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Sex-related differences in isokinetic muscular contraction
Diferenţe ale contracţiei musculare izocinetice între cele două sexe

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Abstract

Background. The ability of muscle to develop torque depends on many factors, such as muscular mass, fibre type, activation characteristics, factors that are different enough in males and females.

Aims. To analyse the differences between the two genders concerning isokinetic muscular contraction in knee extensor and flexor muscles.

Methods. 22 healthy volunteers (10 males and 12 females) were included in this study. After a 5-minute warm-up period, subjects had to perform an isokinetic muscle testing protocol on a Gymnex Iso 2 isokinetic dynamometer, consisting of 30 maximal reciprocal isokinetic contractions (knee flexion – extension) on the dominant lower limb, at 180°/sec velocity. Analysed parameters (for extension and flexion) were: peak torque, work, power, muscle endurance index. Parameters were analysed in absolute values and relative to body mass.

Results. Significantly higher absolute values ($p<0.05$) were registered in men than in women for peak torque, work and power, for both extension and flexion. When parameters were calculated relative to body mass, statistical significance was no longer met ($p>0.05$). On the other hand, significantly faster fatigue with lower values of the muscular endurance index ($p<0.05$) were registered in men than in women.

Conclusions. Muscle contraction ability and muscle fatigue are gender-specific, which could be a possible explanation for the different predisposition for certain injuries in males and females.

Keywords: gender, muscular contraction, isokinetic, knee.

Rezumat

Premize. Capacitatea muşchiului de a produce forţă depinde de mai mulţi factori, precum masa musculară, tipul de fibre, caracteristicile de activare, factori care diferă destul de mult între femei şi bărbaţi.

Obiective. Analizarea diferenţelor dintre cele două sexe, din punct de vedere al contracţiei musculare izokinetice la nivelul extensorilor şi flexorilor genunchiului.

Metode. În studiu au fost incluşi 22 de voluntari sănătoşi (10 bărbaţi şi 12 femei). După o perioadă de încălzire de 5 minute, subiecţii au fost supuşi unui protocol de testare musculară izokinetică, utilizând un dinamometru izokinetic Gymnex Iso 2. Protocolul a constat din 30 de contracţii izokinetice maximale reciproce (flexii – extensii de genunchi) la nivelul membrului inferior dominant, la o viteză unghiulară de 180°/sec. Parametrii analizaţi (pentru extensie şi flexie) au fost: torque-ul maxim, lucrul mecanic, puterea, indicele de rezistenţă musculară. Parametrii au fost analizaţi în valoare absolută şi raportaţi la greutatea corporală.

Rezultate. La bărbaţi s-au înregistrat valori absolute semnificativ mai mari ($p<0,05$) decât la femei, pentru torque-ul maxim, lucru mecanic, putere, atât pentru extensie, cât şi pentru flexie. Când parametrii au fost raportaţi la masa corporală nu s-au mai obţinut semnificaţii statistice ($p>0,05$). Pe de altă parte, la bărbaţi oboseala musculară s-a instalat semnificativ mai rapid, cu valori mai scăzute ale indicelui de rezistenţă musculară ($p<0,05$) decât la femei.

Concluzii. Capacitatea de contracţie musculară şi fatigabilitatea musculară sunt sex-specifice. Aceasta ar putea reprezenta o explicaţie pentru predispoziţia diferită către anumite tipuri de leziuni la bărbaţi şi la femei.

Cuvinte cheie: sex, contracţie musculară, isokinetic, genunchi.

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Introduction

Muscle force-generating ability depends on many factors, such as muscle mass, muscle fibre type, and muscle activation characteristics (Pincivero et al., 2003), which are quite different between men and women.

Thus, a recent trial found that thigh cross-sectional area decreased with age mainly because of a decrease in muscle cross-sectional area in men and in fat cross-sectional area in women. Furthermore, the rate of decrease in muscle cross-sectional area was 1.5-fold higher in men than in women. At the same time, muscle cross-sectional area decreased with age mainly because of a decrease in quadriceps cross-sectional area, especially in women. Nevertheless, there was no difference in the decrease of muscle quality with age between the two genders (Kasai et al., 2014).

