Comparison of elbow flexor isokinetic peak torque and fatigue index between men and women of different training level

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Abstract

The purpose of the study was to compare elbow flexion peak torque (PT) and fatigue index (FI) during isokinetic concentric contractions in men and women with different training levels. Sixty-eight young men and women were divided into four groups: resistance trained men (RTM), non-resistance trained men (NRTM), resistance trained women (RTW) and non-resistance trained women (NRTW). Participants performed two tests on an isokinetic dynamometer, one to evaluate PT and one to evaluate FI. Significant interactions were found for sex and resistance training status with both PT and FI. In general, resistance-trained subjects had higher PT, and women showed lower PT than men. PT values were 67.12 ± 9.93 N·m for RTM, 49.9 ± 8.5 N·m for NRTM, 41.84 ± 7.52 N·m for RTW, and 26.05 ± 3.34 N·m for NRTW. Separate analysis revealed that RTM had higher PT than all other groups. However, FI was higher for NRTM than for RTM and NRTW and no difference was found between RTM and NRTW. FI was 37.86 ± 10.89 % for RTW, 45.74 ± 13.17 % for NTRW, 45.89 ± 8.24 % for RTM, and 51.92 ± 4.5 % for NRTM. Women produce lower PT, and have a higher fatigue tolerance than men of similar training status. Considering that women showed to be more resistant to fatigue than men, women can manipulate training variables differently from men, such as, including more repetitions at the same relative load or using higher relative loads at the same number of repetitions.

Key Words: Strength Training; Isokinetic Dynamometer; Muscle Performance; Fitness; Exercise Prescription

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Resistance training (RT) can bring many benefits for women, such as, increases in muscle strength,[1,2] changes in body composition,[3] and improvements in health related outcomes in menopause,[4] and others. In order to design a safe and effective program for women, it is important to consider sex differences in response to RT. However, a considerable part of the scientific literature regarding RT has been performed in men and information about the differences in acute response to RT are still controversial. Current evidences suggest that there are differences in muscle strength and fatigue tolerance between men and women.[5–10] However, other studies reported no sex differences in muscle fatigue.[11–14] These discrepant findings might be related to the differences in testing protocols, muscle groups (ie., upper and lower body), intensity (ie., maximal and submaximal loads), or contraction type (ie., isotonic, isometric and isokinetic). One important point is that most of these studies utilized prolonged or intermittent isometric actions in their comparisons. Since previous studies revealed that different muscle actions show different patterns of muscle recruitment strategies and fatigability,[15,16] this might limit the application of the previous studies in a real world setting, since resistance training is often performed with dynamic actions. Although there are a high number of studies exploring sex differences, we are not aware of any comparison involving different training levels using dynamic muscle contractions. Considering that men are habitually more involved in high intensity activities than women,[17–19] one may question if the differences are inherent to specific features of each sex or are due to training history. Understanding sex differences in fatigue resistance is extremely important because, if women

respond differently from men to the same stimuli, this must be considered when designing RT programs. Information regarding sex difference in fatigue tolerance would bring valuable information to professionals involved with RT prescription, as it will allow sex specific individualization of training programs. Therefore, the purpose of the present study was to compare elbow flexion peak torque (PT) and fatigue index (FI) during concentric isokinetic contractions in men and women at different training levels. Our first hypothesis is that women will produce lower force and present a higher resistance to fatigue during dynamic muscle actions when compared to men of the same training status. The second hypothesis is that non resistance trained men will have lower resistance to fatigue than all other groups.

METHODS

Experiment overview

The study involved 68 participants, divided in four groups: [resistance trained men (RTM)], [non-resistance trained men (NRTM)], [resistance trained women (RTW)] and [non-resistance trained women (NRTW)]. Participants performed two tests on an isokinetic dynamometer: 1) PT assessment using 2 sets of 4 concentric repetitions at 60°/s, and 2) FI assessment using a set of 30 maximal concentric actions at 180°/s. The results were used for comparisons between men and women, in accordance to their RT experience.

