



Junta de Andalucía
Consejería de Educación y Deporte

Revista Andaluza de Medicina del Deporte

<https://ws072.juntadeandalucia.es/ojs>



Original



The effect of short-term resistance training on hand reaction time improvement is independent of sexual dimorphism

A.L.B. Silveira^{a,b,c,d*}, L.M. Carvalho^{a,b,c}, C.N. Lima^a, C.R.M. Costa^{a,b,c}, C.M. Bentes^{a,d}

^a Laboratory of Physiology and Human Performance. Department of Physical Education and Sports. Institute of Education. Federal Rural University of Rio de Janeiro. Seropédica. Brazil.

^b Multicenter Postgraduate Program of Physiological Sciences. Brazilian Society of Physiology. Brazil.

^c Department of Physiological Sciences. Institute of Health and Biological Sciences. Federal Rural University of Rio de Janeiro. Seropédica. Brazil.

^d Laboratory of Strength Training, Kinanthropometry and Human Performance. Department of Physical Education and Sports. Institute of Education. Federal Rural University of Rio de Janeiro. Seropédica. Brazil.

ARTICLE INFORMATION: Received 4 September 2020, accepted 6 November 2020, online 16 November 2020

ABSTRACT

Objective: The aim was to evaluate the effects of four weeks of resistance training and sexual dimorphism on Manual reaction time in apparently healthy subjects.

Methods: The subjects of the sample were randomly allocated in two groups, as follow: Control (CTRL) - kept 4 weeks without any systematized physical activity ($N_{\text{males}} = 8$, age= 24±3 yrs., body weight= 76.9±15.4 kg; $N_{\text{females}} = 8$, age= 22.5±4 yrs., body weight= 70.8±17.5 kg); Experimental (EXP) - 4 weeks of resistance training ($N_{\text{males}} = 8$, age= 23±3 yrs., weight= 69.6±11 kg; $N_{\text{females}} = 8$, age= 22.5±1 yrs., body weight= 59.77±6.8 kg). The resistance training consisted of 4 exercises for upper limbs (3 sets x 8-12 reps) and 4 exercises for lower (3 sets x 12-15 reps). Manual reaction time was evaluated in a manufactured Arduino-based reaction time device connected to a computer.

Results: For men, there was a significant decrease in Manual reaction time after resistance training within EXP ($p < 0.0001$) and between groups ($p < 0.0001$). Women showed the same results within EXP ($p < 0.0001$) and between groups ($p < 0.0001$). Additionally, there was no sexual dimorphism before or after four weeks of resistance training.

Conclusion: The results suggest that just four weeks of resistance training was sufficient to improve Manual reaction time, regardless of sexual dimorphism. Therefore, resistance training inclusion in the training periodization seems essential to improve or rehabilitate the fast voluntary motor response, especially for activities or sports that require it.

Keywords: Gender Difference; Psychomotor Performance; Strength Training; Response Time; Central Nervous System; Visual Perception.

El efecto del entrenamiento de resistencia a corto plazo en la mejora del tiempo de reacción manual es independiente del dimorfismo sexual

RESUMEN

Objetivo: El objetivo fue evaluar los efectos de cuatro semanas de entrenamiento de resistencia y dimorfismo sexual sobre el tiempo de reacción manual en jóvenes aparentemente sanos.

Métodos: Los sujetos de la muestra fueron asignados aleatoriamente en dos grupos, como sigue: Control (CTRL) - mantenido 4 semanas sin ninguna actividad física sistematizada ($N_{\text{hombres}} = 8$, edad= 24 ± 3 años, peso corporal= 76.9 ± 15.4 kg; $N_{\text{mujeres}} = 8$, edad= 22.5 ± 4 años, peso corporal= 70.8 ± 17.5 kg); Experimental (EXP) - 4 semanas de entrenamiento de resistencia ($N_{\text{hombres}} = 8$, edad= 23 ± 3 años, peso corporal= 69.6 ± 11 kg; $N_{\text{mujeres}} = 8$, edad= 22.5 ± 1 año, peso corporal= 59.77 ± 6.8 kg). El entrenamiento de resistencia consistió en 4 ejercicios para las extremidades superiores (3 series x 8-12 repeticiones) y 4 ejercicios para las inferiores (3 series x 12-15 repeticiones). El tiempo de reacción manual se evaluó utilizando una placa Arduino fabricada conectada a la computadora.

Resultados: Para los hombres, hubo una reducción significativa en tiempo de reacción manual después de entrenamiento de resistencia intra EXP ($p < 0.0001$) y entre grupos ($p < 0.0001$). Los mismos resultados se observaron en mujeres, intra EXP ($p < 0.0001$) y entre grupos ($p < 0.0001$). Además, no hubo dimorfismo sexual antes y después de 4 semanas de entrenamiento de resistencia.

