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Original article

Resistance training of knee flexors and extensors: is there a relationship between the number of weekly repetitions and antagonist agonist balance?

Treinamento de resistência de flexores e extensores de joelho: existe relação entre o número de repetições semanais e equilíbrio de agonistas antagonistas?

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ABSTRACT

Introduction: Weekly volume training is a monitoring method and can show balance in muscles involved in joint movements, as quadriceps and hamstring muscles to knee extension and flexion movements. The hamstring (H)/quadriceps (Q) ratio in isokinetic torque test is a way to analysis for knee injury risk. **Objective:** test the hypothesis that there is a relationship between the volume of repetitions weekly RT and the balance of the knee extensors and flexors muscles. **Methods:** To evaluate the relationship between the weekly repetitions volume and muscle balance of knee extensors and flexors in 21 strength trained subjects in isokinetic torque test at 60°/s and 300°/s angular velocities. **Results:** The data analysis demonstrated that there was no difference in the weekly volume of reps performed for Q and H and shows poor H/Q ratio at 60°/s, despite of a good H/Q ratio at 300°/s. **Conclusion:** These data contradict the current literature, as studies show differences in weekly volume training between quadriceps and hamstring, as well as better values of H/Q ratio at 60°/s for no knee injury people. Our data contribute to the ongoing discussion about muscle balance and preservation of knee health.

Keywords: strength training; agonists and antagonists; muscle balance; resistance training.

RESUMO

Introdução: O treinamento de volume semanal é um método de monitoramento e pode mostrar o equilíbrio dos músculos envolvidos nos movimentos articulares, como quadríceps e isquiotibiais até os movimentos de extensão e flexão do joelho. A relação isquiotibiais (I)/quadríceps (Q) no teste de torque isocinético é uma forma de analisar o risco de lesão no joelho. **Objetivo:** Testar a hipótese de que existe relação entre o volume de repetições semanais de TR e o equilíbrio dos músculos extensores e flexores do joelho. **Métodos:** Avaliar a relação entre o volume de repetições semanais e o equilíbrio muscular dos extensores e flexores do joelho em 21 sujeitos treinados em teste de torque isocinético em velocidades angulares de 60°/s e 300°/s. **Resultados:** A análise dos dados demonstrou que não houve diferença no volume semanal de repetições realizadas para Q e I, e apresentar ser pobre em I/Q, apesar de uma boa relação I/Q pobre em 300°/s. **Conclusão:** Esses dados contradizem a literatura atual, pois estudos mostram diferenças no treinamento de volume semanal entre quadríceps e isquiotibiais, bem como melhores valores da relação I/Q a 60°/s para pessoas sem lesão no joelho. Nossos dados contribuem para a discussão contínua sobre o equilíbrio muscular e a preservação da saúde do joelho.

Palavras-chave: treinamento de força; agonistas e antagonistas; equilíbrio muscular; treinamento de resistência.

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Introduction

The number of repetitions per muscle group is an important variable to determine the training volume and it is considered important that both agonist and antagonist muscles should be equally trained to maintain an adequate muscle balance [1]. An imbalance between agonist and antagonist muscles could increase the risk of injury [2-4]. The isokinetic dynamometer is the gold standard method to determine important muscle performance variables such as strength, power, work, and balance in muscle groups [5].

The hamstring-to-quadriceps ratio (H/Q) is the result of the peak torque value of knee flexors/extensors equation in concentric/concentric mode [6-8]. Although some studies investigated the optimal weekly repetitions volume per muscle group [9] and several studies have assessed the relationship between agonist and antagonist muscles balance using the isokinetic dynamometer [6,10-14], few studies have associated the weekly repetitions volume with the deficit of knee joint flexor and extensor muscle strength. The objective of this study is to test the hypothesis that there is a relationship between the volume of weekly repetitions of RT and the balance of the knee extensor and flexor muscles.

Métodos

Subjects

21 subjects (male n = 10; female n = 11) were recruited by convenience. They were training in a fitness center, with time of experience at last three years, informed by an interview, and had no knee injuries. All subjects were informed of the experimental procedures and subsequently provided written informed consent to participate. The study was approved by the Research Ethics Committee of the Metropolitan University of Santos (protocol 1.598.072).

Weekly repetitions volume

Exercises were selected considering specific exercises for the quadriceps muscles (Q) and hamstrings muscles (H) according to the table proposed by Teixeira *et al*. [15]. The analysis of weekly repetitions volume performed per muscle group of each subject was calculated by the equation: number of repetitions x number of sets x weekly training frequency per muscle group.

