ORIGINAL ARTICLE

DIFFERENCES IN KNEE SENSORIMOTOR CONTROL BY PHYSICAL ACTIVITY LEVEL AND SEX

DIFERENÇAS NO CONTROLE SENSORIMOTOR DO JOELHO POR NÍVEL ATIVIDADE FÍSICA E SEXO

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ABSTRACT

Objective: The aim of this study was to compare the differences in knee sensorimotor control between healthy men and women by measuring the joint position sense (JPS), sensation of muscle tension (steadiness), and onset of muscle activation (OMA). Methods: Twenty-four healthy women and 27 healthy men were tested. Knee sensorimotor control was assessed using the JPS test with electrogoniometers in 3 different ranges of motion, sensation of muscle tension using the isometric steadiness technique, and OMA against a mechanical perturbation. Each assessment was compared by sex, physical activity level, and right or left lower limb. Results: The men obtained better values in the JPS test between 90° and 60° and between 30° and 0° than the women. The subjects with higher levels of physical activity also showed better values, between 90° and 60° and between 30° and 0°. The best results for steadiness were found in the women and the subjects with higher levels of physical activity. In the OMA test, no significant differences were found in the studied variables. Conclusion: The results suggest that higher levels of physical activity may determine better sensorimotor control. Men have better articular sensation, and women have better muscle strength control. ***Level of evidence III, Cross sectional study.***

Keywords: Knee. Physical Activity. Proprioception.

RESUMO

*Objetivo: O objetivo desse estudo foi comparar as diferenças no controle sensório-motor de joelho entre mulheres e homens saudáveis medindo o sensação da posição articular (SPA), Coeficiente de variações da força (Steadiness) e inicio ou ativação muscular (IAM) Métodos: Foi avaliado 24 mulheres saudáveis e 27 homens saudáveis, realizando avaliações de SPA, o Sensação de tensão muscular (Steadiness) e o IAM, comparadas segundo sexo, nível de atividade física e extremidades inferiores direita ou esquerda. Resultados: SPA: Os homens obtiveram melhores valores nessa prova entre 90-60° (p=0,0127) e em 30-0° (p=0,0017) ao comparado com as mulheres. as pessoas com maior nível de atividade física também se encontram melhores resultados entre 90-60° (p=0,0328) e 30-0° (p=0,0173). STEADINESS: Os melhores resultados foram para as mulheres em ambas extremidades (direita p=0,0002 e esquerda p=0,0009) e pessoas com maior nível de atividade física (direita p=0,0065 e esquerda p=0,0173). Para IAM não foi encontrado diferenças significativas nas variáveis estudadas. Conclusão: Os resultados sugerem que tanto maior nível de atividade física puderam determinar maior resultado no controle sensório-motor. Os homens tiveram maior sensação articular e as mulheres maior controle steadiness. **Nível de evidência III, Estudo transversal.***

Descritores: Joelho. Atividade física. Propriocepção.

INTRODUCTION

The sensorimotor system (SSM) is responsible for transporting and integrating the sensory and motor information, central integration and processing of all components involved in maintaining articular homeostasis during body movements.[1] This means that the SSM provides functional joint stability throughout human movements and an inadequate functioning of this system can predispose to articular injuries.[2] Recent studies have shown that there are difference when evaluating the SSM between sex.[3] Moreover, SSM differences have been found between at different levels of activity.[4] Therefore, studies assessing the difference between gender and activity level are needed.

The main purpose of this study was to compare the differences in knee sensorimotor control combining measures of joint position

sense (JPS), steadiness and onset of muscle activation, relating them to level of physical activity, gender and differences between the two extremities.

MATERIALS AND METHOD

Subjects

The sample is composed of 51 voluntary healthy subjects; 27 men (24,27 ± 3,28 years; 1,76 ± 0,06 m; 75,91 ± 8,54 Kg) and 24 women (24,67 ± 3,53 years; 1,64 ± 0,06 m; 58,71 ± 8,73 Kg), with a level of physical activity with a score of 2 to 8 on the Tegner´s scale.[5] Each one of the participants signed an informed consent previous to the assessments that were performed. This study was approved by the bioethics committee of the Pontificia Universidad Católica de Chile (Protocol number 14-146).