In another trial, sex-related differences were found in mRNA and protein content for 66 genes involved in metabolism, mitochondrial function, transport, protein biosynthesis, cell proliferation, signal transduction pathways, transcription, translation and determination of muscle fibre type. Thus, mRNA for acyl-coenzyme A acyltransferase 2, trifunctional protein beta, catalase, lipoprotein lipase, and uncoupling protein-2 was higher in women, as well as myosin heavy chain I and peroxisome proliferator-activated receptor delta. The authors suggested that the higher area percentage of type I skeletal muscle fibres in women (Maher et al., 2009) and the decreased fast-twitch fibre size in men (Yu et al., 2007) could be related to these differences.

Sex-related differences have also been described in muscle activation pattern. Thus, when a discrete functional task (carrying a grocery bag) was analysed, it was found that the number of bursts in women was 85% less compared with men, but the burst duration and burst area were approximately three times more extensive in women compared with men (Harwood et al., 2008).

At the same time, the maximal rate of muscle relaxation, which was correlated with muscle fatigability, was found to be lower in women, indicating that their muscles were slower than those of men. The authors proposed the difference in fibre type composition as a possible factor leading to the sex-related difference in skeletal muscle fatigue resistance, which could not be explained by differences in motivation, muscle size, oxidative capacity or blood flow between sexes (Wüst et al., 2008).

In this context, we tried to prove that all these sex-related differences in muscle structural and functional properties also influence muscle performance, leading to differences between men and women.

Hypothesis

The purpose of the study was to analyse the differences between the two genders concerning isokinetic muscular contraction parameters (peak torque, work, power, muscle fatigue) in knee extensor and flexor muscles. We assumed that men would develop more strength and would produce higher levels of peak torque, power and work, but would also present earlier and greater muscle fatigue than women.

Materials and methods

We mention that the research protocol was in conformity with the Helsinki Declaration, Amsterdam Protocol and Directive 86/609/EEC, and the approval of the Ethics Committee of the University of Medicine and Pharmacy Cluj-Napoca regarding research on human subjects was obtained. The research procedures were explained to all the study participants and an informed consent was also obtained from all patients prior to the study.

Research protocol

The research was structured as an observational cross-sectional study.

a) *Period and place of the research*

The study was conducted between May and July 2008, in the Rehabilitation Hospital Cluj-Napoca.

b) *Subjects*

The study included 22 healthy volunteers (10 men and 12 women). They were recruited from the students and physical therapists working at the Rehabilitation Hospital Cluj-Napoca. Inclusion criteria: age between 18 and 40 years. Exclusion criteria: BMI greater than 35kg/m^2, history of musculoskeletal impairments, high blood pressure, chronic diseases.

c) *Tests applied*

The subjects were assessed once. Strength testing of knee extensor and flexor muscles was performed isokinetically, using a Gimnex Iso 2 dynamometer. The evaluation protocol included a 5-minute warm-up session on the ergometric bicycle. Afterwards, there was a short period of familiarization with the dynamometer, consisting of one set of 5 submaximal repetitions of knee flexions and extensions at a velocity of 240°/sec. After a rest period of 2 minutes, muscle performance was assessed by a set of 30 maximal reciprocal concentric isokinetic contractions (knee flexion – extension) on the dominant lower limb, at a velocity of 180°/sec. A comparison was made between the performance of men and women. For both extensor and flexor muscles, the following parameters were analysed: peak torque, work, power, muscular endurance index (calculated as the percentage ratio between the average work of the last three repetitions and the average work of the first three repetitions). These parameters were analysed in absolute values, but also relative to body mass.

d) *Statistical processing*

Quantitative variables were expressed as mean ± standard deviation (SD). Once the normal distribution of data was confirmed by the Kolmogorov-Smirnov test, the statistical analysis of differences between the two groups (men and women) was carried out using the Student t test for independent samples (variance was tested previously). The statistical significance threshold was at $p \leq 0.05$. The software used was Microsoft Excel 8.0 for Windows and MedCalc 12 (trial version).

Results

There was no significant difference in age between men and women, but the body mass index (BMI), body weight and height were significantly higher in the group of men (Table I).

Table I

Patient demographic characteristics.

Variable	Women (mean±SD)	Men (mean±SD)	Statistical significance (p)
Number	12	10	-
Age (years)	27.0±6.9	29.6±4.5	0.32
BMI (kg/m²)	21.3±2.8	24.9±2.9	<0.01
Body weight (kg)	57.6±8.1	79.9±11.5	<0.01
Height (m)	164.4±6.9	178.9±5.9	<0.01

Higher absolute peak torque values were recorded in men than in women for both extensor and flexor muscles (Figure 1).

