# Conventional Ratio of Knee Flexors and Extensors Obtained Using an Isokinetic Dynamometer and Isoinertial Devices[1]

## Relación convencional de flexores y extensores de la rodilla obtenida mediante un dinamómetro isocinético y dispositivos isoinerciales

## Rácio flexor-extensor do joelho convencional obtido a partir de um dinamómetro isocinético e de dispositivos isoinerciais

[Article]

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## Abstract

This study aimed to analyze the conventional ratio values of knee flexors and extensors obtained using an isokinetic dynamometer (IsoRatio), an adjusted torque test of 5RM (Ratio5RM), and absolute values of 5RM (Ratio5RML). Fifteen male volunteers (28,47 ± 5.78 years; 78,30 ± 6,59kg; 1,79 ± 0,65m) performed a 5RM test on leg extension and leg curl machines. The volunteers executed knee flexion and extension movements at 60°/s angle speed without significant differences between protocols. Regression analysis showed that the Ratio5RML correlates with the isokinetic reference ratio (r=0,649; p=0,009). The result of the paired t-test showed no significant difference between the means of the isokinetic ratio and the ratio predicted by the equation. The results of the present study suggest that the 5RM test performed with isoinertial machines can be used to estimate conventional ratio and identify imbalance between the knee flexors and extensors muscles.

**Keywords:** Exercise, Hamstring to quadriceps ratio, Isokinetic dynamometry, Repetition maximum tests, Muscle strength.

## Resumen

Este estudio tuvo como objetivo analizar los valores de relación convencionales de flexores y extensores de rodilla obtenidos mediante dinamometría isocinética (IsoRatio), torque ajustado en la prueba de 5RM (Ratio5RM) y valores absolutos de 5RM (Ratio5RML). Quince varones (28,47 ± 5.78 años; 78,30 ± 6,59 kg; 1,79 ± 0,65 m) realizaron un test de 5RM en máquinas de extensión y curl de piernas. Los movimientos de flexión y extensión de la rodilla se realizaron a una velocidad angular de 60°/s. No hubo diferencias entre los protocolos. El análisis de regresión mostró que la Ratio5RML se correlaciona con la relación isocinética (r=0,649; p=0,009). La prueba t pareada no mostró diferencias entre los valores obtenidos de la relación isocinética y de la relación predicha por la ecuación. Los resultados sugieren que el test de 5RM realizado en máquinas isoinerciales se puede estimar la relación convencional e identificar el desequilibrio entre los músculos flexores y extensores de la rodilla.

**Palabras clave:** dinamometría isocinética, ejercicio, fuerza muscular, pruebas de repetición máxima, relación isquiotibiales a cuádriceps.

## Resumo

Este estudo teve como objetivo analisar os valores das razões convencionais de flexores e extensores de joelho obtidos pela dinamometria isocinética (IsoRatio), torque ajustado no teste de 5RM (Ratio5RM) e valores absolutos de 5RM (Ratio5RML). Quinze voluntários do sexo masculino (28,47 ± 5,78 anos; 78,30 ± 6,59kg; 1,79 ± 0,65m) realizaram um teste de 5RM em aparelhos de extensão e flexão de joelhos, que foram realizados em velocidade angular de 60°/s. Não houveram diferenças significativas entre os protocolos. A análise de regressão mostrou que Ratio5RML se correlaciona com a razão isocinética de referência (r=0,649; p=0,009). O resultado do teste t pareado não mostrou diferença significativa entre as médias da razão isocinética e a razão prevista pela equação. Os resultados do presente estudo sugerem que o teste de 5RM realizado em máquinas isoinerciais pode ser utilizado para estimar razão convencional e identificar desequilíbrio entre os músculos flexores e extensores do joelho.

**Palavras-chave:** dinamometria isocinética, exercício, força muscular, relação isquiotibiais/quadríceps, testes de repetições máximas.