Outcomes Measurement

JPS Test

The aim of this test was to evaluate JPS, the ability of subjects to actively replicate a previously determined joint position. A uniaxial electrogoniometer (Kinectecnic Ltda, Santiago, Chile) for the measurement of the knee articular angle in 3 ranges of motion was used: 90° – 60°, 60° – 30° y 30° – 0° (Figure 1A). The subject was in sitting position with their knees initially in 90° of flexion. In each repetition the difference between the angle reached by the subject and the target angle is calculated by averaging the difference of 10 repetitions for each angle and extremity. For signal processing, the Igor Pro 6.0 (WaveMetrics Inc, Lake Oswego, USA) program was used.

Steadiness. Sensation of muscle tension

The purpose of this assessment was to evaluate the ability of subjects to maintain a constant force at 15% of maximum voluntary isometric contraction, which reflects fine muscle control.[6] First, the maximum voluntary isometric contraction (MVIC) was assessed. The patient was sitting with a knee flexion angle of approximately 90° anchoring to the distal end of the leg a load cell where the subjects were asked to perform a maximum isometric voluntary contraction of the extensor muscles of the knee. This was measured using an S beam load cell (Interface, Arizona, USA). The signal was captured using a Trigno Wireless System (Delsys, Boston, USA) with a sampling frequency of 2000 Hz.

Knee isometric steadiness was evaluated with the same setup as the MVIC assessment. Each subject was asked to exert knee extensor force to reach a specific target, a trapezoidal figure which represented the 15% of their MVIC (Figure 1B). Subjects were asked to reproduce this paradigm that lasted 20 seconds. To quantify fine muscular control, the coefficient of variation was calculated between the paradigm displayed on the screen and the exerted force of the the subject

Onset of Muscle Activation

The onset of muscle activation in the knee muscles was estimated utilizing surface electromyography, a method that was previously used in other studies.[7] EMG bipolar sensors (Delsys, Boston, USA) were positioned on the vastus medialis, vastus lateralis, semitendinosus, and biceps femoris muscles of each subject according to SENIAM recommendations.[8] The subjects were ask to stand over two destabilizing platforms (Figure 1C). A sudden fall of the platforms causes 20° of inversion at the ankle in a weight-bearing condition. The drop of the platforms was captured with a triaxial accelerometer, which was synchronized with sEMG signals. Both signals were sampled at 2000 hz. Activation latency for each muscle was calculated as delta time between the onset of acceleration during perturbation and onset of muscle activation.

Figure 1. (A) Shows the joint position sense test with the uniaxial electrogoniometer. (B) Shows the steadiness test with the load cell and the paradigm to 15% of the MVIC. (C) Shows the knee muscle onset test with the position of the sEMG sensors and the platform.

Each one of the assessments was performed on both extremities in all subjects.

In order to make comparisons, subjects were divided into different groups depending on their individual characteristics (Table 1). In all assessments, each of the data obtained between the different groups was compared.

Statistical analysis

To evaluate the normal distribution of the data the Shapiro-Wilk test was used. The difference mean test was used in the case of data with normal distribution and the signed rank Wilcoxon test otherwise. A statistically significant result was considered when the p value was less than or equal to 0.05. STATA 9.1 software was used for the statistical analysis. For the different measured tests (JPS, Steadiness and onset of muscle activation) gender differences, differences between groups with different levels of physical activity, differences between the dominant and non-dominant limb, and differences between right versus left limb of the same subject were compared.

RESULTS

JPS Test

A significant difference was found between men and women in the knee JPS test at 90°-60° (p=0,0127) and at 30°-0° (p=0,0034) when comparing the right extremities of both genders (Figure 2 A). When comparing left extremities a significant difference was found in the range of 60°-90° (p=0,0034) (Figure 2 B). In both comparisons men had better results.