Conclusión: Los resultados sugieren que solo cuatro semanas de entrenamiento de resistencia fueron suficientes para mejorar el tiempo de reacción manual, independientemente del dimorfismo sexual. La inclusión del entrenamiento de resistencia en la periodización del entrenamiento parece importante para mejorar o rehabilitar la respuesta motora voluntaria rápida, especialmente para actividades o deportes que lo requieran.

Palabras clave: Diferencias Género; Entrenamiento Fuerza, Percepción Visual, Rendimiento Psicomotor, Sistema Nervioso Central, Tiempo Reacción.

* Corresponding author.

E-mail-address: andersonsilveira@ufrj.br (A.L.B. Silveira).

<https://doi.org/10.33155/j.ramd.2020.11.001>

© 2021Consejería de Educación y Deporte de la Junta de Andalucía. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

O efeito do treinamento resistido de curto prazo sobre a melhora do tempo de reação é independente do dimorfismo sexual

RESUMO

Objetivo: O objetivo foi avaliar os efeitos de quatro semanas de treinamento resistido e do dimorfismo sexual sobre o tempo de reação manual em jovens aparentemente saudáveis.

Metodos: 32 jovens destreinados de ambos os sexos compuseram a amostra. Eles foram aleatoriamente alocados em 2 grupos: Controle (CTRL) – ficaram 4 semanas sem exercícios físicos ($N_{\text{homens}} = 8$, idade= 24 ± 3 anos, peso corporal= 76.9 ± 15.4 kg; $N_{\text{mulheres}} = 8$, idade= 22.5 ± 4 anos, peso corporal= 70.8 ± 17.5 kg); Experimental (EXP) - 4 semanas de treinamento resistido ($N_{\text{homens}} = 8$, idade= 23 ± 3 anos, peso corporal= 69.6 ± 11 kg; $N_{\text{mulheres}} = 8$, idade= 22.5 ± 1 anos, peso corporal= 59.77 ± 6.8 kg). O treinamento resistido consistiu em 4 exercícios para membros superiores (3 séries x 8-12 reps) e 4 para inferiores (3 sets x 12-15 reps). tempo de reação manual foi avaliado através de uma placa manufaturada de Arduino conectada ao computador.

Resultados: Para os homens, houve uma redução significativa no tempo de reação manual após treinamento resistido intra EXP ($p < 0.0001$) e entre os grupos ($p < 0.0001$). Os mesmos resultados foram observados em mulheres, intra EXP ($p < 0.0001$) e entre os grupos ($p < 0.0001$). Adicionalmente não houve dimorfismo sexual antes ou após 4 semanas de treinamento resistido.

Conclusão: Os resultados sugerem que apenas quatro semanas de treinamento resistido foram suficientes para melhorar o tempo de reação manual, independente do dimorfismo sexual. Portanto, a inclusão do treinamento resistido na periodização de treinamento parece importante para melhorar ou reabilitar a resposta motora voluntária rápida, principalmente para atividades ou esportes que assim necessitem.

Palavras-chave: Diferenças Sexuais; Percepção Visual; Performance Psicomotora; Sistema Nervoso Central; Treinamento Força; Tempo Resposta.

Introduction

Reaction Time (RT) is defined as the necessary time to interpret a stimulus and start a voluntary motor response. This variable represents a reliable measure of sensory speed processing of the central nervous system,¹ and cognitive function.² Studies about RT have raised interest in researches, especially about its influence in daily life activities,³ the prognosis of general fitness of athletes,⁴ or to identify new talents for sports.⁵

In practical terms, an individual that has long RT could mean a delay in motor responses to depolarizing the muscles involved in the movement, which has a strong association with an increase of fall risk for the elderly,⁶ raising odds of joint injury⁷ and automobilist accidents.⁸ On the other hand, short RT shows some advantages, mainly in moments that require a fast change of body position,⁵ immediate reactions to dodge opponents blows in fighting sports,⁹ or track and field sprint start.¹⁰ Therefore, improving RT seems to be directly related to a high quality of life² and sports performance.⁴

Besides, even among several factors that may interfere in RT, sexual dimorphism¹¹ and physical exercise⁴ are discussed in the literature.^{4,11} In this sense, strength and muscle fiber differences between men and women can influence on Manual Reaction Time (MRT).¹² Another sex difference that also can change MRT is the hormone and menstrual cycle.¹³ For Stenbaek et al., sex hormones fluctuation can impair the cognitive processing speed.¹³

Physical exercise characterized as a non-pharmacological instrument seems to be associated with practice time¹⁴ and consequently, to improve RT.¹⁵ Since, physically active and experienced athletes, long-term involved with aerobic training program, show a short RT compared to sedentary people and beginner athletes.⁴ On the other hand, short and chronic changes promoted by systematized resistance training on MRT from young subjects still unclear.