Participants

Volunteers were recruited through electronic messages and social media. Sixty-eight college-aged of males and females (age 25 ± 5.13 years; height 169.3 ± 8.4 cm, body weight 67.31 ± 11.73 kg) participated in the study. Volunteers were divided into four groups, RTM (n=17), NRTM (n=17), RTW (n=17) and NRTW (n=17). In order to be classified as trained, participants must have been performing RT, including upper body exercises, for at least six months prior to testing, uninterruptedly. All participants reported that most of their training sessions comprised 1-2 exercises performed with 3 sets of 10-15 repetitions performed to volitional failure.[23] Non-trained participants, had no previous history of resistance training. The criteria adopted for entering the study included being free of clinical problems that could be aggravated by the protocol, being at least 18 years of age and have no history of anabolic steroids use. All subjects were informed of the experimental risks, read and signed an informed consent form before participating in the study. The Ethics Committee of the College of Health Science at the University of Brasilia approved the experiment (CAAE: 26443413.7.0000.0030).

Procedures

Isokinetic Peak Torque and Fatigue Index

Isokinetic PT and FI were measured on the Biodex system 3 Isokinetic Dynamometer (Biodex Medical, Inc., Shirley, NY, USA). Elbow flexion PT was tested after specific sub-maximal warm up consisting of a set of 10 repetitions at 300°/s. Following 60 s of recovery, 2 sets of 4 maximal concentric repetitions at 60°/s on a Biodex System 3 isokinetic dynamometer (Biodex Medical, Inc., Shirley, NY, USA), with 60 s of rest between sets. Sixty seconds after the last set of the PT test was performed, FI was measured by performing a 30 repetitions set of maximal concentric actions at 180°/s. The FI was calculated using the percentage PT difference found on the first and last 3 repetitions of 30 repetitions protocol at 180°/s. All procedures were performed with the right elbow flexors and verbal encouragement was given throughout the test. Calibration of the dynamometer was performed prior to each testing session, in accordance with the manufacturer's specifications. Women were evaluated in the luteal phase of menstrual cycle.

Statistical analyses

Standard statistical methods were used to calculate means and standard deviations (SD). A 2-way mixed-factor 2 × 2 (sex × training status) ANOVA was used for comparing group means. Multiple comparisons with confidence interval adjustment by the LSD method were used when necessary. Statistical significance was set at $p \leq 0.05$ and the version 16.0 of SPSS (SPSS, Chicago, Ill, USA) was used in the statistical analysis.

Results

Significant interactions were found for sex by training status for both PT and FI. When sex was analyzed, men had higher PT and FI than women ($p < 0,05$). Regarding training status, trained persons were stronger and more fatigue resistant than non-trained ($p<0.05$). Separate analysis revealed that RTM had higher PT than all other groups, while NRTM had higher PT than RTW and NRTW. RTW had higher PT than NRTW (Table 1).
FI was 37.86 ± 10.89 for RTW, 45.74 ± 13.17 for NTRW; 51.92 ± 4.5 for RTM and 45.89 ± 8.24 (table 1). FI values for RTW were lower than for all other groups ($p <0.05$). Both RTM and NRTW had lower FI than NRTM ($p <0.05$), but no difference was found between NRTW and RTM ($p < 0,05$).

Discussion

The present study compared PT and FI of the elbow flexors during dynamic muscle actions of men and women with different training status. To our knowledge this was the first study to compare fatigue index of men and women using dynamic muscle actions. The results of the present study confirmed the hypothesis that men have a higher PT in comparison to women [2,24]. The fact that men presented higher FI than women, with the same training status, in the present study are in agreement with previous studies that compared the FI

Table 1 : Characteristics of the participants

	Height(cm)	Age (years)	Body mass (kg)	PT (N·m)	FI%
NRTW	163.00±7.15	26.47±5.33	57.27±8.57	26.05±3.34	45.74±13.17#
RTW	165.13±4.62	28.00±6.00	65.98±7.74	41.84±7.52*	37.86±10.89
NRTM	173.45±6.95	23.53±3.79	70.66±12.00	49.90±8.50*,#	51.92±4.50#
RTM	176.99±5.46	21.50±1.90	77.28±8.68	67.12±9.93*,#,†	45.89±8.24#