The group with higher level of physical activity had significantly better values in at 90°-60° (p=0,0328) in the right limb and 30°-0° (p=0,0173) in the left limb compared with the group that performed a lower level of physical activity (Figure 2 C and 2 D). No significant differences were found when comparing the dominant limb with the non dominant limb, however the results showed that the left limb showed better results in JPS at 60°-30° (p = 0.0048) (Figure 2 E). (Table 2 A, B)

Steadiness

Women had significant better values compared to men in the right (p=0,0002) and left limb (p=0,0009), (Figure 3 A). The group with higher level of physical activity had significant better values in right steadiness (p=0,0065) and left (p=0,0173) compared to the group that performed a lower level of physical activity (Figure 3 B). (Table 3 A, B)

Onset of Muscle Activation

The left limb showed better results in the timing of muscle onset for vastus medialis (p = 0.0466) when compared with the right leg. (Figure 4 E). (Table 4 A, B)

Table 1. Mean +/- (standard deviation) of demographic data for subjects who complete the 3 evaluations.

Variable	Groups	
Gender	**Men (n=27)**	**Women (n=24)**
Level of physical activity Tegner´s scale	More than 5 (n=28)	Less or equal to 5 (n=23)
Age	Older than 25 years (n=18)	Younger or equal to 25 years (n=33)
Dominance	Dominant limb (n=51)	Non dominant limb (n=51)
Extremity	Right (n = 51)	Left (n=51)

Information of each group in which subjects were divided to make comparisons of each evaluation. n = number of subjects per category.

DISCUSSION

JPS Test

Previous studies have demonstrated significant differences between men and women when comparing knee proprioception.[3,9] In these studies women present reduce proprioception ability, which is consistent with the data obtained in our study where worse values in joint repositioning are shown in the female population in the most extreme measurement ranges (90°-60° y 30°-0°). A possible explanation for this is that women have greater articular laxity, so capsuloligamentous receptors would need a greater stimulus to trigger a response equal to that of men.[1] Men also have a higher proportion of muscle mass, which could provide them with more quantity of musculotendinous proprioceptive receptors.

Subjects with a lower level of physical activity also presented worse values in knee JPS. Some studies in professional footballers[4] and in elite tennis players[10] agree with our data and confirm that physical activity level is also a factor that can influence the proprioceptive assessment performance. Moreover, higher proprioception ability have been found in competitive athletes.[11] Therefore, it is possible to hypothesized that training enhance the proprioception ability.

In this study no significant differences were found between the dominant and non-dominant limb. However, when comparing the left and right limb (i.e.: without considering dominance) we found better values in the joint repositioning test in the left side. This is consistent with the results published by Daniel J. Goble[12], which indicates a close relationship between the left side of the body and the right hemisphere of the brain. Moreover, Natio et al. used a regional map with neuroimaging of the brain's response while applying vibrations to tendons and found that the proprioceptive signals from the proprioceptive receptors generated more information to the right hemisphere of the brain, so the left side of the body should have better proprioceptive values.[13,14] Therefore, it seems that the left lower limb have better proprioceptive performance.

Steadiness

The results of the present study also show better steadiness values in the group of women as compared to men, as the study of Brown et al.[15] According to this study, the main difference in steadiness is attributable to the absolute muscle strength, which is higher in men compare to women. Regarding to the physical activity level, results show that subjects with a higher level of physical activity present better isometric steadiness than sedentary subjects. Different studies have shown that strength training improves isometric steadiness due to sensorimotor control improvements, which would explain the better result in trained subjects.[16,17] Moreover, this assessment has be related to a greater risk of injury, as seen in various publications that patients with anterior cruciate ligament reconstruction.[18] Therefore, this assessment provides an insight in muscle function and may be use in other clinical settings.

