A comparison of motor performance between men and women in multiple sets of weight exercises

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ABSTRACT

The magnitude of men and women's neuromuscular, metabolic, and morphologic responses seems to be quite different even when both are submitted to exercise protocols using similar weight exercises protocols. However, differences in the motor performance between men and women have been predominantly reported in protocols based on isometric and isokinetic contractions. Thus, this study aimed to analyze men and women's behavior during multiple sets of weight exercises achieving the exhaustion, and later verifying possible differences as to the physical performance between genders using weights with similar intensity. For this, 83 subjects (50 men, and 33 women), 48 hours after being submitted to 1-RM tests in bench press, squat and arm curl performed a protocol composed by four sets at 1-RM 80% up to achieving the exhaustion in each of three exercises to evaluate the endurance ability to the fatigue in different muscular groups. It was used the ANOVA and ANCOVA for repeated measurements, followed by the Tukey's *post hoc* test, where $P < 0.05$ to the data treatment. It was verified a significant fall in the performance both in men and in women since the first up to the fourth sets of every exercise investigated ($P < 0.01$). Although the fatigue magnitude was higher in men in all the three exercises, the effect on the gender was only identified in the arm curl exercise ($P < 0.01$). The results of this study indicated that men and women presented quite different behavior in multiple sets of weight exercises, and women presented a more stable performance and a higher endurance ability to the fatigue in the arm curl as well.

Keywords: Motor performance. 1-RM test. Strength resistance. Muscular fatigue. Weight exercises.

INTRODUCTION

The constant practice of weight exercises has attracted men and women of different ages and of several levels of physical skills related to the health, such as strength and muscular endurance.

This fact is highly justifiable because of the scientific knowledge advancement in the area of weight training (WT), mainly in the last two decades, and this can be verified through the high number of publications available in the literature emphasizing the countless benefits coming from the practice of such exercise, including those to treat cardiovascular diseases, non-insulin dependent *diabetes mellitus*, obesity, and osteoporosis, among other health problems that may affect the human body along the lifetime.

Despite of this, there are still a few controversies involving the way WT programs are mounted, once different combinations among major variables related to such kind of training (number of exercises, order of execution, number of sets and repetitions, velocity of execution, recovery interval between sets and exercises, weekly frequency) may propitiate quite different responses.

It is worthy to point out that the magnitude of the response to the WT can also be influenced by the gender factor, once the information available in the literature has indicated that the majority of women present lower values of muscular strength than men both in the upper and in the lower limbs[2], although such differences are quite attenuated whenever comparisons between genders are conducted according to values related to the body mass[3,4]. Furthermore, the plasmatic concentrations of the main anabolic hormones (testosterone, GH and IGF-1) in rest or after intense struggle are quite distinct in men and women[5,6].

Thus, another point that deserves to be clarified is that when men and women are submitted to similar WT programs, they present higher or lower tolerance to high intensity repetitive strength. So, the initial purpose of this study was to analyze men and women's behavior performing multiple sets of weight exercise in different body segments, and later, to verify possible differences of the physical performance between genders in exercises performed under similar intensity.

METHODOLOGY

Subjects

Eighty-three apparently healthy college students (50 men, and 33 women) participated spontaneously in this study. As initial criteria to the inclusion, participants should present mild activity (constant physical activity < twice a week), and they would have not participated in any regular physical exercise program during the last six previous months of the beginning of the experiment. Furthermore, previously to the beginning of the study, each participant answered a questionnaire on his (her) health history with no report of metabolic or muscular-skeletal malfunction.

After being previously clarified on the purposes of the investigation and related procedure they would be submitted to, every participant signed a free and clarified consent term. This study was approved by the Ethic Committee Research of the Londrina State University according to the rules of the National Council of Health's Resolution 196/96 on researches involving human beings.

Anthropometry

The body mass was measured in an 100 g precision and maximum load of 180 kg *Urano* digital scale model *PSI80 A*, and the stature was determined in an 1 mm precise wooden stadiometer, according to procedures recommended by Gordon *et al.*[7]. From these measurements, the body mass index (BMI) was calculated

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by the ratio between the body mass and the square of the stature, the weight was expressed in kilograms (kg), and the stature was expressed in meters (m).