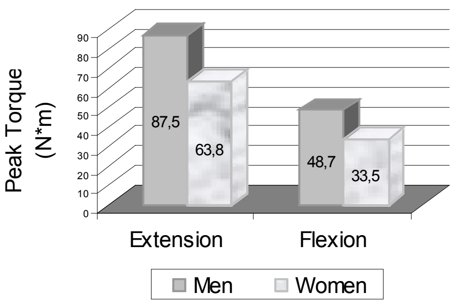

Fig. 1 – Peak torque for extensors and flexors in the two genders.

Also, a better performance was found in men when absolute values for work (Figure 2) and power (Figure 3) were taken into account, both for extensors and flexors.

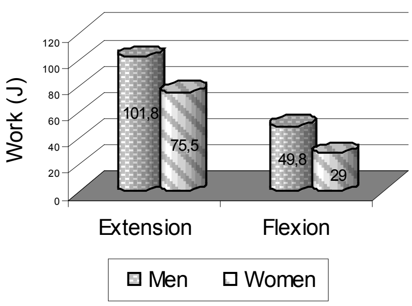

Fig. 2 – Work for extensors and flexors in the two genders.

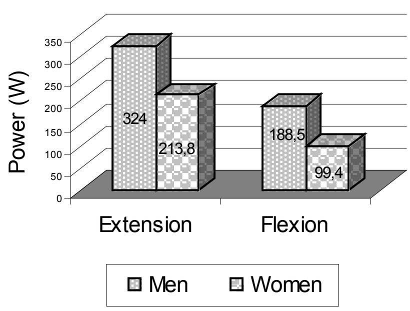

Fig. 3 – Power for extensors and flexors in the two genders.

Higher values in men compared to women were also found when these parameters were calculated relative to body mass, but statistical significance was no longer met for extensors (Table II), or for flexors (Table III).

Table II

Peak torque, power and work for extensors, in absolute values, relative to body mass.

Variable	Men (mean±SD)	Women (mean±SD)	Student t-test
PT Ext (Nm)	87.5±23.7	63.8±14.9	P=0.009
PT Ext / BM (Nm/kg)	1.10±0.28	1.10±0.17	P=0.98
Pw Ext (W)	324.0±96.1	213.8±32.6	P=0.001
Pw Ext / BM (W/kg)	4.0±1.1	3.7±0.6	P=0.39
W Ext (J)	101.8±26.1	75.5±15.0	P=0.007
W Ext / BM (J/kg)	1.28±0.30	1.30±0.14	P=0.79

Table III

Peak torque, power and work for flexors, in absolute values, relative to body mass.

Variable	Men (mean±SD)	Women (mean±SD)	Student t-test
PT Flx (Nm)	48.7±12.3	33.5±8.1	P=0.002
PT Flx / BM (Nm/kg)	0.61±0.14	0.59±0.16	P=0.78
Pw Flx (W)	188.5±69.6	99.4±49.0	P=0.002
Pw Flx / BM (W/kg)	2.3±0.8	1.7±0.9	P=0.16
W Flx (J)	49.8±15.3	29.0±12.1	P=0.002
W Flx / BM (J/kg)	0.61±0.16	0.51±0.22	P=0.23

On the other hand, significantly faster fatigue with lower values of the muscular endurance index were recorded in men than in women (Figure 4).

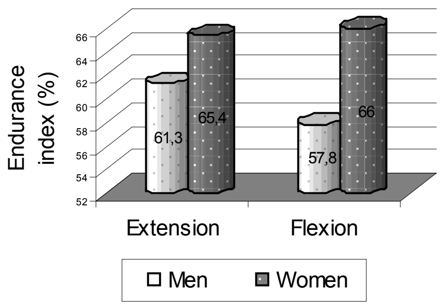

Fig. 4 – Endurance index for extensors and flexors in the two genders.

Muscle strength was always higher in extensors than in flexors.

Discussions

In the present study, muscular performance was compared between men and women, using the isokinetic method of evaluation. We found that men developed significantly higher rates of peak torque, work and power than women, for both extensor and flexor muscles, when absolute values were taken into account. But when these absolute values were normalized to body mass, statistical significance was no longer met in any of the parameters.

At the same time, we found that muscle fatigue appeared earlier in men than in women, corresponding to a significantly lower value of the muscular endurance index in men.

