# The influence of different joint angles obtained in the starting position of leg press exercise and at the end of the frontal pull exercise on the values of 1RM

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## ABSTRACT

The Maximum Repetition test (1RM) has been applied under various circumstances and with diverse objectives, and variables that might potentially influence this test have been constantly studied. This study sought to evaluate the influence of different angles in the initial position of the leg press exercises and in the final position of the frontal pull exercise on the results of the 1RM. Twenty male volunteers (with an average age of 24.5 years, height of 1.75 meters and weight of 72 kg) were measured in the 1RM test for the leg press exercise and the frontal pull exercise. After obtaining their consent to participate in and adapting to the weight-resistance training, the 1RM test was applied in the leg press exercise in three different test angles in the initial position (80º, 90º and 100º degrees of knee flexion) and in the final position of the frontal pull exercise (60º, 70º and 80º degrees of elbow flexion), thus each angle was tested on three different days for each of the exercises. The results indicate that the averages of the 1RM for the leg press exercises are statistically different ($F = 30,199$; $p = 0.000$) amongst themselves (post hoc of Tukey). Although there were differences in the frontal pull exercise, they were not statistically significant ($F = 1.330$; $p = 0.281$). It can be concluded that different techniques used in the execution of exercises that involve different angles, mainly in their initial positions, must be rigorously controlled, since they can affect the amount of weight lifted.


**Key words:** Joint angles. 1RM. Techniques of execution.

## INTRODUCTION

Physical fitness related to the component strength has been measured through strength tests and strength resistance including 1RM* and RM**. The 1RM test has been applied with different purposes in the strength training area, classically and mainly, the bench press or squat[1-4], however, their utilization in other exercises has also been observed[5,6]. The tests' scientific authenticity criteria were researched and published in literature[7,8], thus being applied to children safely as long as the measures protocols are rigorously followed[9], adolescents[10], adults[3] and aged[6,11].


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* Test that evaluates the maximal dynamics on individuals through the amount of weight lifted within a movement previously determined in a single repetition; reason for the designation of 1RM, in other words, one feasible maximal repetition.

** RM means the maximal number of repetitions that an individual is able to perform within a standardized movement (eccentric/concentric and vive versa) using a given weight. For example, to perform 10RM in supine exercise with 50 kg of weight means that the individual is able to perform not more or less than 10 correct and complete repetitions.

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The 1RM test has particular application interest in the weight lifted of train and follow-up of strength gain in athletes[12], but it may also be applied in other populations as long as such procedures have been indicated[13]. Although the cardiac risk due to cardiac frequency elevation, systolic blood pressure or double product is low in the strength work[14], predictive equations of 1RM can be still used[15-17] as useful resource to estimate strength in individuals with cardiac potential risks.

Before the importance and the wide application range of the 1RM test, studies have identified intervenient variables on the test measurement. The influence of the verbal encouragement has proved being significant in increasing the weight lifted[18]. The effect of dehydration[4] and flexibility programs conducted by the static method, presented harmful effects during and after the 1RM strength measurements, respectively[19]. These studies contribute to improve the application procedures of the 1RM test avoiding or minimizing the influence of the intervenient variables.

The importance of the 1RM test for the analysis of the strength behavior and the improvement of its scientific reliability is clear. However, analyses of possible interventions in the results obtained in function of different exercise performance techniques are not yet fully cleared. Few are the studies found with regard of this topic. Signorile *et al.*[20] studied the differentiated recruitment of muscles that compose the triceps surae. The plantar flexion movements were performed with knees at 90º, 135º and 180º, the authors found that a more effective recruitment (evaluated through electromyography) of medial gastrocnemic and soleum are feasible through manipulation of the knee angle and it seems to be due to structural of mono and multi-joint matters of the muscular groups. Escamilla *et al.*[21] studied the behavior of variables muscle activity and compression and tension forces on the knee in the variation of the positioning technique of lower limbs in leg press and squat exercises; through the study's conclusion suggested the performance of exercises with different knee angles in function of the positioning adopted and the dependence of performance or rehabilitation objectives.

The studies mentioned above[20,21] focused the variations on the technique of execution in function of different joint angles adopted; studied forces acting on the joints involved and muscular activity, especially through electromyographic resource; however, the repercussion of these variables on the technique of execution were not related to possible modifications in results of the 1RM test, and this is important, once this test is used for the train weight control and follow-up of the strength gains[12,13]; any interference on the evaluation process will impair the results interpretations, being harmful for the prescription and monitoring of the train weight.