The American College of Sports Medicine (ACSM) position stand for progression models in resistance training for adults, preconized the importance of variation of resistance training (e.g., volume, intensity, muscle group trained, contraction type, movement speed) to promote specific physiological adaptations, such as changes in muscle strength and power, hypertrophy, local endurance, and motor performance.¹⁶

The recommendations to improve reaction time (motor performance) with a resistance exercise is to perform multiple-joint exercises for upper and lower limbs using a moderate load and volume. Nevertheless, there are no studies based on the ACSM position stand/guideline¹⁶ that analyses the MRT.

Additionally, progressive resistance training can have different influences in men and women on strength¹⁷ and hypertrophy.¹⁸ However, still a lack of knowledge about a possible interference of

sexual dimorphism on MRT after resistance training. Knowing that resistance training can influence performance, rehabilitation, and quality of life, we hypothesized that only four weeks of resistance training will reduce manual reaction time and some gender differences. Therefore, this study aimed to investigate resistance training programs influence along four weeks and sexual dimorphism on reaction time in apparently healthy individuals.

Methods

Subjects

The volunteers' inclusion criteria were to be untrained or six months away from resistance training, without any injury declared. The volunteers should not use psychostimulant drugs and should avoid the use of caffeine before MRT tests (Figure 1). The sample was composed of 32 subjects (16 women and 16 men, Table 1).

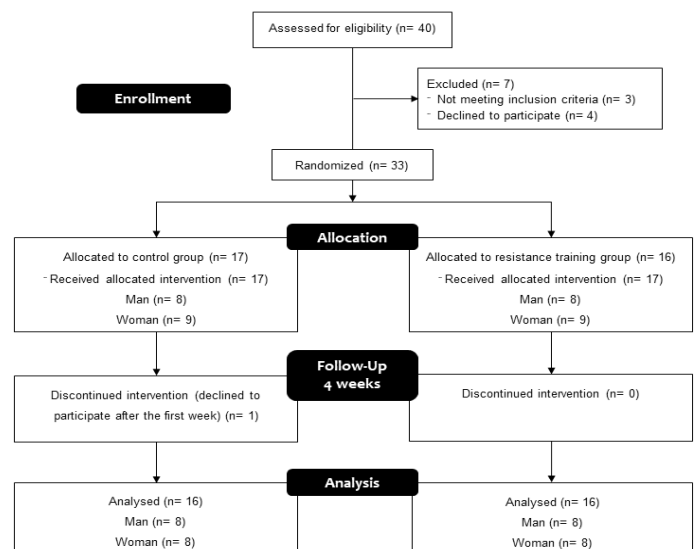


Figure 1. Flow diagram of the subjects selection process

Table 1. Volunteers' anthropometric data

Variables	Male ($\bar{x} \pm DP$)			Female ($\bar{x} \pm DP$)		
	CTRL	EXP	p-value	CTRL	EXP	p-value
Age (yrs.)	24±3	23±3.2	0.55	22.5±3.8	22.5±1.2	0.97
Weight (kg)	76.9±15.4	69.6±11	0.31	70.8±17.5	59.77±6.8	0.30
Height (cm)	175.4±7.7	175.5±7.7	0.97	166±4	163±3.8	0.29
BMI	24.8±3.5	22.4±2.2	0.15	25.9±7.6	22.5±3	0.44

CTRL: Control; EXP: Resistance training for four weeks; BMI: bone mass index. Data described as mean ± standard deviation. Significance adopted $p < 0.05$.

Research Ethics Committee from Federal Rural University of Rio de Janeiro declared that this study had been conducted following resolution no. 466/2012 of the National Health Council Declaration, in Brazil (protocol# 421/2014) and Declaration of Helsinki for research involving human subjects. All subjects assigned an informed consent form authorizing their participation in the study.

Procedures

A randomized controlled trial was used to investigate the effect of resistance training program (RTR) along four weeks and sexual dimorphism on reaction time in apparently healthy individuals. The subjects visited twice the Laboratory of Physiology and Human Performance. In the First visit, all subjects were submitted to an anthropometric evaluation and the MRT test, moreover, they were randomly and voluntarily allocated to control (CTRL: subjects kept four weeks without any systematized physical activity) or experimental group (EXP: subjects performed four weeks of RTR) (Table 1). After four weeks, all subjects visited the laboratory for the second time, and they were submitted to MRT retest.