Onset of Muscle Activation

No significant differences were found in most of the onset of muscle activation. Nevertheless, other studies have found that healthy people that have greater anterior knee laxity present an increase in timing of muscle onset of biceps femoris.[19] If there is an increased time of muscle onset, it can compromise joint stability, being similar to what happens when there is a ligament injury and damage to receptors that send the afferent signal, and the signal initiating this reflex may be compromised.
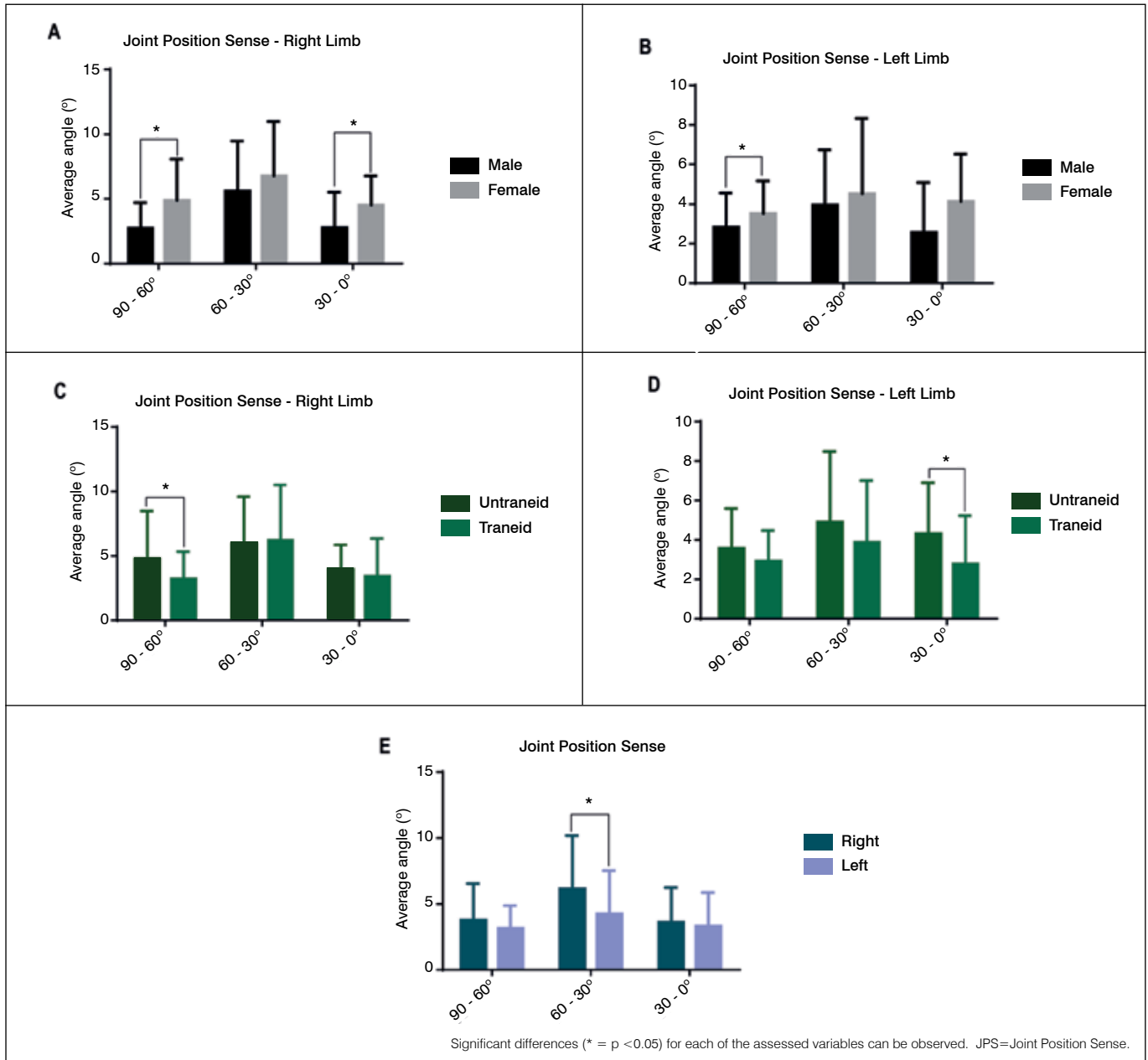
Figure 2. Results for joint position senses (JPS) for the comparisons between male - female, trained - untrained and right limb -left limb. All data shown as median and standard deviation. (A) It shows JPS in degrees for the right limb for males and females. (B) It shows JPS in degrees for the left limb for males and females. (C) It shows JPS in degrees for the right limb for trained and untrained. (D) It shows JPS in degrees for the left limb for trained and untrained. (E) It shows JPS in degrees for the left and right limb.