As the human body movement functions through bio-crowbars that are established according to physical principles[22,23], the alterations on the angles adopted in function of different techniques of execution may influence the results of 1RM obtained. In the attempt of better evaluating the influence of the technique of execution on the values of 1RM, this study had as objective to quantify the influence of different joint angles in the starting position of leg press exercise and in the final position of the frontal pull exercise on the values of 1RM.

## METHODS

This study searched to verify the variations on the results of 1RM in function of different initial and final testing angles in Leg Press and Frontal Pull exercises, respectively. 20 male volunteers with ages ranging from 18 and 30 years were tested; all not much familiarized Resistance Training (RT)[24]*, in other words, between 8 and 11 training sessions. The age was selected due to the strength plateau being found within this ages[22,25] and studies[26,27] to demonstrate that the population that mostly search for bodybuilding academies is found within this age range.

The sample presented average values of 24.5 ± 3.7 years; 1.75 ± 0.10 meters and 72.0 ± 4.5 kg for age, height and body mass, respectively, being previously measured when the objectives and justification of this study were explained and in function of these measures, which measures would be necessary to be performed with individuals who participated in the study. After agreeing in participate in this study, the volunteers signed a free consent form and the adaptation to the TRP was initiated. This adaptation lasted for a period of 8 to 11 training sessions, aiming at the sample tendo-myo-ligamentar strengthening as well as education with regard to the correct posture adopted in the test exercises. The angles of 90° and 70° were considered as adequate posture for the leg press and frontal pull exercises, respectively. These angles were used by being exactly the intermediate angles later used for the testing.

The 1RM test in the Leg Press and Frontal Pull exercises (figures 1 and 2) was in agreement with protocol proposed by Moura *et al.*[8] with testing adjustment through the Effort Subjective Perception as suggested by Moura *et al.*[28]. During testing, verbal encouragements were used as suggested by McNair *et al.*[18] for maximizing results. The description of testing protocols is presented as follows (adapted of Moura *et al.*[8]):

### Leg press

*Objective:* To measure the lower limbs musculature strength.

*Initial position:* Individual sitting in device with knees inflected at 90° as well as hip flexion, feet on the device resistance baffle plate, hands holding base points under the chair.

*Weight resistance point:* Set under the feet as horizontal resistance for pushing movement.

*Execution:* The individual pushes horizontally the resistance performing hip and knee extension.

*Cares:* Attention with regard to the lumbar region of the vertebral column in order to always remain leant against vertical chair support (stabilization of the lumbar column).

### Frontal pull

*Objective:* To measure the trunk musculature strength and lower limbs.

*Initial position:*

a) Individual sitting with erect trunk and knees inflected at approximately 90° with thighs fixed at the standard device baffle plate placed in front of the body.

b) Hands holding pulley alt with elbows fully extended and arms above the body (hold changes in function of testing angles) with erect trunk.

*Weight resistance point:* Resistance is provided through standard barbell against the pull movement (shoulder adduction and elbow flexion).

*Execution:* Individual performs pulling bar against the body down to after the mandible with head oriented in the Frankfurt plane.

*Cares:* Attention for the individual to actually maintain head oriented in the Frankfurt plane and barbell to exceed the mandible.

Three testing days were performed where the 1RM test was conducted each day using a specific angle in the test. Twenty-four hours were given between tests, what according to Sewall and Lander[1] are sufficient for recovery between 1RM tests. The order of the initial testing angle application was random among the three 1RM tests produced. The angles were determined relatively to the other body segments using a universal goniometer label Carci. The measure angles are described following and can be seen in figures 1 and 2.

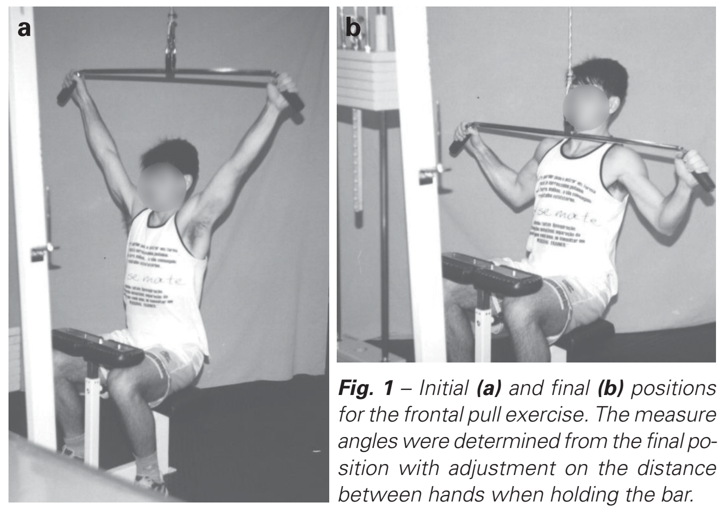


*Fig. 1 – Initial **(a)** and final **(b)** positions for the frontal pull exercise. The measure angles were determined from the final position with adjustment on the distance between hands when holding the bar.*