## Introducción

The biomechanical characteristics of fundamental movement patterns associated with daily activities and specific sports practices – such as squatting, running, jumping, and kicking – increase the knee extensor muscle torque at the expense of flexor torque, producing muscle imbalance (Américo et al., 2011; Evangelidis et al., 2016). The strength of the quadriceps is also critical for the correct functioning of the knee in fundamental movement patterns. At the same time, the strength of the hamstrings promotes greater joint stability and acts as a mechanical brake, reducing the speed of the segment during the knee extension movement (Maia et al., 2014). Thus, the disproportionality in the level of strength between the thigh muscles produced during the movement patterns can be considered as one of the main factors that can cause a higher risk of lower limb injuries. Such injuries can occur when there are substantial deviations from the normal pattern (flexor strength should account to approximately 60% of extensor strength) (Kellis et al., 2014).

The conventional ratio of knee flexors and extensors, which encompasses the relationship between the concentric strength of flexors and extensors, is a modifiable risk factor for major lower limbs injuries, such as thigh stretching and anterior cruciate ligament (ACL) rapture (Croix et al., 2017). This ratio is usually assessed using an isokinetic dynamometer. However, isoinertial muscle actions, which are characterized by the acceleration and deceleration of a constant mass, have shown equivalences in the values of the conventional ratio obtained (Croix et al., 2017; Lauermann et al., 2014; Minozzo et al., 2018).

Sabino, Felício, Guimarães, Abreu, and Vieira (2016) observed a positive correlation between the 1 repetition maximum (1RM) test conducted with an isoinertial device and the isokinetic test when assessing the concentric strength of knee flexors and extensors in 16 young, sedentary, male and female adults aged between 20 and 40. In another study, Silva et al. (2013) found a significant correlation between the 1RM test developed using an isoinertial device and the isokinetic test when they studied the conventional ratio in 32 men with a mean age of 23 years, who were experienced in resistance training. However, the total time required for the determination of the 1RM value associated with the increased risk of delayed-onset muscle soreness (DOMS), functional disability, and injury supports the recommendation of applying multiple repetition maximum tests instead of the 1RM test to assess muscle strength (Bazuelo-Ruiz et al., 2015; Ruf et al., 2018).

The multiple maximum repetition tests –which are constantly cited in the literature as submaximal tests and have less association with functional disability and DOMS– can be applied to trained individuals and beginners (Bazuelo-Ruiz et al., 2015; Niewiadomski et al., 2008). Dohoney, Chromiak, Lemire, Abadie, and Kovacs (2002) reported that it is possible to predict strength with no risk of injuries through submaximal repetition tests ranging from 4–6RM to 7–10RM. Hence, due to its similarity with the isokinetic test protocol, the 5RM test can predict the conventional isokinetic ratio values more accurately (Bazuelo-Ruiz et al., 2015).

Moreover, isokinetic muscle actions, in which a variable overload is moved at a constant angular velocity, are less associated with daily activities and sports movements (Plautard et al., 2018; Van Hooren et al., 2017). Thus, isoinertial analysis can be used to determine the conventional ratio appropriately when using bodybuilding equipment in tests that show a greater correlation with movement patterns and gym routines (Picerno & Manno, 2017).

Assessing muscle strength and conventional ratio can help identify possible differences in the strength magnitude between the anterior and posterior thigh muscles. This may be useful for programs aimed at preventing and rehabilitating lower limbs muscle and joint injuries (Mondin et al., 2018; Sinacore et al., 2017). The relationship between the submaximal repetition tests conducted with isoinertial devices and isokinetic equipment has not yet been well established (Ferraresi et al., 2013; Lee et al., 2018). Thus, the present study hypothesizes that the conventional ratio values verified through a 5RM test and those verified with the isokinetic device will present a positive correlation. Therefore, this study aimed to analyze the conventional ratio values of the knee flexors and extensors obtained through the 5RM test conducted with trained individuals using an isoinertial device and an isokinetic dynamometer.

## Methods

### Participants

This study is characterized as a comparative and correlational experimental research to verify possible associations between the study variables (Thomas et al., 2012).