1-RM tests

The muscular strength was determined by means of the maximum repetition test (1-RM) in three exercises involving segments of the trunk, the lower and upper limbs. The order of execution of the exercises tested was respectively: bench press, squat and arm curl. The interval between exercises was of at least five minutes. These exercises were chosen since they are quite popular in training programs using weights in subjects with different training levels.

Prior to the beginning of the tests, in each sequence of three exercises subjects were submitted to a warming sets (6 to 10 repetitions) with approximately 50% of the estimated load in the first try of the 1-RM test. The testing initiated two minutes after the specific warming. Subjects were oriented to try completing two repetitions. In case two repetitions were completed in the first try, or even if it was not completed a single repetition, it was performed a second try after a recovery interval of three to five minutes with a higher load (first possibility) or lower load (second possibility) to that used in the previous try. This procedure was repeated once again in a third and last try in case the load related to a single maximum repetition was not determined yet. Therefore, the load recorded as 1-RM was the one when it was possible to the subject to complete a sole maximum repetition[8].

Prior to the beginning of the study, it was employed a familiarization protocol, trying to reduce the learning effects, and to establish the reproducibility of the tests in the three exercises. All subjects were tested in similar situation to the protocol adopted in six different sessions, with intervals of 48 hours. The intra-classes coefficient (R) was of 0.98 in the bench press exercise, and 0.96 in the squat and arm curl exercises.

It is worthy to mention that the way and execution technique of each exercise was standardized and continuously monitored, trying to assure the efficiency of the test.

Fatigue evaluation protocol

A protocol to evaluate the fatigue endurance ability was applied between 48 and 72 hours after the last six sessions of the 1-RM tests in the three exercises previously described. The order of execution of exercises of the protocol was identical to the one adopted during the 1-RM test.

The protocol was composed by the execution of four sets of each exercise at 80% 1-RM up to the voluntary exhaustion. Subjects were oriented to try to execute the maximum possible repetition in each sets, until they reached a functional incapacity to surpass the resistance offered. The recovery interval between sets was of two minutes, and in different exercises, the interval was of three to five minutes.

The three exercises were preceded by a warming sets in the own equipment, with a 6 to 10 repetition with an approximately 50% load set for each exercise.

The rate of the declining strength between the first and fourth sets of each exercise was used as the fatigue index, according to the equation proposed by Sforzo and Touey[9] below:

$$FI = [(TS_{(1st\ sets)} - TS_{(4th\ sets)}/TS_{(1st\ sets)}] * 100\%$$

where FI = Fatigue Index and TS = Total Strength (load lifted x number of repetitions executed during the sets).

Statistical treatment

The *t* Student test for independent sampling with different number of elements was used to compare men and women's general features. It was used the variance analysis (ANOVA) 2x2 for repeated measurements, to compare genders (men and women) in different sets of exercises. To those variables where the initial conditions of groups were statistically different, it was used the covariance analysis (ANCOVA), along with the baseline adopted as covariables. It was employed the *post hoc* Tukey's test for multiple comparisons to identify specific differences in variables in which the *F* values found were higher than the statistical significance set ($P < 0.05$).

RESULTS

Table 1 it presents the general features of the subjects investigated. The body mass of men was significantly higher than the one found in women (12.7 kg, or 22%; $P < 0.01$), as well as the stature (13 cm, or 8%; $P < 0.01$). It was found no significant differences in the BMI values compared to both genders ($P > 0.05$).

TABLE 1
General features of the subjects investigated

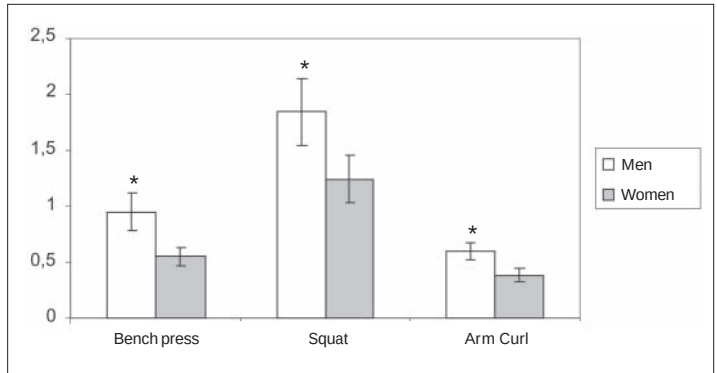
Variables	Men (n = 50)	Women (n = 33)	*P*
Age (years)	21.9 ± 2.9	21.3 ± 3.1	0.49
Body mass (kg)	70.4 ± 9.7	57.7 ± 6.9	< 0.01
Stature (cm)	175.5 ± 6.8	162.5 ± 5.7	< 0.01
BMI (kg/m^2)	22.8 ± 2.4	21.9 ± 2.2	0.08