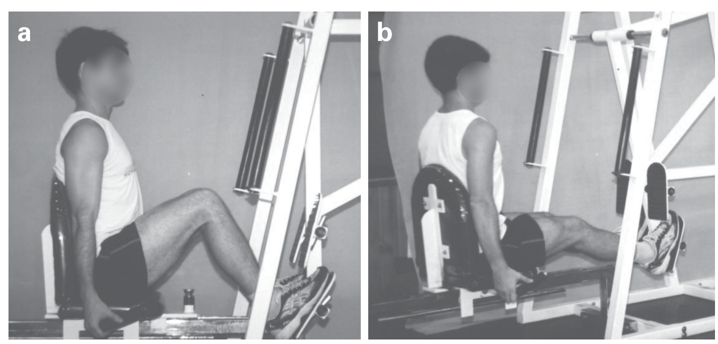


*Fig. 2 – Initial **(a)** and final **(b)** positions for the leg press exercise. The measure angles were determined in the final position between leg and thigh segments.*

- Leg press: 80°, 90° and 100° (angles measured between thigh and leg segments in the 1RM test represent the initial testing position).
- Frontal pull 60°, 70° and 80° (angles measured between forearm and arm segments adjusted during the final testing position without weight (resistance) in machine). The adoption of angles 60°, 70° and 80° are justified due to the fact that elbow angles higher that 80° were not compatible with the length of the exercise bar, in other words, for individuals with very long upper limbs (elevated breadth), the testing with angles higher than 80° would be infeasible, once as angles higher than 80° are formed, the individuals would have hands out of the device standard barbell.

These testing positions were selected by being the effort critical point, in other words, according to Campos[23], the higher is the knee and hip flexion (in the leg press exercise) or the more the

* Term discussed and proposed by Hopf & Moura[24] as adequate form, scientifically, to define body exercising, by common sense, as bodybuilding.

arms are found parallel to the ground (in the frontal pull exercise), the higher the resistance moment arm will be. Therefore, during the test movement arc, the pluck out (beginning) of the movement in the leg press exercise and end of the frontal pull exercise is the maximal effort point due to the resistance moment arm.

The Shapiro-Wilk test was used for the data normality test. After verifying that data are normalized, the descriptive parametric statistics was used and the One-Way ANOVA for repeated measures (*post hoc* Tukey) with the objective of describing data and verifying possible significant differences between scores of 1RM in the angles analyzed. The statistical package SPSS for Windows version 10.0 was used for data treatment and the significance level was adopted as $\alpha \leq 0.05$.

## RESULTS

The data normality was initially tested through the Shapiro-Wilk Test, where it was verified that values of 1RM obtained in different angles analyzed and in different exercises are not significantly different in relation to a normal standard curve. Therefore, the data are normalized and consequently accept statistical treatment through parametric proofs[31].

Table 1 presents averages, standard deviations, variation coefficients and maximum and minimum values of scores of 1RM obtained in different measure angles. In the leg press exercise, the 1RM averages obtained presented a wide variation (80º = 112.8 kg, 90º = 138 kg and 100º = 178 kg). These data were treated statistically through the One-Way Analysis of Variance for repeated measures and presented statistic significance ($p < 0.01$) and applied to the *post hoc* Tukey Test, being demonstrated that the average values of 1RM were statistically different from each other in the three angles evaluated.

With regard to the frontal pull exercise, the same statistical procedure was performed. It was verified that the averages of 1RM (table 1) were different between the three angles analyzed (60º = 63.6 kg, 70º = 61.7 kg and 80º = 58.4 kg). However, the variation was not as wide as in the previous exercise, although the differences between elbow angles measured presented the same magnitude as the leg press exercise, in other words, 10 degrees. The One-Way ANOVA for repeated measures presented no significance, in other words, the averages of 1RM in the frontal pull exercise presented no significant statistical differences between each other ($F = 1.330$; $p = 0.281$).