Table 2 A. Means Angles Values for Joint Position Sense by gender, physical activity or both limbs.

Variable	Indicator	Limb	Mean 90º-60º	SD	Mean 60º - 30º	SD	Mean 30º - 0º	SD
Gender	Male	Right	2,75	1,95	5,59	3,87	2,79	2,71
		Left	2,82	1,73	3,96	2,79	2,56	2,53
	Female	Right	4,88	3,18	6,78	4,20	4,52	2,25
		Left	3,51	1,65	4,52	3,80	4,13	2,40
Level of physical activity	Tegner > 5	Right	3,24	2,07	6,24	4,27	3,42	2,94
		Left	2,93	1,53	3,88	3,13	4,92	3,55
	Tegner ≤ 5	Right	4,77	3,71	5,97	3,62	3,97	1,89
		Left	3,57	2,01	4,92	3,55	4,31	2,59
Limb		Right	3,75	2,79	6,15	4,03	3,60	2,63
		Left	3,14	1,71	4,22	3,28	3,30	2,57

Values expressed in degrees. Abbreviations: SD: Standard Deviation.

Table 2 B. Comparison of Means Angles Values for Joint Position Sense between gender, physical activity or both limbs.

Evaluation	Limb	Range	MD	ES	P. Value
Differences between gender (Female – Male)	Right	90º - 60º	2,12	1,95	0,0127 *
		60º - 30º	1,18	1,13	0,3358
		30º - 0º	1,73	0,70	0,0017 *
	Left	90º - 60º	0,68	0,47	0,1311
		60º -30º	0,56	0,92	0,8949
		30º - 0º	1,57	0,69	0,0034 *
Differences between Level of physical activity (Lower– Higher)	Right	90º - 60º	1,52	0,80	0,0328 *
		60º - 30º	- 0.27	1,20	0,4109
		30º - 0º	0,54	0,78	0,2450
	Left	90º - 60º	0,64	0,50	0,1062
		60º -30º	1,03	0,97	1,0374
		30º - 0º	1,51	0,74	0,0229 *
Differences between Both Limbs (right – left)		90º - 60º	0,60	0,45	0,0941
		60º -30º	1,92	0,72	0,0048 *
		30º - 0º	0,30	0,51	0,2531
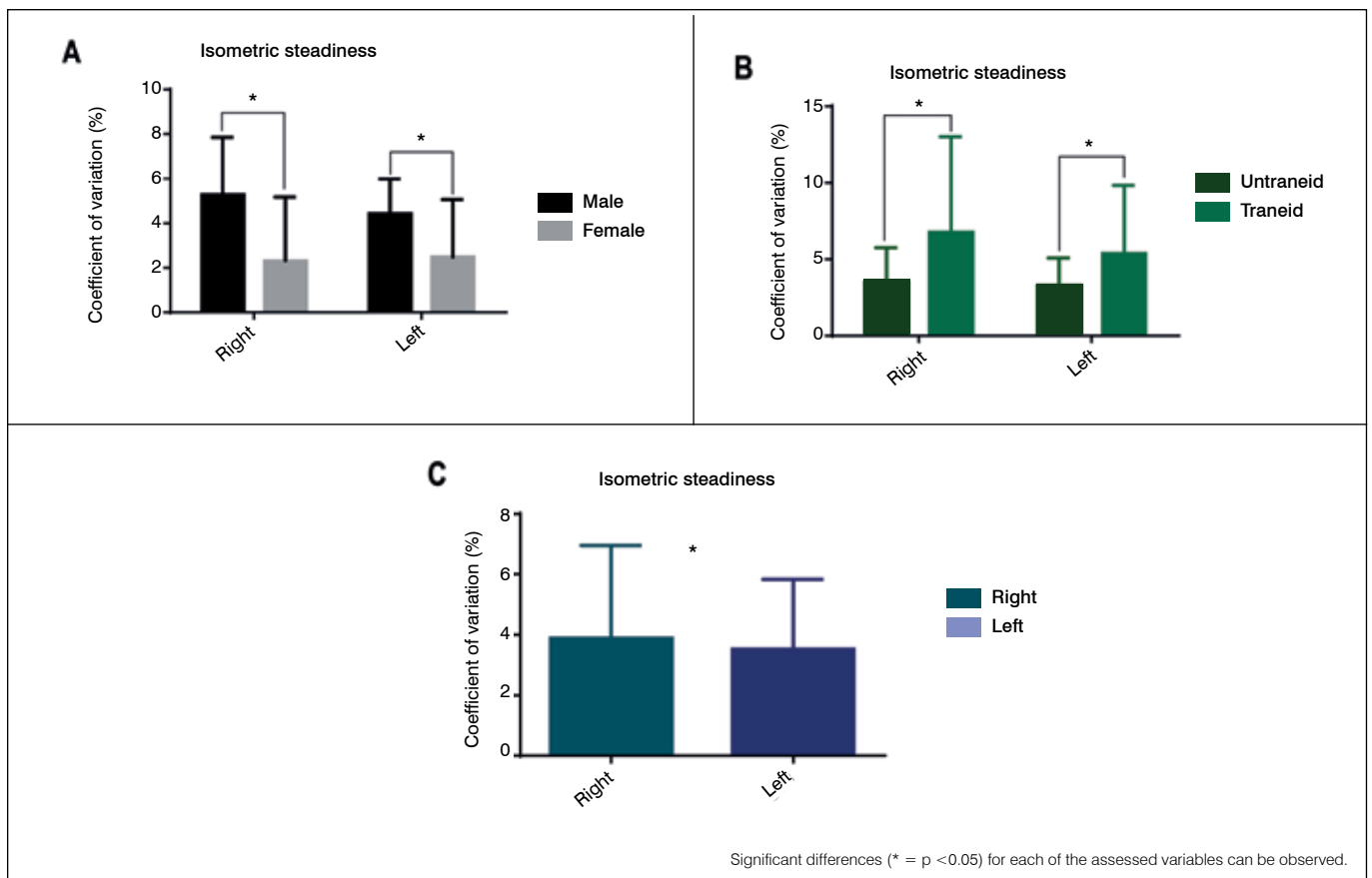
* P < 0,05. Abbreviations: MD= Mean Difference. ES= Error Standard.

