction from the first to the last set was demonstrated for both variables. In the RI3 condition, both mean velocity and power exhibited a reduction in the second set and displayed the last two sets as similar to each other. The difference in the two variables is observed at the point of the second reduction, where mean velocity occurs in the third set, while power only occurs in the fourth set. The execution duration of the repetitions is dependent on the velocity of movement, which can be altered by the overload used and fatigue (Coratella, 2022; Viecelli & Aguayo, 2021).

In addition to these results, the decrease of both mean velocity and power were smaller in RI3 in the last two sets compared to RI1. Davó et al. (2016) analyzed the use of different rest intervals (1, 2, and 3 minutes) in the outcome of power production using 40% of 1RM during the ballistic bench press exercise in 5 sets of 8 repetitions. The 1-minute rest interval showed a greater decrease in power production compared to the other two conditions, which did not show differences between them, corroborating the findings of the present study.

The result found on total work demonstrates a behavior similar to that found for the number of repetitions, which decreased over the sets. Both variables showed reduction from the first to the last set in RI1 and from the first to the third set in RI3. When the conditions were compared, a difference was found in third, fourth and fifth set with higher total work and number of repetitions for RI3. This alignment between the two variables can be explained by the influence of the displacement of the overload during the exercise to obtain the final value of the total work. With fewer repetitions being performed, the less the implement moves. Of this, the total work done decreases (Winter et al., 2016).

For both conditions (RI1 and RI3) positive correlations were found between total work and TUT, number of repetitions, mean velocity, and power. These relationships showed that the greater the total work performed, the longer the exercise duration, the greater the number of repetitions, the higher the average speed at which the movement occurs, and the greater the power production during the exercise. McBride et al. (2009) demonstrated that using total work is the most appropriate way to quantify training volume, but it appears to be challenging to be precise in daily professional activities. The relationship found between total work and TUT in the present study may suggest the use of TUT for the same purpose with greater convenience and certainty. Cronin and Crewther (2004) analyzed 3 different overload percentages equalized by volume (6 × 30% of 1RM, 3 × 60% of 1RM, 2 × 90% of 1RM) and found similar results both for the total TUT and for the total work performed, in which the condition with 30% of 1RM showed higher values for both variables. Nevertheless, when TUT was compared based on the number of repetitions between the conditions, higher overloads demonstrated longer TUT, possibly due to a loss of velocity.

Total work and power also demonstrated a relationship with each other, due to the association with the energy used during exercise. In this context, total work can be considered as the amount of energy transferred to the overload so that it can move (total times force is exerted to displace a mass multiplied by the distance) (Nunes et al., 2021), while power can be considered the rate at work is done to perform a movement against the overload.

The present study found positive correlations between power, number of repetitions, and mean velocity. This demonstrates that the greater one of these variables, the greater the other two as well. Power can be related to the force-velocity relationship, which states that the capability of the neuromuscular system to generate force is dependent on movement velocity (Schilling; Falvo & Chiu, 2008). This may explain the positive relationship found between power and mean velocity in the present study. Regarding the number of repetitions, the faster a movement happens, the higher its frequency of accomplishments within the same time interval. Thus, it is possible to explain the relationship found between this variable and mean velocity and power.

Specific correlations for the conditions (RI1 and RI3) were found. The RI1 condition exhibited a positive correlation regarding TUT and the number of repetitions and between armspan and power. Anthropometric characteristics such as height, sitting height, and armspan can affect the physical performance of athletes (Kukic et al., 2022). On the other hand, the RI3 condition showed a negative correlation between overload and mean velocity, that is, the higher the overload used, the lower the velocity of the movement performed. This relationship is based on the concept of force-velocity described, which establishes that the overload used in the exercise will determine the ability to generate velocity against it, meaning that the lower the overload, the greater the possibility of being fast, and vice versa (González-Badillo; Marques & Sánchez-Medina, 2011; González-Badillo et al., 2017; Viecelli & Aguayo, 2021). In this sense, methods that use movement velocity as a predictor of training intensity, as well as for performance monitoring are being studied based on this pre-established relationship (Conceição et al., 2016; González-Badillo & Sánchez-Medina, 2010).

The present study presented some strong points and limitations. As strong points, it was possible to better observe the relationship between the behavior of the number of repetitions and TUT when analyzed under the same condition. From the results obtained, it seems that repetitions become progressively slower throughout the sets, leading to a discrepancy in the behavior of the two variables. Based on the observation made, it is possible to hypothesize about the difference in velocity behavior in each repetition, whereby, as fatigue sets in, the concentric phase may become slower while the eccentric phase becomes faster throughout the sets. Understanding the proportion of this velocity behavior for each phase of the repetitions may offer a possible explanation for the behavior of TUT and the number of repetitions. Additionally, there were also indications of the potential use of TUT as a means of quantifying training volume.

As limitations in the study, the instrument used to calculate mechanical variables does not provide data on mean propulsive velocity, only the mean velocity of the entire set of movements performed. Futhermore, we used only the bench press exercise to our analysis and only high-performance male athletes were used as a sample, which does not allow the data to be generalized to other sample groups or exercises.

## Conclusion

The present study concluded that larger intervals showed a smaller impact on the reduction of all variables throughout the sets. It was possible to observe the association regarding the TUT and the number of repetitions, possibly influenced by the decrease in mean velocity and power throughout the sets. In this way, sets with a similar number of repetitions but with an increase in TUT or sets with a similar TUT but with a lower number of repetitions were found within the same condition (IR1 or IR3). Regardless of the condition, it was possible to observe that with the overload adjusted to 10RM, the same range of motion, and a higher intentional execution velocity, the third set appears to be a point of performance reduction worth considering depending on the exercise's goal.

Practical applications for prescribing and controlling RT can be observed. Although the two recovery intervals used did not allow for the maintenance of performance across sets, the one-minute interval between sets showed a more significant magnitude of reduction. Therefore, its use may not be interesting, given the sharp decline in performance over the series. Additionally, it was possible to observe the difference in behavior between TUT and the number of repetitions, highlighting that using only the number of repetitions as a parameter to evaluate training volume may not be precise. From the results of speed and power, it appears that not every repetition is the same, and therefore, TUT could contribute to controlling training volume.

In this regard, the relationships found between number of repetitions, TUT, and total work suggest that TUT may possibly be used as variable for controlling training volume, but further studies with designs that can ascertain causality in their results are needed. We also suggest further studies using other exercises and sample groups, other rest intervals, and other overload percentages are recommended. Moreover, it is suggested to use other instruments, such as a linear position transducer system, to capture mechanical variables like mean velocity and power at different isolated moments of each repetition, such as propulsive moment from concentric phase, and the eccentric phase in order to observe with more detail, the behavior of these variables during exercise execution and its influence over the TUT.

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## Declaration of interest statement

All authors certify that they have no conflict of interest with any public or private financial institution with respect to the content in the manuscript.

## Author’s contribution

Conceptualization: GCPSMS, JBPC, JGMO, AOBS, RAMN, GR, VPL, RGSV. Methodology: GCPSMS, JGMO, VLP, RGSV. Formal analysis: GCPSMS, JBPC, RAMN, GR, VLP, RGSV. Investigation: GCPSMS, JGMO, AOBS, VPL, RGSV. Writing: GCPSMS, JBPC, RGSV. Visualization: GCPSMS, JBPC, JGMO, AOBS, RAMN, GR, VPL, RGSV. Supervision: GCPSMS, JBPC, VPL, RGSV.

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