Research tool

To evaluate muscle performance and balance, the researchers used an isokinetic dynamometer (Biodex, Lumex Inc., Ronkonkoma, NY, USA), from the Department of Human Movement Sciences, Epidemiology and Human Movement Laboratory (EPIMOV), Santos (SP Brazil).

Procedures

Initially, all subjects were familiarized with the isokinetic dynamometer test. Each subject was positioned on the knee-testing table of the isokinetic dynamometer with the stabilization straps across the chest and a horizontal pad over the middle third and proximal half of the distal third of the thighs. The trunk was against the backrest of the testing table. The knee joint axis was aligned with the mechanical axis of the dynamometer. The initial range of motion of the knee joint was 90° flexion. Once positioned, the subjects performed a familiarization session with three submaximal repetitions at the same speeds used in the tests in order to reduce the learning effects and to guarantee reproducibility of the data collecting [16]. The maximal tests and concentric contraction of extensors and flexors were performed in the dominant limb, one with an angular velocity of 60°/s (a set of five repetitions) and 3000/s (a set of 30 repetitions) to analyze the variables. The muscle contraction variables measured were average peak torque, average power, total work output and the H/Q.

The subjects performed five cycles of the extensor/flexor muscles concentric contraction with maximal effort and were strongly encouraged by the researcher during all the test procedure [17]. Gravitational influence was corrected during the test.

To descriptive data, after confirmation of non-normality by Shapiro-Wilk test, Mann-Whitney test was chosen to comparisons the body mass index (BMI), time of practice and weekly hamstring muscle training volume, all between sexes, while after confirmation of normality, t Student test was chosen to comparison age, weight, height and weekly quadriceps muscle training volume, all between sexes. The results of sexes comparison descriptive data shows no significant differences between sexes for hamstring and quadriceps weekly volume training, and shows significant differences for BMI, weight and height. Therefore, the comparison of peak torque and muscles volume training (hamstring and quadriceps) were limited only intragroups.

The Shapiro-Wilk test shows non-normality for both sexes weekly hamstring and quadriceps volume training, for all peak torque velocities, and for agonist/antagonist ratio. Therefore, Wilcoxon test was chosen to compare intragroups the weekly training volume of the hamstring muscle and quadriceps muscle exercises, and to comparison between the peak torque of the knee flexors and extensors isokinetic tests. Spearman correlation test was chosen to verify the association between weekly volume training and muscular torque results.

The Shapiro-Wilk test shows for H/Q at 60o/s and at 300o/s in both sexes groups, so t Student test was chosen to compare this ratio between maximus force (60o/s) and resistance force (300o/s). The significance adopted for all analysis was $p \leq 0.05$.

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Results

Table I shows the general characteristics of the sample. Men are heavier and have greater height when compared to women; therefore, in the analysis of BMI, males are classified as overweight and females eutrophic. About the time of strength training practice, 81% of the sample has at least 6 years of systematic and uninterrupted training.

Table I - Data description of participants recruited

Subjects	Age (years)	Weight (kg)	Height (m)	BMI (kg / m²)	Time of practice (anos)
			Men		
1	31.00	70.00	1.75	22.86	6.00
2	23.00	89.00	1.76	28.73	6.00
3	30.00	85.00	1.73	28.40	10.00
4	27.00	88.00	1.88	24.90	6.00
5	26.00	119.00	1.78	37.56	7.00
6	27.00	90.00	1.78	28.41	7.00
7	48.00	87.00	1.86	25.15	20.00
8	45.00	77.00	1.71	26.33	20.00
9	45.00	81.00	1.81	24.72	25.00
10	30.00	67.00	1.75	21.88	6.00
Average	**33.20**	**85.30***	**1.78***	**26.89****	**11.30**
SD	**9.16**	**14.29**	**0.05**	**4.41**	**7.38**
			Women		
1	30.00	65.00	1.65	23.88	8.00
2	37.00	70.00	1.69	24.51	10.00
3	34.00	64.00	1.68	22.68	8.00
4	18.00	70.00	1.76	22.60	3.00
5	21.00	66.00	1.73	22.05	3.00
6	21.00	71.00	1.74	23.45	3.00
7	41.00	58.00	1.55	24.14	20.00
8	43.00	54.00	1.50	24.00	10.00
9	37.00	64.00	1.64	23.80	20.00
10	43.00	49.00	1.49	22.07	3.00
11	21.00	82.00	1.69	28.71	7.00
Average	**31.45**	**64.82**	**1.65**	**23.81**	**8.64**
SD	**9.68**	**8.96**	**0.09**	**1.83**	**6.27**