The absolute values of the lifted load during the 1-RM tests in the bench press, squat and arm curl exercises of men ad women are presented in table 2. In the three exercises, women presented a lower performance compared to men's. Thus, women reached around 47% of the load lifted by men in the bench press exercise ($P < 0.01$), ~57% in the squat exercise ($P < 0.01$), and ~54% in the arm curl exercise ($P < 0.01$).

TABLE 2
Load lifted by non-trained young men and women in 1-RM tests

Variables	Men (n = 50)	Women (n = 33)	*P*
Bench press (kg)	67.8 ± 15.4	31.8 ± 5.5	< 0.01
Squat (kg)	127.5 ± 30.2	72.1 ± 12.1	< 0.01
Arm curl (kg)	42.1 ± 7.6	22.6 ± 3.9	< 0.01

Whenever comparisons between men and women's performance in 1-RM tests were set based on the body mass, differences were reduced; however, they have kept statistical significance (figure 1). In such sense, values of the muscular strength related to the body mass found in women were of ~58% in the bench press ($P < 0.01$), ~68% in the squat ($P < 0.01$), and ~65% in the arm curl ($P < 0.01$) of those reached by men.



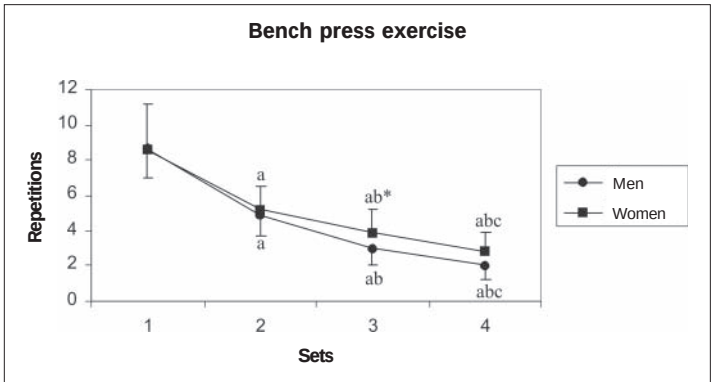
* P < 0.01.
Note: Results expressed in average values (± SD)

Fig. 1 *– Relative muscular strength (total load lifted in 1-RM tests/body mass) of men (n = 50) and women (n = 33) in the bench press, squat, and arm curl exercises.*

TABLE 3
Number of repetitions performed in sets 1 and 4 in strength resistance tests (1-RM 80%) performed in the bench press, squat, and arm curl exercises in men (n = 50) and women (n = 33)

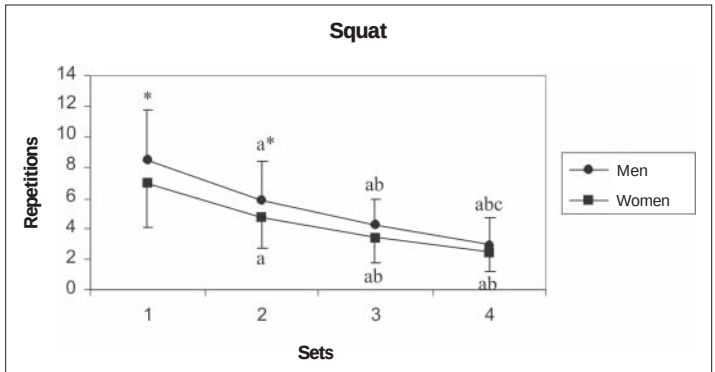
Variables	Men	Women	Effects	F	P
Bench press			**ANOVA**		
Sets 1	8.7 ± 1.7	8.6 ± 2.6	Gender	1.23	0.27
Sets 4	2.0 ± 0.8*	2.8 ± 1.1*	Sets	690.46	< 0.01
FI (%)	–77.0	–67.4	Gender x Sets	4.49	0.04
Squat			**ANCOVA**		
Sets 1	8.5 ± 3.2	7.0 ± 2.9	Gender	< 0.01	0.97
Sets 4	2.9 ± 1.8*	2.5 ± 1.3*	Sets	260.08	< 0.01
FI (%)	–65.9	–64.3	Gender x Sets	3.21	0.08
Arm curl			**ANCOVA**		
Sets 1	9.3 ± 2.4	11.7 ± 3.1	Gender	10.57	< 0.01
Sets 4	3.5 ± 1.4*	5.6 ± 2.1*	Sets	410.59	< 0.01
FI (%)	–62.4	–52.1	Gender x Sets	0.10	0.75