**TABLE 1**
**Descriptive values and analysis of variance for the three measure angles of 1RM in the frontal pull and leg press exercises**

| Angles | Average (kg) | Standard deviation (kg) | Variation coefficient | Min-Max (kg) | ANOVA F | ANOVA p |
|---|---|---|---|---|---|---|
| **Leg press exercise** | | | | | | |
| 80º | 112.8 | 16.3 | 14.4% | 89.0-144.0 | 30.199* | < 0.001 |
| 90º | 138.0 | 23.2 | 16.8% | 105.0-183.0 | | |
| 100º | 178.9 | 37.3 | 20.8% | 111.0-261.0 | | |
| **Frontal pull exercise** | | | | | | |
| 60º | 63.6 | 7.0 | 11.0% | 51.0-76.0 | 1.330 | 0.281 |
| 70º | 61.7 | 6.7 | 10.8% | 48.0-73.0 | | |
| 80º | 58.4 | 6.7 | 11.5% | 48.0-71.0 | | |

* Post Hoc Tuckey Test with differences statistically significant ($p < 0.05$) among all averages.

In the leg press exercise, the data variation was becoming higher (elevation of the standard deviation and variation coefficient) as the initial testing angle increased (CV = 14.4; 16.8 and 20.8% for angles 80º, 90º and 100º, respectively). Such behavior of data was not identified for frontal pull exercises regardless the testing angle at the final position; the data variation remained similar (CV = 11.0; 10.8 and 11.5% for angles de 60º, 70º and 80º, respectively).

Table 2 presents the values of 1RM in measures using different angles. The weigh absolute difference in 1RM between 80º and 90º in the leg press exercise almost doubled when angles were changed from 90º to 100º (25.2 kg and 40.9 kg; respectively). These alterations were also relatively high 22.3%, 29.6% and 58.6% between angles 80º, 90º and 100º, respectively.

In the frontal pull exercise, the variations both absolute and relative were less expressive. The difference absolute values of 1RM between the different angles were 1.9 kg; 3.3 kg and 5.2 kg and 3.0%, 5.6% and 8.9%, respectively between the absolute and relative values between angles 60º-70º, 70º-80º and 60º-80º.

**TABLE 2**
**Absolute (in kg) and relative (in %) differences between values of 1RM in different angles and exercises analyzed**

| Angle | Average (kg) | Variation of 1RM (absolute values in kg) | Variation of 1RM* (relative values in %) |
|---|---|---|---|
| **Leg press exercise** | | | |
| 80º | 112.8 | 80º p/ 90º = 25.2 | 80º p/ 90º = 22.3 |
| 90º | 138.0 | 90º p/ 100º = 40.9 | 90º p/ 100º = 29.6 |
| 100º | 178.9 | 80º p/ 100º = 66.1 | 80º p/ 100º = 58.6 |
| **Frontal pull exercise** | | | |
| 60º | 63.6 | 60º p/ 70º = 1.9 | 60º p/ 70º = 3.0 |
| 70º | 61.7 | 70º p/ 80º = 3.3 | 70º p/ 80º = 5.6 |
| 80º | 58.4 | 60º p/ 80º = 5.2 | 60º p/ 80º = 8.9 |

* Values calculated through simple rule of three where the first angle is equivalent to 100% and the weight increase with the new value and in this increase, the search of what gain or drop in the case of the frontal pull exercise in percentile. Ex. 112.8 kg__100% and 25.2 kg (gain) and how much it represents from the total 112.8 kg.

## DISCUSSION

The variation in the initial testing angle significantly affected only the leg press exercise, making the average values of 1RM different between each other ($p = 0.000$); this also influenced data that, as the initial testing angle increased, the results became progressively more heterogeneous for the leg press exercise; the same was not observed for the frontal pull exercise.

The initial testing angle alternation seemed to influence more the leg press exercise than the angle alternation in the frontal pull exercise. This could be explained through the fact that value of the resistance moment arm is higher as the value of the hip and knee flexion is higher in the leg press exercise[23], in other words, the lower the angle between leg/thigh and thigh/abdomen is, the higher the movement resistance shall be. Thus, the movement initial position is the testing critical point during the 1RM test as the movement continues from the initial to the final testing point, the resistance moment arm decreases and the effort becomes progressively lower. For the frontal pull exercise, the highest resistance moment arm is obtained when arm is parallel to the ground[23], in other words, at the end of movement, not at the beginning. As movement continues, the effort becomes progressively higher up to the critical point in which arms are parallel to the ground or go beyond this point.