The sample size was calculated using the GPower 3.1 program (Germany) (Faul et al., 2007; Faul et al., 2009), considering a two-tailed correlation model with an effect size of 0.6, an alpha error probability of 0,05, and power of 0,80 (Beck, 2013). The sample size calculated with this information was 17 participants.

The participants were male adults, aged between 22 and 31, physically active, experienced between 6 months and 2 years in strength training, and a training frequency between 4 and 6 sessions per week. As inclusion criteria, the individuals had to practice the proposed exercises for at least 6 months with a minimum frequency of 2 sessions per week before the assessment. The study adopted the following exclusion criteria: Individuals who had pain that could interfere with exercise performance, a positive result to a Physical Activity Readiness Questionnaire (PAR-Q), or failing to attend any of the test stages. Two individuals were excluded for lacking data collection in the second stage of the study. Finally, the sample included 15 male individuals experienced in resistance training (age: 28,47 ± 5,78 years; body mass: 78,30 ± 6,59 kg; height: 1,79 ± 0,65 m).

This study conformed to the specific legislation 466/2012 Resolution of the Brazilian National Health Council and the Declaration of Helsinki and was approved by HUPE-UERJ Research Ethics Committee under the number 3,233,005. All participants signed the consent form.

### Data Collection Procedures

The experimental protocol was conducted in three sessions with a minimum interval of 96 hours between them. On the first session, the anthropometric measurements of height and body mass of the participants were recorded using a mechanical anthropometric scale with a stadiometer (Welmy, model 110CH, São Paulo, Brazil). Subsequently, the participants received information about the test protocols.

The isokinetic and isointerial tests were conducted in the following two sessions. The tests were conducted randomly to the participants to avoid possible effects regarding the order in which the tests were performed (Carvalho et al., 2013). The participants executed the isokinetic knee flexion and extension tests using a Cybex model dynamometer at a speed of 60°/s. The data collected during the tests to be analyzed were the concentric knee flexion, the extension peak torque, and the conventional ratio (Croix et al., 2017; Lauermann et al., 2014; Minozzo et al., 2018).

The participants executed the 5RM tests in leg extension (Technogym M991, ITA) and leg curl machines (Technogym M990, ITA). We recorded the total load lifted by the participants for the later calculation of the mechanical torque and the conventional ratio for the condition tested (Bazuelo-Ruiz et al., 2015).

The exercises were performed smoothly and continuously on the isoinertial machines. This strategy was chosen in accordance with Sabino's statement, which affirms that a low speed of 60°/s in the isokinetic test allows reproducing the exercise in isoinertial machines, which are used in clinical environments where it is not possible to precisely control the execution speed (Sabino et al., 2016).

The participants were instructed not to perform any physical activity and not to ingest any stimulant substances (caffeine or alcohol) on the day before or on the day of the tests. The use of such substances could affect their performance in the experiment proposed in the present study, as caffeine can increase physical performance (Wilk et al., 2019) and alcohol can reduce sleep quality and energy levels (Devenney et al., 2019).

### 5RM Test

The order in which the tests were performed was randomized by assigning the participants shuffled cards labeled with numbers to generate a random sequence (Carvalho et al., 2013). The tests were interrupted when the participants performed the movement using the incorrect technique and/or when they produced voluntary concentric failures on 5RM. Concentric failures means that the participants were unable to maintain the cadence or that they did not complete the movement.

To reduce the margin of error during the 5RM test performance, the strategic measures recommended in the studies of Bezerra et al. (2009) were applied. The participants estimated the initial load they would lift and 2.5 or 5 kg were added in each attempt. The repetition stipulated was a maximum of 3 attempts for each exercise. During warm-up, the participants performed one set with 50% of the initially estimated weight. During the 5RM test, the intervals between each attempt were five minutes. After the participants lifted the estimated load for a given exercise, a minimum time of 20 minutes was respected before they performed the next. The performance techniques for all the exercises were standardized for all tests.