*P < 0.01 x Sets 1.
Note: Results expressed in average values (± SD). FI = Fatigue Index (%) calculated from changes observed between sets 1 and 4.



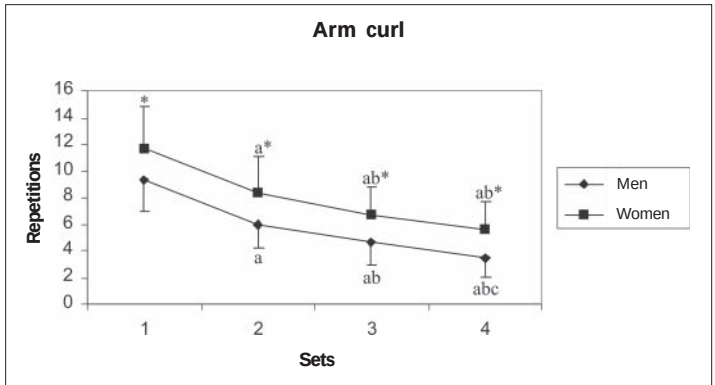
[a]P < 0.01 x sets 1; [b]P < 0.01 x sets 2; [c]P < 0.01 x sets 3 (intra-group comparisons).
Note: Statistically significant differences in the intra-group comparisons were found only in sets 3 (*P < 0.05).

Fig. 2 *– Average values (± SD) related to the number of repetitions performed by men (n = 50), and women (n = 33) in four sets of the bench press exercise*



[a]P < 0.01 x sets 1; [b]P < 0.05 x sets 2; [c]P < 0.01 x sets 3 (intra-group comparisons).
Note: Statistically significant differences in the intra-group comparisons were found only in sets 1 and 2 (*P < 0.05).

Fig. 3 *– Average values (± SD) related to the number of repetitions performed by men (n = 50) and women (n = 33) in four sets of the squat exercise*



[a]P < 0.01 x sets 1; [b]P < 0.01 x sets 2; [c]P < 0.01 x sets 3 (intra-group comparisons).
Note: Statistically significant differences in the intra-group comparisons were found in every sets (*P < 0.05).

Fig. 4 *– Average values (± SD) related to the number of repetitions performed by men (n = 50) and women (n = 33) in four series of the arm curl exercise*

The number of repetitions performed by men and women in strength resistance tests (1-RM 80%) in the first and fourth sets of the three exercises investigated is presented in table 3. It was verified a significant decrease in the motor performance in every exercise analyzed between the first and fourth sets ($P < 0.01$) both in men and women, although the effect of the gender factor was identified only by ANCOVA in the arm curl exercise, with women presenting a lower fatigue index (FI) than men ($P < 0.01$). It was found no sets x gender interaction in any of the exercises studied. Figure 2-4 present a more detailed analysis on men and women's behavior during the four sets performed in the bench press, squat, and arm curl exercises.

DISCUSSION

Several studies of the literature investigated the motor performance of men and women in isometric, isokinetic, and dynamic contractions, as well as the endurance ability to the fatigue. This study analyzed men and women's behavior in multiple sets of exercises performed using free weights in different body segments (upper limbs, trunk, and lower limbs), and possible sexual differences in the endurance ability to the fatigue.

This investigation also identified differences in the muscular strength between genders both in absolute and relative terms in every exercise analyzed, and men presented higher values than women in 1-RM tests. Although our findings have strengthen information available in the literature, the magnitude of differences found between genders in different studies have been quite different, and this can be at least in part explained by several factors, such as: type of exercise performed, body segment evaluated, levels of physical ability of the subjects investigated, equipments used (free weights or machines), type of maximum voluntary contraction employed (concentric and/or eccentric).