Therefore, due to the fact that the critical angle of the leg press exercise is at the initial position, inversely to the frontal pull exercise, it is verified that variations next to the critical angle produce relevant influences on the values of 1RM, once in the case of the leg press exercise, the movement could not even be initialized when the hip and knee flexion occurred with high weights. Contrarily, the frontal pull exercise could be accelerated during the movement arc up to the end. Such fact could provide higher traction for the same weight, once a higher speed of the movement execution seems to influence the strength scores[32].

Studies on the analysis of the training angles and strength gains are identified in literature in relation to the isometric strength training. The fact that the strength gains are specific to the training angles in the isometric training is well established[33,34], however, works that could be compared to results of the present study are scarce in literature.

A study of Mookerjee and Ratamess[3] verified that in dynamic work with movement partial amplitude (lower work angles), the performance in 1RM (4.8%) and 5RM (4.1%) increase significantly ($p \leq 0.05$) if compared to total amplitudes in the execution in the bench press exercise. Such fact occurred to the leg press exercise, where initial testing angle decreased the movement arc and increased the weight lifted. For the frontal pull exercise, the highest final testing angle (elbow angle), lowest work arc and the averages were decreased, however, not significantly. It is verified that the lowest movement arc did not lead to lower weights in the 1RM test probably due to the fact that the angle measured is the elbow's, as final movement adjustment, what caused small variations on the shoulder's angle, and as the movement is multi-joint involving shoulder and elbow joints and as the primary motive muscles perform the shoulder adduction for the movement of the frontal pull exercise and as this joint presented small variation with the elbow's joint alternation, it may explain, at least in part, the small variations on the values of 1RM.

Thus, the movement execution arc (movement angular distance) seems to influence the scores of 1RM when the initial testing angle is modified. Such relation may be based on the dynamic muscular work performed, where, physically, the work will be equal to the force employed multiplied be the distance elapsed of the mobilized object ($w = fxd$). In the case of resistance exercises, the distance is angular represented by the movement arc around a joint, the force is represented by the weight lifted and the total work is the sum of the concentric and eccentric works during the 1RM test. Therefore, the higher the movement arc is (angular distance) as long as the weight is maintained, the more work is performed, once $w = fxd$ and it seems to influence the scores of 1RM. It can be also speculated that the higher is the movement arc (sum of the eccentric and concentric arcs), the longer the muscular contraction time will be, as long as the same execution speed is maintained and, although the movements of 1RM does not exceed ten seconds of execution[8], a longer contraction time may cause higher muscular fatigue in the acid/base and enzymatic balance[33].

Simpson *et al.*[2] correlated the scores of 1RM between the bench press exercise in free-weight bench press machines ($r = 0.95$ for women and 0.94 for men) and the leg press exercise in the free-weight squat machine ($r = 0.66$ for women and 0.67 for men) and the differences in the correlation analysis may be credited to the fact that in the bench press exercise the movement is identical between machine and free weights. In the performance of the leg press exercise, the movement is performed with hip flexion more intense than in the squat exercise. Such cinesiological analysis demonstrates that small modifications in the movement format will influence results of the 1RM test. It was also emphasized that in the same exercise (supine and leg press), different labels of RT machinery provide average results of 1RM with difference statistically significant ($p = 0.000$) due to differences in crowbars, power, weight resistance points and machinery adjustment[36]. It is verified that the angulation in TRP machinery are vital in the attainment of strength scores. These works emphasize that the design in TRP machinery and modifications in the execution angles cause alternations in the effort performed, therefore, these results are in agreement with results found in the present study.

The length-tension curve confirms the existence of an optimum length in which the muscular fiber (specifically the sarcomere) alone produces its maximal strength, once it depends on the number of crossed bridges that interact between myosin and the active sites of actin[37]. The leg press exercise, as it is initialized with knee flexion at 80°, 90° and 100°, caused no excessive stretching of the mono-articular portions (vastus medialis, vastus lateralis and intermedius) and the biarticular (rectus femoris) of the quadriceps, where the highest elongation possible, due to its origin and insertion positions, would be the maximal knee flexion, however, alterations on the fiber length were verified. In the same exercise, the hip extensors (gluteus maximus and ischio-crural) are not found in their maximal elongation, once the knee flexion minimizes the ischio-crural stretching and the hip flexion is not so relevant to cause a strong stretching of the gluteus maximus, however, once again a variation on the fiber length between the angles analyzed was verified. In the frontal pull exercise, from the main muscles involved in the shoulder adduction movement and elbow flexion, the teres major and latissimus dorsi, due to their origin and insertion, could be considered in higher muscular stretching position if compared to other muscles involved in the pull and leg press movements. Thus, theoretically, the length-tension curve should be considered as one of the factors that could have influenced the results, although this could not be decisively affirmed, once it is not part of the objectives of this study.