To calculate the conventional ratio in the isoinertial device, the flexion and extension torque were obtained with the 5RM test after correcting the lever arm, which is considered as the distance between the tibial plateau and the lateral malleolus in the dominant member (Américo et al., 2011). Leg weight was added to the 5RM value obtained in the leg extensor machine and subtracted in the leg curl machine. Subsequently, the values were multiplied by the acceleration of gravity (9.8 $m/s^2$) and, finally, multiplied by tibia length to calculate the torque. The ratio was obtained by dividing the flexion torque by the extension torque (Américo et al., 2011; Silva et al., 2013). We also performed the calculation of the conventional load ratio, dividing only the absolute loads of 5RM verified in the test.

### Standard Performance of the Exercise on the Leg Extension Machine

To perform the exercise on the leg extension machine, the participants remained seated, with their spines straight, the arms positioned beside their trunks, and the knees with a 90° flexion as certified by a goniometer (Carci, São Paulo, Brazil). During the exercise, the participants performed the extension and flexion movements with their knees using the dominant limb until the leg was completely extended. The criteria observed to determine movement failure were the extension described above, moving the back away from the chair and/or inclining the trunk during the exercise (Chaves et al., 2004). The dominant side was determined as the leg preferred by the participants to kick a ball and to climb a step of approximately 40 centimeters. In the cases in which there were differences between the initial tests the leg moved by the participants to avoid a forward fall was defined as the dominant limb (Ruiter et al., 2010).

### Standard Performance of the Exercise on the Leg Curl Machine

The participants remained seated to perform the exercise on the leg curl machine, with their spines fully supported on the upholstery, their arms positioned at the side of their bodies, their hands holding the support of the device, knees fully extended, and the roller of the device positioned on the distal posterior part of both legs. During the exercise, the individuals performed knee flexion with the dominant limb up to an angle of 90° between the leg and the thigh, as certified by a goniometer (Carci, São Paulo, Brazil), this being the endpoint observed to determine movement failure (Chaves et al., 2004; Maior et al., 2005).

### Isokinetic Dynamometer

Before performing the isokinetic test, the participants practiced with an ergometer cycle (Monark, Ergomedic 828E, Vansbro, Sweeden) for 5 minutes with a load of 25W to warm up. After warming up, the participants were positioned and stabilized in the dynamometer (Ronkonkoma, model Cybex Norm, New York, USA), with belts and velcro mounted on the thigh, hip, and trunk to avoid compensatory movements. The inclination of the back of the chair was set to 85°, the epicondyle of the knee was aligned with the axis of rotation, and the support of the lever arm was fixed in the distal part of the leg above the medial malleolus of the tibia. The participants performed one set of 5RM knee flexions and extensions at 60°/s using their dominant limb. The angular range of the knee extension and flexion was 0° (total knee extension) to 90° (knee flexion). The participants were familiarized with the equipment and the speed at which they would be evaluated by performing 3 submaximal repetitions at 60°/s. During the maximum contractions, the participants received visual and verbal stimuli (Santos et al., 2014; Silva et al., 2013; Weber et al., 2010).

The variables collected with the isokinetic device to be later analyzed were the concentric knee flexion and the extension peak torque. The conventional ratio was calculated at a speed of 60°/s by dividing the flexor torque by the extensor torque.

### Statistical Analyses

The data collected were processed using the IBM SPSS Statistics 23 statistical program and presented as mean, standard deviation, and minimum and maximum values. The Shapiro-Wilk test was applied for the analysis of normality. A Student t-test was used to compare the torque obtained with the isokinetic and the isoinertial devices. A One-way ANOVA, followed by a Bonferroni post hoc, was applied to identify possible differences between the conventional ratio obtained with the isokinetic dynamometer, using an adjusted torque in the 5RM test, and absolute values of 5RM. The Pearson correlation test was used to analyze the possible associations between the study variables. An equation model to calculate the conventional isokinetic ratio from the conventional ratio of the 5RM test was estimated with a Stepwise linear regression method. A Student's t-test for dependent samples was applied to compare the possible differences between the conventional isokinetic ratio and 5RM ratios. The Bland and Altman test was used to analyze the level of agreement between the results of the obtained and predicted conventional ratios. The level of $p < 0,05$ was adopted for statistical significance.