In a similar study investigating gender-specific knee extensor torque, knee flexor torque and muscle fatigue responses during maximal effort contractions, Pincivero observed that males generated significantly higher levels of knee extensor and flexor torque in absolute values, similarly to our study. But when absolute values of torque were normalized to body mass, even if differences between genders were less important, Pincivero found that they were still statistically significant (Pincivero et al., 2003), which was later also reported by Musselman (Musselman & Brouwer, 2005), contrary to our findings. On the other hand, Musselman noticed that males experienced a significantly higher rate of quadriceps femoris and hamstring muscle fatigue than females, corresponding to our observations and those of Pincivero, where healthy young men were shown to exhibit a faster rate of knee extensor torque fatigue than women, which was highly correlated with peak voluntary work (Pincivero et al., 2003). Musselman also found that the percent decreases in peak torque, work and power were not significantly different between the quadriceps and hamstrings. The conclusion of the study was that muscle force-generating ability and fatigue followed a gender-specific pattern: males generated greater knee extensor and flexor peak torque, work and power than females, but the result was a higher rate of muscle fatigue. They suggested that this gender-specific muscle fatigue pattern could be implicated in gender-related injury patterns. Numerous factors, such as muscle fibre type, oxidative potential, muscle activation, and specific tension, have been mentioned as playing a significant role in the gender-specific response of muscle fatigue. Similarly to our study, Deschenes found not only that peak torque was significantly higher in men than in women during isokinetic testing, but also that total work and power followed the same pattern (Deschenes et al., 2012).

The discordance between our study and Pincivero's study concerning the significance of sex-related differences in relative peak torque values (normalized to body mass) could be explained by differences in the characteristics of the populations included in the two studies (such as body weight, age). In this sense, Maffiuletti found that obese subjects displayed higher absolute, but lower relative (normalized to body mass) muscle torque values than lean subjects. Moreover, voluntary torque loss, corresponding to muscle fatigue, was significantly higher in obese than in lean subjects. These muscle function impairments (voluntary fatigue and relative strength) could contribute to the reduced functional capacity of obese subjects during daily living activities (Maffiuletti et al., 2007).

Muscle fatigue, classically defined as an exercise-induced decline in maximal voluntary muscle force or power (Enoka et al., 2008), was found to be less important in women than in men, mainly in young people, but the magnitude of sex differences in the performance of a fatiguing contraction is lessened or disappears among older adults (Hunter, 2009). In the same review, Hunter also demonstrated that the mechanisms involved in this sex difference are task specific. Furthermore, Avin showed that sex differences in fatigue resistance are muscle group dependent. In his study, women were more resistant to fatigue than men at the elbow, but not at the ankle (Avin et al., 2010). The authors of another systematic review and meta-analysis also noticed that older individuals tended to fatigue less than young individuals, regardless of sex, but the final conclusion was that additional large sample size studies were needed in order to clarify the age-sex interaction in the development of muscle fatigue (Christie et al., 2011). At the same time, they emphasized that muscle power was highly predictive for future morbidity and strongly related to physical function and, therefore, further research of muscle fatigue should use power as a fatigue index.

Recent studies have tried to elucidate the physiological mechanisms underlying these sex differences. In this sense, Ayala noticed that the hamstrings reaction time profile was different in the two genders: women had longer total reaction time, pre-motor time and motor time values than men, with a possible role in the greater anterior cruciate ligament injury risk in women (Ayala et al., 2013). Clark found that men synergistically recruit the rectus femoris compartment of the quadriceps muscle to a lesser extent than women in association with muscle fatigue and that women achieve an overall greater relative activation of the quadriceps at task failure than men (Clark et al., 2005). In her very recent and complex review, Hunter included as possible physiological mechanisms responsible for sex-based differences in fatigability the activation of the motor neuron pool from cortical and subcortical regions, synaptic inputs to the motor neuron pool via activation of metabolically sensitive small afferent fibres in the muscle, muscle perfusion and skeletal muscle metabolism and fibre type properties. Task variables leading to sex differences in fatigability, such as the type, intensity and speed of contraction, the muscle group assessed and environmental conditions, were also listed. Nevertheless, the author concluded that further research is very much needed in order to understand the sex differences in neuromuscular function and fatigability (Hunter, 2014).

Conclusions

Muscle contraction ability and muscle fatigue are gender-specific. This could be a possible explanation for the different predisposition for certain injuries in males and females.

Conflicts of interest
There are no conflicts of interest.

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