SD = standard deviation; kg = kilograms; m = meters; *$p \leq 0{,}05$ by t Student test sexes comparison; ** $p \leq 0{,}05$ by Mann-Whitney test sexes comparison

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Table II shows similar weekly training for hamstring and quadriceps in both sexes groups. All knee extension variables produced significantly more maximum strength, muscle endurance and muscle power when compared to knee flexion for both genders. However, significant differences were found between extension and flexion isokinetic for all parameters.

Table II - Comparisons between weekly muscles volume training, peak torque and power

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Men														
Average	46.30	43.30	271.20[a]	131.07	137.72[b]	88.32	173.51[c]	97.48	276.35[d]	162.66	249.96[e]	124.14	101.90[f]	67.70
SD	10.50	7.67	60.98	24.04	32.27	21.08	41.51	21.94	48.54	38.49	61.38	25.49	23.16	12.84
Women														
Average	45.36	45.27	175.33[g]	79.97	93.09[h]	62.32	115.58[i]	57.82	181.11[j]	105.47	162.04[k]	74.39	68.06[l]	47.55
SD	13.31	13.34	44.63	18.76	20.58	13.55	35.19	17.25	50.32	30.14	41.58	18.69	17.74	8.61

SD = standard deviation; A = weekly quadriceps volume training; B = weekly hamstring volume training; C = extension peak torque 60o/s (Nm); D = flexion peak torque 60o/s (Nm); E = extension peak torque 300o/s (Nm); F = flexion peak torque 300o/s (Nm); G = extension power 60o/s (watts); H = flexion power 60o/s (watts); I = extension power 300o/s (watts); J = flexion power 300o/s (watts); K = extension average peak torque 60o/s (Nm); L = flexion average peak torque 60o/s (Nm); M = extension average peak torque 300o/s (Nm); N = flexion average peak torque 300o/s (Nm); a = p ≤ 0,05 by Wilcoxon test C vs D in men group;b = p ≤ 0,05 by Wilcoxon test E vs F in men group; c = p ≤ 0,05 by Wilcoxon test G vs H in men group; d = p ≤ 0,05 by Wilcoxon test I vs J in men group; e = p ≤ 0,05 by Wilcoxon test K vs L in men group; f = p ≤ 0,05 by Wilcoxon test M vs N in men group; g = p ≤ 0,05 by Wilcoxon test C vs D in women group; h = p ≤ 0,05 by Wilcoxon test E vs F in women group; i = p ≤ 0,05 by Wilcoxon test G vs H in women group; j = p ≤ 0,05 by Wilcoxon test I vs J in women group; k = p ≤ 0,05 by Wilcoxon test K vs L in women group; l = p ≤ 0,05 by Wilcoxon test M vs N in women group

Strong and significant correlations was found between parameters for each concentric movement (extension and extension or flexion and flexion), as between concentric movements (extension and flexion), as show at tables III and IV.

Table III - Correlation men group (part 1)