Figure 3. Results for isometric steadiness for the comparisons between male - female, trained - untrained and right limb -left limb. All data shown as median and standard deviation. (A) It shows the coefficient of variation for the isometric steadiness for males and females. (B) It shows the coefficient of variation for the isometric steadiness for trained and untrained. (C) It shows the coefficient of variation for the isometric steadiness for right limb and left limb.

Table 3 A. Mean Percentages for Values Steadiness by gender, physical activity or limb evaluated.

Variable	Indicator	Right Limb Mean	SD	Left Limb Mean	SD
Gender	Male	5,28	2,57	4,44	1,55
	Female	2,32	2,86	2,49	2,58
Level of physical activity	Tegner > 5	3,50	2,24	3,28	1,79
	Tegner ≤ 5	6,71	6,23	5,38	4,45
Limb		3,88	3,07	3,52	2,30

Values expressed in percentage. Abbreviations: SD: Standard Deviation.

Table 3 B. Comparison of Mean Percentage for Values Steadiness by differences between gender, physical activity or both limbs.

Evaluation	Limb	MD	ES	P. Value
Gender (Female – Male)	Right	- 2,90	0,70	0,0002*
	Left	- 1,90	0,50	0,0009*
Level of physical activity (Lower – Higher)	Right	3,20	1,20	0,0065*
	Left	2,00	0,90	0,0173*
Limb (right – left)		0,30	0,50	0,2531