## Results

Table 1 presents the sample characteristics and the results of the 5RM test. The study variables presented a distribution close to the normal curve.

**Tabla 1**

*Mauris et orci*

| Variables | Mean | SD | Minimum | Maximum | p-value (SW) |
|---|---|---|---|---|---|
| Age (years) | 28,47 | 5,78 | 22,00 | 47,00 | 0,051 |
| Body mass (kg) | 78,30 | 6,59 | 67,00 | 91,00 | 0,954 |
| Height (m) | 1,79 | 0,06 | 1,65 | 1,90 | 0,817 |
| BMI (kg/m$^2$) | 24,47 | 1,23 | 21,78 | 26,30 | 0,256 |
| Tibia length (m) | 0,38 | 0,01 | 0,35 | 0,40 | 0,408 |

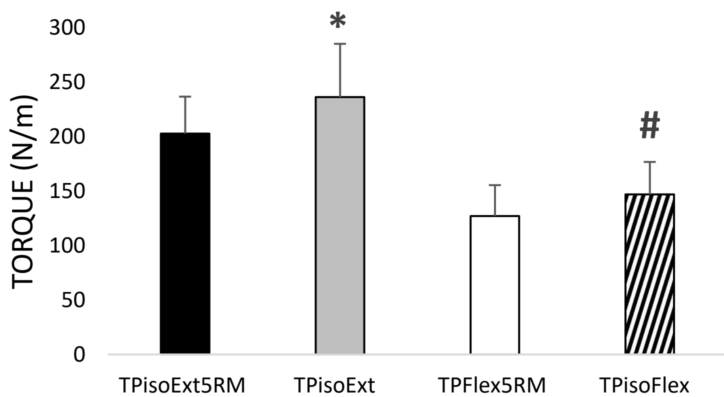
| | | | | | |
|---|---|---|---|---|---|
| Ext5RM (kg) | 49,67 | 7,13 | 40,00 | 62,50 | 0,112 |
| Flex5RM (kg) | 38,83 | 6,87 | 25,00 | 52,50 | 0,951 |

SD = standard deviation; BMI = body mass index; Ext5RM = extension 5RM value; Flex5RM = flexion 5RM value; SW = Shapiro-Wilk.

Figure 1 shows the comparison of the torque values for knee flexion and extension performed with an isoinertial and an isokinetic device. The comparison between the devices showed that the torque values obtained with the isokinetic device were higher for flexor torque ($p = 0,003$) and for extensor torque ($p < 0,001$) when compared to the values obtained with the isoinertial devices in 5RM.

**Figure 1**

*Mechanical torque values obtained with isoinertial and isokinetic devices (N/m).*




TPisoExt5RM = corrected extensor torque peak; TPisoExt = isokinetic extensor torque peak; TPflex5RM = corrected flexor torque peak; TPisoFlex = isokinetic flexor torque peak.

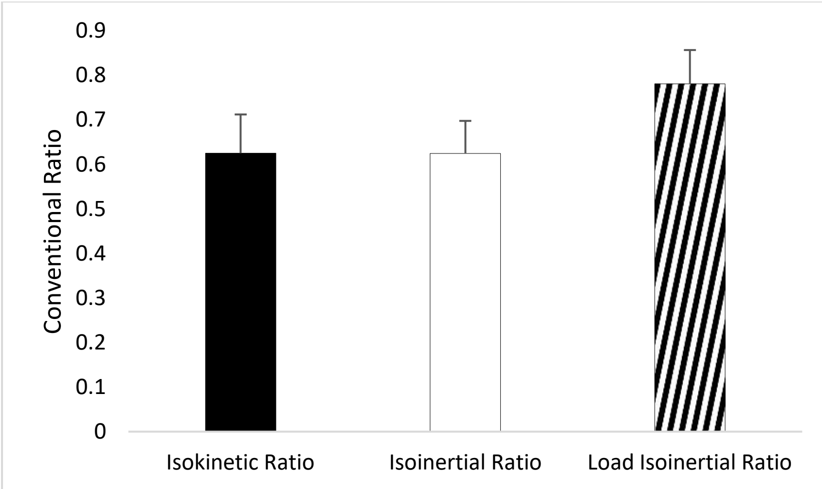
* p<0,05, significant difference between TPisoExt5RM and TPisoExt.