		A1	B1	C1	D1	E1	F1	G1	A2	B2	C2	D2	E2	F2	G2
A1	Correlation coefficient	1.000	-0.228	-0.272	0.006	-0.228	0.006	-0.336	.907**	-0.488	-0.488	-0.304	-0.095	-0.443	-0.545
	Sig. (2 extremes)		0.526	0.446	0.986	0.526	0.986	0.343	0.000	0.153	0.153	0.393	0.794	0.199	0.103
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
B1	Correlation coefficient	-0.228	1.000	0.588	.903**	0.539	.939**	0.612	-0.380	.891**	.697*	.806**	0.479	.842**	.697*
	Sig. (2 extremes)	0.526		0.074	0.000	0.108	0.000	0.060	0.279	0.001	0.025	0.005	0.162	0.002	0.025
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
C1	Correlation coefficient	-0.272	0.588	1.000	.721*	.927**	.685*	.988**	-0.386	0.600	.806**	0.430	0.430	0.491	.661*
	Sig. (2 extremes)	0.446	0.074		0.019	0.000	0.029	0.000	0.270	0.067	0.005	0.214	0.214	0.150	0.038
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
D1	Correlation coefficient	0.006	.903**	.721*	1.000	.661*	.988**	.709*	-0.222	.806**	.721*	.782**	0.588	.770**	.685*
	Sig. (2 extremes)	0.986	0.000	0.019		0.038	0.000	0.022	0.538	0.005	0.019	0.008	0.074	0.009	0.029
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
E1	Correlation coefficient	-0.228	0.539	.927**	.661*	1.000	0.624	.952**	-0.367	0.588	.818**	0.455	0.527	0.467	.709*
	Sig. (2 extremes)	0.526	0.108	0.000	0.038		0.054	0.000	0.296	0.074	0.004	0.187	0.117	0.174	0.022
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
F1	Correlation coefficient	0.006	.939**	.685*	.988**	0.624	1.000	.673*	-0.184	.794**	.673*	.745*	0.503	.745*	.636*
	Sig. (2 extremes)	0.986	0.000	0.029	0.000	0.054		0.033	0.611	0.006	0.033	0.013	0.138	0.013	0.048
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
G1	Correlation coefficient	-0.336	0.612	.988**	.709*	.952**	.673*	1.000	-0.462	.661*	.867**	0.491	0.491	0.552	.733*
	Sig. (2 extremes)	0.343	0.060	0.000	0.022	0.000	0.033		0.178	0.038	0.001	0.150	0.150	0.098	0.016
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10

A1 = weekly quadriceps volume training; B1 = extension peak torque 60o/s (Nm); C1 = extension peak torque 300o/s (Nm); D1 = extension power 60o/s (watts); E1 = extension power 300o/s (watts); F1 = extension average peak torque 60o/s (Nm); G1 = extension average peak torque 300o/s (Nm); A2 = weekly hamstring volume training; B2 = flexion peak torque 60o/s (Nm); C2 = flexion peak torque 300o/s (Nm); D2 = flexion power 60o/s (watts); E2 = flexion power 300o/s (watts); F2 = flexion average peak torque 60o/s (Nm); G2 = flexion average peak torque 300o/s (Nm)
*$p \leq 0.05$ by Spearman test; ** $p \leq 0.01$ by Spearman test

Table III - Correlation men group (part 2)

		A1	B1	C1	D1	E1	F1	G1	A2	B2	C2	D2	E2	F2	G2
A2	Correlation coefficient	.907**	-0.380	-0.386	-0.222	-0.367	-0.184	-0.462	1.000	-.665*	-.665*	-0.545	-0.412	-.634*	-.710*
	Sig. (2 extremes)	0.000	0.279	0.270	0.538	0.296	0.611	0.178		0.036	0.036	0.103	0.237	0.049	0.022
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
B2	Correlation coefficient	-0.488	.891**	0.600	.806**	0.588	.794**	.661*	-.665*	1.000	.879**	.939**	.673*	.976**	.927**
	Sig. (2 extremes)	0.153	0.001	0.067	0.005	0.074	0.006	0.038	0.036		0.001	0.000	0.033	0.000	0.000
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
C2	Correlation coefficient	-0.488	.697*	.806**	.721*	.818**	.673*	.867**	-.665*	.879**	1.000	.770**	.636*	.818**	.952**
	Sig. (2 extremes)	0.153	0.025	0.005	0.019	0.004	0.033	0.001	0.036	0.001		0.009	0.048	0.004	0.000
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
D2	Correlation coefficient	-0.304	.806**	0.430	.782**	0.455	.745*	0.491	-0.545	.939**	.770**	1.000	.794**	.976**	.879**
	Sig. (2 extremes)	0.393	0.005	0.214	0.008	0.187	0.013	0.150	0.103	0.000	0.009		0.006	0.000	0.001
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
E2	Correlation coefficient	-0.095	0.479	0.430	0.588	0.527	0.503	0.491	-0.412	.673*	.636*	.794**	1.000	.697*	.721*
	Sig. (2 extremes)	0.794	0.162	0.214	0.074	0.117	0.138	0.150	0.237	0.033	0.048	0.006		0.025	0.019
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
F2	Correlation coefficient	-0.443	.842**	0.491	.770**	0.467	.745*	0.552	-.634*	.976**	.818**	.976**	.697*	1.000	.903**
	Sig. (2 extremes)	0.199	0.002	0.150	0.009	0.174	0.013	0.098	0.049	0.000	0.004	0.000	0.025		0.000
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10
G2	Correlation coefficient	-0.545	.697*	.661*	.685*	.709*	.636*	.733*	-.710*	.927**	.952**	.879**	.721*	.903**	1.000
	Sig. (2 extremes)	0.103	0.025	0.038	0.029	0.022	0.048	0.016	0.022	0.000	0.000	0.001	0.019	0.000	
	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10