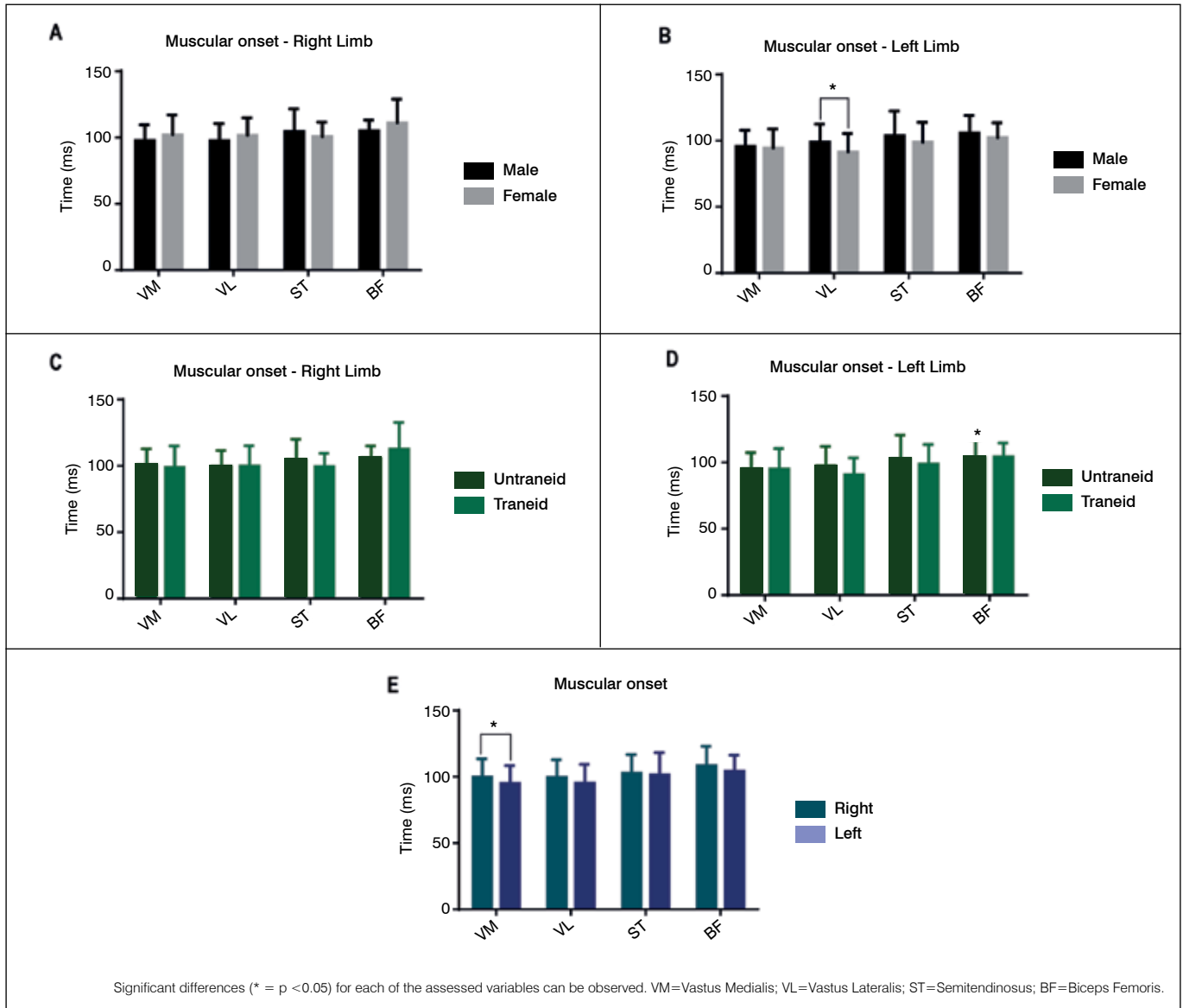* P < 0,05. Abbreviations: MD= Mean Difference. ES= Error Standard.

Figure 4. Results for muscular onset for the comparisons between male - female, trained - untrained and right limb -left limb. All data shown as median and standard deviation. (A) It shows time of muscular onset for the right limb, for males and female. (B) It shows time of muscular onset for the left limb, for males and females. (C) It shows time of muscular onset for the right limb, for trained and untrained. (D) It shows time of muscular onset for the left limb, for trained and untrained. (E) It shows time of muscular onset for the right limb and left limb.