# p<0,05, significant difference between TPflex5RM and TPisoFlex.

Figure 2 shows the comparison between the ratio obtained with the isokinetic device and the ratio verified with the torque adjusted in the isoinertial device in the 5RM test, and the ratio verified by the absolute load. The values showed no difference between the three measures.

**Figure 2**

*Comparison between the isokinetic ratio, the isoinertial ratio, and the load isoinertial ratio.*




The study showed a negative correlation between age and isoinertial conventional ratio (r = - 0,659; p = 0,008). The 5RM test-corrected extensor and flexor torque peaks showed significant positive correlations with the respective isokinetic data (r = 0,809; p < 0,001; r = 0,722; p = 0,002, respectively).

Table 2 presents the results of the correlations between the conventional ratio values obtained in the isokinetic device (IsoRatio), in the isoinertial device with the calculation of the peak torque (Ratio5RM), and in the isoinertial device with the absolute load of the 5RM test (Ratio5RML). Correlations were observed between the three ways of calculating the conventional ratio.

**Table 2**

*Correlation between the conventional ratio in the isokinetic device, the isoinertial device, and the isoinertial load model.*

| | IsoRatio | Ratio5RML |
|---|---|---|
| Ratio5RML | r = 0,649* | |
| | p = 0,009 | |
| Ratio5RM | r = 0,613* | r = 0,984* |
| | p = 0,015 | p < 0,001 |

* p<0,05, Pearson correlation; IsoRatio = isokinetic ratio; Ratio5RML = ratio verified in the 5RM test through the load values; Ratio5RM = adjusted ratio verified in the 5RM test.

The regression analysis showed that the ratio obtained through the absolute load verified in the 5RM test correlates with the isokinetic reference ratio. The regression equation for isokinetic value prediction was modeled as follows: Isokinetic ratio = 0,036 + (Ratio5RML × 0,755), with a standard error of estimate (SEE) of 0,069, R of 0,649, $R^2$ of 0,421, and adjusted $R^2$ of 0,376. Figure 3 shows the trend line generated between the isokinetic ratio and the ratio predicted by the equation.

**Figure 3**

Association between the ratio predicted by the equation and the isokinetic ratio.

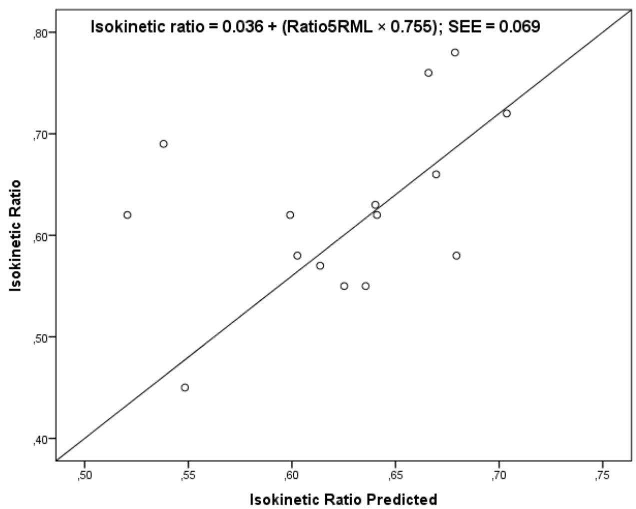



Table 3 presents the comparison between the isokinetic ratio and the predicted isokinetic ratio obtained using the absolute load values of the 5RM test (5RML). The result of the paired t-test showed no significant difference between the means of the isokinetic ratio and the ratio predicted by the equation. These findings support the use of the equation to predict the isokinetic ratio.