A1 = weekly quadriceps volume training; B1 = extension peak torque 60o/s (Nm); C1 = extension peak torque 300o/s (Nm); D1 = extension power 60o/s (watts); E1 = extension power 300o/s (watts); F1 = extension average peak torque 60o/s (Nm); G1 = extension average peak torque 300o/s (Nm); A2 = weekly hamstring volume training; B2 = flexion peak torque 60o/s (Nm); C2 = flexion peak torque 300o/s (Nm); D2 = flexion power 60o/s (watts); E2 = flexion power 300o/s (watts); F2 = flexion average peak torque 60o/s (Nm); G2 = flexion average peak torque 300o/s (Nm).

*$p \leq 0.05$ by Spearman test; ** $p \leq 0.01$ by Spearman test

Table IV - Correlations for women group (part 1)

		A1	B1	C1	D1	E1	F1	G1	A2	B2	C2	D2	E2	F2	G2
	Correlation coefficient	1.000	-0.216	-0.230	-0.221	-0.174	-0.160	-0.268	.781**	-0.244	-0.103	-0.301	-0.202	-0.362	-0.183
A1	Sig. (2 extremes)		0.523	0.496	0.514	0.609	0.639	0.426	0.005	0.469	0.762	0.369	0.551	0.274	0.590
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.216	1.000	.745**	.964**	.664*	.973**	.645*	-0.395	.845**	.718*	.827**	.664*	.891**	0.545
B1	Sig. (2 extremes)	0.523		0.008	0.000	0.026	0.000	0.032	0.229	0.001	0.013	0.002	0.026	0.000	0.083
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.230	.745**	1.000	.836**	.955**	.755**	.945**	-.605*	.836**	.936**	.691*	.727*	.727*	.773**
C1	Sig. (2 extremes)	0.496	0.008		0.001	0.000	0.007	0.000	0.049	0.001	0.000	0.019	0.011	0.011	0.005
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.221	.964**	.836**	1.000	.755**	.982**	.727*	-0.479	.918**	.800**	.891**	.764**	.927**	.691*
D1	Sig. (2 extremes)	0.514	0.000	0.001		0.007	0.000	0.011	0.136	0.000	0.003	0.000	0.006	0.000	0.019
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.174	.664*	.955**	.755**	1.000	.664*	.982**	-0.516	.700*	.900**	.655*	.718*	.664*	.836**
E1	Sig. (2 extremes)	0.609	0.026	0.000	0.007		0.026	0.000	0.104	0.016	0.000	0.029	0.013	0.026	0.001
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.160	.973**	.755**	.982**	.664*	1.000	.627*	-0.377	.900**	.736**	.882**	.745**	.918**	0.582
F1	Sig. (2 extremes)	0.639	0.000	0.007	0.000	0.026		0.039	0.253	0.000	0.010	0.000	0.008	0.000	0.060
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	Correlation coefficient	-0.268	.645*	.945**	.727*	.982**	.627*	1.000	-0.535	.673*	.845**	0.591	.645*	.609*	.845**
G1	Sig. (2 extremes)	0.426	0.032	0.000	0.011	0.000	0.039		0.090	0.023	0.001	0.056	0.032	0.047	0.001
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11

A1 = weekly quadriceps volume training; B1 = extension peak torque 60o/s (Nm); C1 = extension peak torque 300o/s (Nm); D1 = extension power 60o/s (watts); E1 = extension power 300o/s (watts); F1 = extension average peak torque 60o/s (Nm); G1 = extension average peak torque 300o/s (Nm); A2 = weekly hamstring volume training; B2 = flexion peak torque 60o/s (Nm); C2 = flexion peak torque 300o/s (Nm); D2 = flexion power 60o/s (watts); E2 = flexion power 300o/s (watts); F2 = flexion average peak torque 60o/s (Nm); G2 = flexion average peak torque 300o/s (Nm)
*$p \leq 0.05$ by Spearman test; ** $p \leq 0.01$ by Spearman test

Table IV - Correlation women group (part 2)