Significant differences (* = p <0.05) for each of the assessed variables can be observed. VM=Vastus Medialis; VL=Vastus Lateralis; ST=Semitendinosus; BF=Biceps Femoris.

Table 4 A. Mean Values for time of Muscle Onset by gender, physical activity and both limbs.

Variable	Indicator	Limb	MV Mean	SD	LV Mean	SD	ST Mean	SD	FB Mean	SD
Sex	Male	Right	97,57	12,01	97,42	13,19	104,74	16,83	105,07	8,12
		Left	95,61	12,31	98,94	13,57	103,87	18,49	105,85	13,25
	Female	Right	102,0	15,07	101,72	13,12	100,64	10,89	111,12	17,81
		Left	94,38	14,61	91,42	14,00	98,98	14,95	102,25	11,31
Level of physical activity	Tegner > 5	Right	100,45	12,32	99,43	12,20	104,32	15,85	105,83	9,29
		Left	94,91	12,51	97,45	14,64	102,87	17,78	103,87	13,44
	Tegner ≤ 5	Right	98,76	16,26	99,95	15,23	99,53	9,87	112,73	20,07
		Left	95,06	15,32	90,83	12,54	98,63	14,90	104,23	10,46
Limb Left		Right	99,85	13,69	99,62	13,18	102,69	14,16	108,48	14,57
		Left	94,97	13,42	95,09	14,15	101,42	16,80	104,00	12,28

Values expressed in milliseconds. Abbreviations: SD: Standard Deviation. MV= Medial Vastus. LV= Lateral Vastus. ST= Semitendinosus. FB= Femoral Biceps.

Table 4 B. Comparison between Mean for time of Muscle Onset by differences between gender, physical activity and both limbs.

Evaluation	Limb	Muscle	MD	ES	P. Value
Gender (Female – Male)	Right	MV	4,46	4,07	0,2858
		LV	4,29	3,92	0,2287
		ST	- 4,10	4,27	0,6555
		BF	6,04	4,66	0,3012
	Left	MV	- 1,23	4,09	0,7421
		LV	- 7,51	4,11	0,0357 *
		ST	- 4,89	5,07	0,4595
		BF	- 3,60	3,75	0,6269
Level of physical activity (Lower - higher)	Right	MV	- 1,68	4,30	0,3487
		LV	0,52	4,15	0,4504
		ST	- 4,79	4,49	0,1464
		BF	6,90	4,72	0,0763
	Left	MV	0,15	4,25	0,4860
		LV	- 6,62	4,34	0,0675
		ST	- 4,23	5,36	0,2175
		BF	0,36	3,92	0,4631
Limb (right – left)		MV	4,88	2,87	0,0466 *
		LV	4,52	2,88	0,0602
		ST	1,26	3,31	0,3516
		BF	4,47	2,96	0,0677

* $P < 0,05$. Abbreviations: MD= Mean Difference. ES= Error Standard. MV= Medial Vastus. LV= Lateral Vastus. ST= Semitendinosus. FB= Femoral Biceps.

CONCLUSION

Men presented better JPS and steadiness that women, which may be attributable to a higher laxity of women and higher muscle strength of men, respectively. Subjects with higher training showed better JPS and steadiness values. This is consistent with the literature, where training results in sensorimotor adaptation.

AUTHORS' CONTRIBUTIONS: All authors contributed individually and significantly to the development of this article. CSM (0000-0001-9913-3310)*: wrote and reviewed the manuscript, contributed to the intellectual conceptualization of the study and the entire research project. AV: wrote and reviewed the manuscript. IC (0000-0003-3831-6513)*: performed measurements for the assessments and outcome assessment analysis. FJB (0000-0003-3552-8262)*: contributed to the intellectual conceptualization of the study and reviewed the manuscript. CO (0000-0001-7240-1928)*: performed the statistical analysis and reviewed the manuscript. FL (0000-0001-9255-2555)*: performed measurements for the assessments and wrote the manuscript. *ORCID (Open Researcher and Contributor ID).

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