**Table 3**

*Comparison between isokinetic ratio and the predicted isokinetic ratio.*

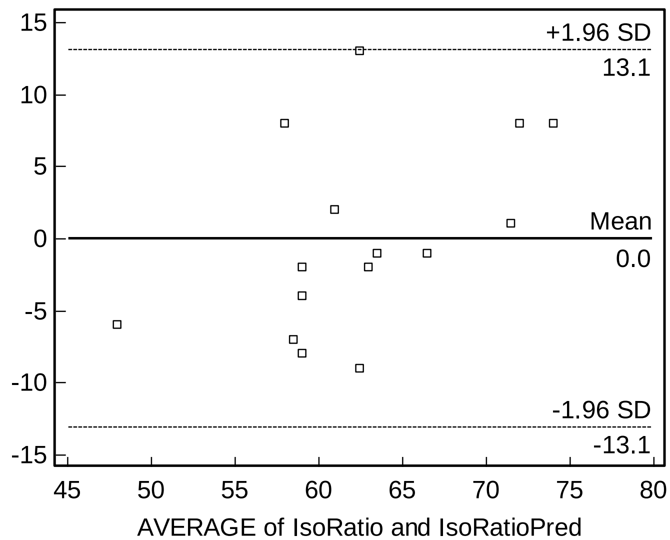
| IsoRatio | IsoRatioPred | Δ | p-valor | R |
|---|---|---|---|---|
| 0,63 | 0,62 | 0,00067 | 0,971 | 0,642 |

IsoRatio = isokinetic ratio; IsoRatioPred = isokinetic ratio predicted by the 5RM test.

Figure 4 shows the results of the Bland and Altman test. It was found that the results obtained using the mean differences between the isokinetic ratio and the isokinetic ratio predicted using the 5RM test had adequate levels of agreement.

**Figure 4**

*Analysis of agreement between the obtained (IsoRatio) and the predicted isokinetic (IsoRatioPred) means differences.*




## Discussion

The results of the present study showed no significant differences between the conventional ratio of knee flexors and extensors evaluated in the 5RM test performed on isoinertial machine with the ratio verified in isokinetic dynamometry in trained individuals. The conventional ratio performed by the participants with the adjusted torque and verified with the load absolute values of the 5RM test did not show any difference either. There was a significant and positive correlation between the conventional isokinetic ratio and the conventional ratio for the absolute load obtained by the 5RM test, which enabled a regression for prediction.

Silva et al. (2013) studied the applicability and accuracy of the conventional ratio assessment using isoinertial resistance machines. The authors applied the 1RM test and the isokinetic test to 32 volunteers to obtain the values of the conventional ratio, the maximum strength, and the peak torque (PT) of the knee flexors and extensors. Significant correlations were observed between the 1RM ratio and the isokinetic ratio ($r = 0,65$, $p < 0,001$). These findings were similar to the ones from the present study, which revealed a similar correlation between both ways of calculating the conventional ratio.

Sabino et al. (2016) compared the means of the ratio obtained using an isokinetic dynamometer and those obtained using the 1RM test and observed a strong correlation ($r = 0,89$, $p < 0,05$). The authors indicated that the 1RM ratio tends to overestimate isokinetic results when they are considered high and to underestimate them when they are considered low. However, these considerations were not observed in the present study. This may have occurred due to the application of the 5RM test, as this test is closer to the participants' actual practice because it uses loads and repetitions that are similar to their training sessions and due to the characteristics of the isokinetic protocol adopted to evaluate conventional ratio.