Due to the fact that the difference percentiles of 1RM between angles of 80°-90° and 90°-100° are progressive (22.3% and 29.6%), the relation between the increase on the knee angle and 1RM for the leg press exercise seems to be non-linear; thus, the weight of 1RM does not increase proportionally to the increase on the knee angle.

A slight difference on the positioning of the chair in the leg press device causes alteration on the knee angle and consequently in the weight of 1RM; the same may be speculated in the training weight, thus emphasizing the importance of maintaining an adequate posture in this exercise. For instance, an individual with a percentile training prescription of 80% of 1RM with knee initial position at 90°, if this individual decides to place a thin mattress between the vertebral column lumbar region and the chair vertical back to feel more comfortable, this will cause a projection of the body ahead (next to the pedals of the machine) and consequently a decrease on the knee angle and an increase on the effort performed. Therefore, the training weight should be reviewed with the use of the thin mattress. If in this example, the knee angle is reduced on 4°, a using a simple rule of three with data from table 2

(80° for 100° = 20°, being 20° equivalent to the variation of 66.1% in the value of 1RM), it is verified that 4° is equivalent to a change of 13.2% on the weight performed. If the individual trains with weight of 80 kg with the use of mattress, he would be with 10.58 kg of weight increase that is equivalent to a change of 13.2% caused by an alteration of 4° in the knee angle. The modifications on the angle and alterations on the weight of 1RM seem to be non-linear. The simple rule of three was used only as illustrative factor of the cares with regard to the angulations, once they cause modifications on the weights and therefore, do not correspond to rigid values of modifications on the weights of 1RM.

It is observed that the results of this study may not be exactly the same in 1RM tests that follow the same exercises here analyzed, however, performed in different label machinery due to the fact that they are not similar with regard to the design, where differences on the crowbar arms generating different power for the same weight may occur. The same reasoning may be used with regard to the gender female. Once differences in the values of 1RM with men[36] are observed, women may present results different from results of the present work due to the bio-crowbar dimensions.

Possible harmful effects on the 1RM performance in function of the dehydration as verified by Schoffstall *et al.*[4] cannot be considered in this study, once the individuals were allowed to drink as much water as they wanted during the testing processes.

However, possible apprenticeship effects of the 1RM test on the results obtained should be considered, once Ploutz-Snyder and Giamis[8] observed that for untrained young individuals (23 ± 4 years) in TRP, only when they performed from three to four test sessions the scores of 1RM were consistent, in other words, with differences smaller than 1 kg in the knee extension exercise among the 1RM test days. However, as the testing angles sequence was random, such interference on the internal validity of this study must have been minimized[39].

In short, the results of this study confirm expressive changes of the effort with variations on the initial testing angles. However, this relation is not generic that could be applied indiscriminately to all formats of weight-resistance exercise. The critical testing angle (highest resistance moment arm) in the initial testing position, seems to influence the scores of 1RM more than at the final of the movement, thus discriminating the influence of the angles between different exercises. The findings of this study confirm results of other studies that as the work arc decreases, the mechanic work also decreases, enabling higher weight of 1RM lifted. Factors such as the movement arc, muscular contraction time for the execution of the 1RM movements, joints in which the testing angles are verified and if they represent the initial or final testing position, altogether, seem to have strong influence on the scores of 1RM, therefore, these factors should considered in the exercises execution technique.

One concludes that RT professionals should be very careful with regard to the positioning of individuals in all exercises, especially in exercises presenting critical angles in the movement final and initial positions in order to provide higher safety in the prescription and monitoring of trains. The use different execution techniques of weight-resistance exercises should be carefully analyzed and applied, especially if they change the work joint angles.

New studies should be conducted with the same objectives as this one, however, applied to women with the objective of identifying if the data behavior is the same and analyzing the frontal pull exercise in which the reference angles are performed on the shoulder joint. New studies should be conducted with alternations smaller than ten degrees in joints and with more than three observation points as in the present study in order to establish a regression curve (cubic, quadratic, logarithmic, etc.) between alternation of the joint degrees and modification on the 1RM weights.

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