		A1	B1	C1	D1	E1	F1	G1	A2	B2	C2	D2	E2	F2	G2
A2	Correlation coefficient	.781**	-0.395	-.605*	-0.479	-0.516	-0.377	-0.535	1.000	-0.530	-0.586	-0.554	-0.493	-.605*	-0.395
	Sig. (2 extremes)	0.005	0.229	0.049	0.136	0.104	0.253	0.090		0.093	0.058	0.077	0.123	0.049	0.229
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
B2	Correlation coefficient	-0.244	.845**	.836**	.918**	.700*	.900**	.673*	-0.530	1.000	.809**	.836**	.845**	.873**	.627*
	Sig. (2 extremes)	0.469	0.001	0.001	0.000	0.016	0.000	0.023	0.093		0.003	0.001	0.001	0.000	0.039
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
C2	Correlation coefficient	-0.103	.718*	.936**	.800**	.900**	.736**	.845**	-0.586	.809**	1.000	.718*	.800**	.745**	.655*
	Sig. (2 extremes)	0.762	0.013	0.000	0.003	0.000	0.010	0.001	0.058	0.003		0.013	0.003	0.008	0.029
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
D2	Correlation coefficient	-0.301	.827**	.691*	.891**	.655*	.882**	0.591	-0.554	.836**	.718*	1.000	.873**	.982**	.664*
	Sig. (2 extremes)	0.369	0.002	0.019	0.000	0.029	0.000	0.056	0.077	0.001	0.013		0.000	0.000	0.026
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
E2	Correlation coefficient	-0.202	.664*	.727*	.764**	.718*	.745**	.645*	-0.493	.845**	.800**	.873**	1.000	.845**	.664*
	Sig. (2 extremes)	0.551	0.026	0.011	0.006	0.013	0.008	0.032	0.123	0.001	0.003	0.000		0.001	0.026
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
F2	Correlation coefficient	-0.362	.891**	.727*	.927**	.664*	.918**	.609*	-.605*	.873**	.745**	.982**	.845**	1.000	.609*
	Sig. (2 extremes)	0.274	0.000	0.011	0.000	0.026	0.000	0.047	0.049	0.000	0.008	0.000	0.001		0.047
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11
G2	Correlation coefficient	-0.183	0.545	.773**	.691*	.836**	0.582	.845**	-0.395	.627*	.655*	.664*	.664*	.609*	1.000
	Sig. (2 extremes)	0.590	0.083	0.005	0.019	0.001	0.060	0.001	0.229	0.039	0.029	0.026	0.026	0.047	
	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11

A1 = weekly quadriceps volume training; B1 = extension peak torque 60o/s (Nm); C1 = extension peak torque 300o/s (Nm); D1 = extension power 60o/s (watts); E1 = extension power 300o/s (watts); F1 = extension average peak torque 60o/s (Nm); G1 = extension average peak torque 300o/s (Nm); A2 = weekly hamstring volume training; B2 = flexion peak torque 60o/s (Nm); C2 = flexion peak torque 300o/s (Nm); D2 = flexion power 60o/s (watts); E2 = flexion power 300o/s (watts); F2 = flexion average peak torque 60o/s (Nm); G2 = flexion average peak torque 300o/s (Nm).
*p ≤ 0.05 by Spearman test; ** p ≤ 0.01 by Spearman test

Table V shows muscle imbalance between the flexor and extensor muscles of the knee joint in the assessment at 60o/s (maximus force), although shows significant major H/Q ratio at 300o/s (resistance force). These findings are below the recommended minimum for literature that is of 50% [14], emphasizing that these data are indicated for healthy subjects, and those evaluated in the present study are trained.

Table V - H/Q ratio for 60o/s and 300°/s isokinect test

Sexes groups	H/Q Ratio (±SD) 60o/s	H/Q Ratio (± SD) 300o/s
Men	0.49 (± 0.05)	0.65 (± 0.10)*
Women	0.46 (± 0.07)	0.67 (±0.06)*

*$p \leq 0.01$ for t Student test between H/Q ratio 60o/s and H/Q ratio 300°/s

Discussion

Training volume performed for each muscle group in resistance training programs, designed for different adaptations, has been analyzed for many scientific studies [9,18-21]. Several researches investigated the result of different load-volumes in RT for different purposes. The number of exercises, sets, repetitions and frequency are some of the variables used to control the volume of resistance training [22-24]. For this reason, to investigate the weekly volume of repetitions we considered the equation: number of exercises x number of sets x number of repetitions x number of weekly sessions. The results of cited studies showed a statistically higher volume of weekly repetitions for the quadriceps muscles compared to the hamstring muscles.