Taylor and Fletcher (2013) used the 8RM test to measure muscle strength and compare it with the reference value of the isokinetic test. Thirty volunteers performed an 8RM test and an isokinetic test at three different angular velocities (60°, 120°, and 240°/s). The results showed significant correlations between the 8RM and the PT at each of the assessed velocities with a correlation coefficient (r) between 0,71 and 0,85 with the highest correlation values related to lower angular speeds. These results were similar to the findings of the present study and reinforce the possibility of using maximal repetition tests as an alternative to isokinetic and 1RM tests.

The results observed in the studies previously mentioned indicate that RM tests have satisfactory reproducibility when compared to the results obtained with isokinetic devices. In the present study, 37% of the variability of the isokinetic ratio was predicted by the 5RML. Therefore, the 5RML ratio value can be corrected using the regression equation to predict the isokinetic ratio value. There was no difference ($p > 0,05$) between the means of the isokinetic ratio and the ratio predicted by the equation, a result that strengthens the use of the equation to calculate the conventional ratio.

In the present study, the analysis of the corrected extension and the flexion PT showed significant correlations with the corresponding isokinetic data. In the study of Silva et al. (2013), the correlation between the extension PT and the value obtained in the 1RM test on the leg extension machine was 0,75 ($p < 0,001$) and 0,73 ($p < 0,001$) for the corresponding flexion data. Taylor and Fletcher

(2013) found even higher values of the correlation coefficient (r) when analyzing the 8RM test and isokinetic PT at 60°/s, which were 0,85 ($p < 0{,}001$). These values are similar to those observed in the present study: 0,80 between the corrected extension PT and the isokinetic extension PT, and 0,72 between the corrected flexion PT and the isokinetic flexion PT. The results showed moderate to strong correlations, which can be attributed to the specificity of the test. Both the mentioned studies and the present study used the same range of motion and movement pattern in the tests.

Furthermore, in the present study, significant correlations were observed between the 5RM ratio and the knee flexion strength values in the two conditions analyzed, which were the 5RM test performed on the leg flexion machine (r = 0,690; p < 0,05) and the corrected flexion torque peak (r = 0,680; p < 0,05). However, no correlations were observed with strength when the knee extensors were under the same conditions. Knee flexors' strength is crucial for muscular balance due to their role in maintaining the stability of the knee joint (Baroni et al, 2020). Increasing muscle strength, angular speeds, or work overload, such as when strength is tested, ultimately results in increased conventional ratio (Baroni et al., 2020). The reduction or increase of thigh strength results in decreased or increased conventional ratio (Américo et al., 2011), which explains the results here observed.

The current study has some limitations. One of them is that the 1RM test was not used for comparison, as this test is considered important in the evaluation of muscle strength under non-laboratory conditions. Moreover, the maximum force and the peak torque values obtained with the 1RM test could be compared to the values of the isokinetic and multiple repetition tests. This could generate greater robustness to the findings of the present study. Another limitation is the absence of evaluation of the different patterns of muscle activation and bows of movement. Lastly, the data for this study were collected from young, healthy and physically active male individuals and may not necessarily be replicated for other populations. Thus, the results of this study should be interpreted with caution.

## Conclusion

The results of the present study did not show differences for the conventional ratio verified with an isokinetic dynamometer, the ratio verified with the adjusted torque of 5RM and that obtained only with the load values. There was a positive correlation between the conventional ratio determined in the three protocols.

Thus, the use of RM tests in isoinertial machines to estimate the conventional ratio of knee flexors and extensors showed to be favorable as an option to the isokinetic test and supports the use of the regression equation to estimate the conventional ratio in a simple way for male individuals experienced in strength training. This enables an increase in the efficiency of physical exercise programs aimed at the prevention and rehabilitation of lower limb injuries in trained individuals.

Future studies should consider samples with women, older individuals, participants with other training levels and different patterns of muscle activation and bows of movement. Moreover, research conducted with upper-limbs may contribute to new findings concerning strength asymmetry and imbalance in internal and external rotator shoulder muscles or elbow flexors and extensors.

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