On the other hand, several studies using maximum voluntary contractions or using electromyography have indicated a higher tolerance to the struggle in women[10-13].

Despite the previous investigations indicate that the higher women's capacity to resist to the fatigue seems to decrease according to the need of struggle increases or even that women present a higher endurance ability to the fatigue only in sub-maximum struggle performed under intensity up to 70% of maximum voluntary contraction[14,15], our study indicated that such fact can also be noted in strength performed at an intensity equivalent to 1-RM 80%.

In such sense, women presented a lower performance decrease than men's in the three exercises investigated, although the effect of the gender has been statistically confirmed only in the arm curl exercise ($P < 0.01$).

It is worthy to mention that trying to assure the quality of the information obtained from 1-RM tests applied in the three exercises investigated, every subject was submitted to six testing sessions, in order to be familiarized with the demanded procedures. It is believed that the adoption of such procedure may have reduced

considerably the possibility that the loads, mainly in females, have been underestimated in the fatigue resistance protocol (1-RM 80%).

Another aspect that deserves our attention is that the majority of the researches available in the literature on the ability to resist to the fatigue has been using protocols involving isometric or isokinetic contractions, and this is substantially different from the information produced by this study, once exercises were performed before dynamic, concentric and eccentric contractions.

Although the possible mechanisms to explain the gender related differences as to the capacity to resist to the fatigue is not yet clearly set by the literature[10], it is believed that differences in the muscular mass upon the use of substrates, in the muscular morphology or even in the muscular activation between men and women should be analyzed more judiciously, trying to explain such phenomenon.

Furthermore, changing the proportion of the types of muscular fibers between men and women may interfere in the capacity to resist to the fatigue, once in general terms, women present lower differences in the proportion between type I and II fibers compared to men[16], and this can help to increase the capacity to resist to sub-maximum struggles for extended periods of time.

It is important to point out that in this study the decreasing rate of the motor performance was merely estimated by the difference between the number of repetitions performed in the first and last sets in each of the three exercises analyzed, according to the mathematic model proposed by Sforzo and Touey[9]. In such sense, this study did not succeed to answer whether there is any physiological or biochemical difference able to justify such different behavior between genders.

Another interesting feature observed was that both men and women presented a higher fall in the performance of the first exercise (bench press) compared to the second one (squat), and from this one related to the third one (arm curl). This indicates that the fatigue generated by the first exercise of the sequence do not seems to be negatively reflected on the performance of other exercises, when the requested muscular groups are different from those previously demanded. However, it remains to be clarified if a changing in the order of execution of exercises or even if they re performed solely (in different days) would cause a similar behavior to that found in this investigation.

Another important finding in this study is that the number of repetitions related to the 80% intensity of 1-RM was not preserved in none of the exercises tested along with the four sets performed, and this seems to risk the training prescriptions based on 1-RM percentages to develop the muscular strength, potency, muscular endurance, and mainly hypertrophy recently suggested[1].

Furthermore, the number of repetitions executed in the first sets by men and women was relatively different in each exercise. This information strengthen what was found by Hoeger *et al.*[20,21] indicating that the strength based on the 1-RM percentage would not be the better way to prescribe exercise programs using weights, once the number of repetitions performed in sole sets of different exercises can oscillate quite pronouncedly, even when the struggle intensity is similar, such as that used in the present investigation (1-RM 80%).

CONCLUSIONS

The results in this study indicated that men and women presented relatively different behavior in multiple sets of weight exercises, and women presented a more stable performance and a higher capacity to resist to the fatigue, mainly in the arm curl exercise.

Both the number of repetitions performed in the first sets of each exercise and the total number of repetitions performed along the four sets seems to be variable according to the motor duty demanded and the gender.

The decreasing performance verified in this investigation was higher in the first exercise of the sequence in both genders, and this indicates that the fatigue generated in the beginning does not seem to compromise the execution of the other sequential exercises when the muscular groups demanded are different.

Despite the results of this study indicate a significant performance decrease when men and women are submitted to multiple sets of weight exercises, as well as the mechanisms responsible by the differences in the endurance ability to the fatigue of men and women still deserve to be further investigated.

All the authors declared there is not any potential conflict of interests regarding this article.

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