Considering that the aim of the present study was to analyze the weekly volume of repetitions for the quadriceps and hamstrings, and the muscle balance of knee joint extensors and flexors, the data of our study confirmed the initial hypothesis only to H/Q ratio for resistance force (300o/s) as a result of equated weekly volume of muscle strength training for quadriceps and hamstring, but not for maximus force (60o/s) although our study shows strong and significant correlations between isokinetic parameters for knee extension and flexion.

Teixeira *et al.* [15] quantified the weekly volume of sets for different muscle groups of men and women aiming muscle hypertrophy. A total of 105 training logs were analyzed, 42 women and 63 men, with at least six months of RT experience. The average weekly volume of sets for quadriceps (Q) and hamstrings (H) in men was 16 sets and eight sets respectively, and in women the values were 30 sets for Q and 16 sets for H, which was different from what was found in our study, since the study cited showed a difference in training volume between Q and H.

Socio-cultural factors might, in part explain the reason why people overestimate some muscle groups in relation to other muscle groups (quadriceps/hamstrings muscles, abdominal muscles/lumbar muscles), but the biomechanical properties of some muscles and complexity of some exercises may explain the phenomenon too [15]. Specific hamstring exercises should be performed to increase strength and reduce muscle imbalance between knee joint extensors and flexors, reducing the risk of injury like anterior cruciate ligament injury (ACL) [25].

The H/Q ratio, evaluated on the isokinetic dynamometer, shows the muscle balance between the (Q) and the (H), which is extremely useful, for both athletes and nonathletes. At lower speeds (60-180°/s), the H\Q ratio should be around 60% (or 0.6). Values below 50% (or 0.5) indicate a severe degree of muscle imbalance [16,26].

A study by Grygorowicz *et al.* [27] evaluated 48 athletes in the isokinetic dynamometer test at 60o/s and found an average H/Q ratio of 0.58 in the group who had no injuries (group A), and a lower H/Q ratio in groups B (mild injuries) and C (serious injuries). Lee *et al.* [28] found, for nonathletes, in their isokinetic dynamometer test at 60o/s, values of the H/Q ratio about 0.56 ± 0.17 in group with injury, and 0.58 ± 0.006 in control group. The average H/Q ratio found in our study shows a poor H/Q ratio for maximus force (60o/s), and a good H/Q ratio for resistance force (300o/s), which contradicts the findings of the cited studies H/Q ratio at 60o/s, and that despite the sample subjects not having knee injuries, which may be some limitation for this discussion, there was a balance in the weekly training volume for Q and H muscles, and the H/Q at 60o/s ratio was expected to be better.

There are some limitations regarding the use of the H/Q ratio and the risk of injury, since the ratio is done by using values of concentric action of the extensor muscles in relation to the flexor muscles, while in sports or daily life activities a concentric action of extensor muscles is accompanied by an eccentric action of the flexor muscles [28]. In this way, the flexor muscles play a role of braking the joint movement in different sport-specific motor gestures. Based on the principle of specificity, eccentric muscle actions for the knee flexors should be included in RT programs.

One important limitation of the present study was the fact that the authors had no access to another training variable such as intervals, weight and intensity of 1RM, and other biomechanics parameters to knowledge more clear about muscle activity in training response.

All limitations pointed can may partially explain the results found in our study, which conflict with the current and limited literature.

Conclusion

The results demonstrated no significant difference in the weekly volume of repetitions performed for Q and H muscles, but a poor H/Q ratio at 60o/s and a good H/Q ratio at 300o/s, which contradicts the findings of the other studies. Our data contribute to future discussions, and more studies are needed that can contribute to a better understanding of strength training programs, with a focus on knee health.

Potential conflict of interest
No potential conflicts of interest relevant to this article have been reported.

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Authors' contributions
Conception and design of the research: Rodrigues D, Figueira Jr A; **Data analysis and interpretation:** Guedes Jr D, Junior A, Dourado VZ; **Statistical analysis:** Nogueira HS, Dourado VZ; **Writing of the manuscript:** Brugnerotto G, Lima LEM, Nogueira HS; **Critical review of the manuscript for important intellectual content:** Silva RP.

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