PT – peak torque; FI – fatigue index; NRTW – Non-resistance trained women; RTW - Resistance trained women; NRTM - Non-resistance trained men; RTM - Resistance trained men
* higher than NRTW ($p < 0.05$); # higher than RTW ($p < 0.05$); † higher than NRTM ($p < 0.05$)

between men and women using isometric contractions.[5,7,9,25–27] Previously, Celes *et al.*[24] examined the effect of two different rest intervals between sets on isokinetic knee extension PT in young women (n = 17) and men (n = 16). Participants performed 3 sets of 10 unilateral isokinetic knee extension at 60° and 180°/s, with either 60 and 120 seconds of rest between sets. Similar to the present study, men were significantly stronger than women. There was no significant decline in PT in women during both 60 and 120s rest intervals at 180º/s, while men showed a significant decrease in PT when using 60s rest intervals during the 3 sets. According to the authors, these results can be in part due to males exhibiting lower resistance to fatigue and higher strength than females at fast contraction velocities,[28] which was partially confirmed by the present results. Our results are contrary to Clark *et al.*[5], who did not find differences in fatigue resistance between men and women with the same training levels. The discrepancy might be due to the methods used, since Clark *et al.* [5] used lower intensity isometric contractions (50% MVC) and evaluated lumbar extensors, which have a more oxidative characteristic due to its involvement in postural control.[29] Our study, on the other hand, analyzed the elbow flexors during maximal voluntary dynamic actions. As for the possible causes, differences between men and women with the same training levels are probably due to peripheral factors, as suggested by Temesi *et al.*[30], who found differences between men and women for peripheral, but not central, fatigue. These may be associated to force production, since stronger muscle actions may cause greater blood flow restriction, resulting in higher metabolic accumulation. These byproducts can lead to peripheral fatigue, associated with phosphate and hydrogen ion accumulation, leading to a decrease in blood pH.[31] Although previous analysis has shown that men and women have similar muscle fiber composition,[32] men present larger cross sectional areas of type II fibers in the elbow flexors,[33] which can explain the higher peak torque as well as the higher fatigue index. The larger area occupied by type II fiber can lead men to rely more on the glycolytic system, while women rely more on the oxidative system,[14,34] that is known to have longer work capacity. Our results show that trained people have higher PT and lower FI than untrained counterparts, which contradicts previous suggestions that greater force production is correlated with greater fatigue.[24,35] This divergence is possibly due to the type of training performed by the subjects, since training oriented for muscle hypertrophy results in specific metabolic adaptations in comparison to training for muscular strength/power.[36] In this regard, previous studies reported that training with high load and fewer repetitions (i.e. 3-5 RM) has been shown to increase muscle strength but decrease resistance to fatigue.[37] However, training at moderate to high repetitions, as commonly done for muscle hypertrophy, increases both muscle strength and resistance to fatigue. Considering that the participants of the present study usually performed their training at the 10-15RM range, their strength gains were probably accompanied by an increase in fatigue resistance. It is important to note, however, that the notion that different repetition ranges may produce different adaptations in strength or fatigue resistance have been questioned in recent studies.[38,39] Based on the present results, we conclude that women produce less force but are more resistant to fatigue than men with the same training level. These results can be useful when designing and implementing RT programs since it brings more information about differences in muscle behavior between sex during effort, in both health and disease.[40-42] Coaches and health professionals involved with RT should be aware of this difference, as it suggests that women can train with more repetitions at a same relative load (i.e. % of 1RM) or, perform the same number of repetitions at higher relative loads. In addition, our results support the idea that the rest interval between sets during strength training must also be considered between men and women, inasmuch as women may use shorter rest intervals between sets.

List of acronyms

PT – peak torque
FI – fatigue index
NRTW – Non-resistance trained women
RTW - Resistance trained women
NRTM - Non-resistance trained men
RTM - Resistance trained men

Author's contributions

Each author contributed in equal part to the manuscript.

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Conflict of Interest

The authors declare no conflicts of interests.

Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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