RTR consisted of convectional resistance training method (3 times per week, during four weeks), with workloads prescribed aiming muscle hypertrophy (75% 1RM), for both upper (3 sets x 8-12 repetitions) and lower limbs (3 sets x 12 – 15 repetitions).¹⁶ The RTR consisted of bench press; lat pulldown; low seated row; shoulder press; leg press; leg curl; leg extension; calf press.

Workloads were weekly and systematically adjusted until the end of RTR. That procedure consisted of to increase 20% over the last performed workload when subjects exceed the only limit of repetition in the last exercise set (e.g., upper limbs 12 repetitions; lower limbs 15 repetitions). Volunteers in the CTRL group were instructed to maintain their daily physical activities without training or systematized physical activity along four weeks. All the RTR exercises were performed bilaterally.

MRT evaluation used Arduino® as the data acquisition board (ArduinoUnoRev3 R3 Atmega328 Dip, San Jose, California, USA), connected to a computer. That board was plugged to a breadboard with green, red, and yellow light-emitting diode display (LED), as well as to a manufactured push-button stopwatch deactivation. We developed a simple software to control the order of LEDs activation and start the stopwatch and record the MRT and calculated the mean of trials.

First, the hardware turns on the yellow LED to alert the subjects. After that, a green LED was randomly displayed, starting the stopwatch. At this moment, the subjects should push the push-button stopwatch deactivation and finish the test. If the subject has pushed the button before to display the green LED, the hardware displayed a red LED, meaning an error has occurred, and the trial was discarded. In this study, MRT was defined as the time from the visual signal (green light) until the push-button press.

During the MRT, the volunteers were taken seated on a chair, facing the equipment, backs in an upright position, and their feet parallel on the floor. The test was performed with the dominant hand in a neutral position (at 90°), and the volunteers must hold the stopwatch deactivation device with the thumb over the button. The evaluator seated and positioned the apparatus in front of the volunteers, ensuring that they could not see their test values on the computer screen. MRT value of each volunteer was determined as the average of ten consecutive trials. Both groups (CTRL or EXP) performed two evaluations of MRT (Pre and post four weeks).

Statistical Analysis

This study first verified the primary variable's data normality, and MRT showed a Gaussian distribution following the Shapiro-

Wilk test. Thus, a two-way ANOVA was performed to verify the differences within and between factors. Tukey post hoc test was applied when the F value from ANOVA was significant. Unpaired Student T-test was also performed to compare anthropometric features for both groups in the same gender. The significance adopted was $p < 0.05$. All statistical analyses were performed by GraphPad Prism (version 6.0, San Diego, California). All results were described as mean \pm standard deviation.

The effect size (ES) was used to verify the magnitude of differences. When individuals are untrained, ES < 0.50 means trivial, ES of 0.50-1.25 means small, ES of 1.25-1.9 means moderate, and when ES > 2.0 means large.¹⁹

Results

Basal Results

Before any intervention (Pre), there was any statistical difference and a trivial ES for MRT between CTRL and EXP for men (CTRL: 491.9 ± 50.4 vs. EXP: 510.4 ± 48.1 ms; $p > 0.05$; ES = 0.36; Figure 2A). For women, the results were similar to those shown for men but with an ES which means small differences (CTRL: 475.6 ± 40.4 vs. EXP: 511.5 ± 35.4 ms; $p > 0.05$; ES = 0.88; Figure 2B). These results confirmed the sample homogeneity since both groups started at the same level of MRT.

There was any difference for MRT between women and men at this moment (Figure 2C) and how expected, the ES magnitude was trivial for CTRL (Women: 511.5 ± 35.4 vs. Men: 510.4 ± 48.1 ms; ES = 0.03 $p > 0.05$) and small ES for EXP groups (Women: 287.4 ± 18.4 vs. Men: 300.8 ± 14.3 ms; ES = 0.72 $p > 0.05$).

Four Weeks of Resistance Training Results

MRT evaluation after four weeks (Post) showed that daily activities (CTRL) were not efficient to change for both men (CTRL_{Pre}: 491.9 ± 50.4 vs. CTRL_{Post}: 468.1 ± 20.7 ms; ES = 0.45 $p > 0.05$; Figure 2A) and women (CTRL_{Pre}: 475.6 ± 40.4 vs. CTRL_{Post}: 498.6 ± 40.0 ms; ES = 0.56 $p > 0.05$; ES: 0.56; Figure 2B) and the ES confirmed that with trivial differences.

On the other hands, four weeks of RTR promoted a significant decrease with a large ES magnitude of MRT for men (Figure 2A) within (EXP_{Pre}: 510.4 ± 48.1 vs. EXP_{Post}: 300.8 ± 14.3 ms; ES: -4.35; $p < 0.0001$) and between groups (CTRL_{Post}: 468.1 ± 20.7 vs. EXP_{Post}: 300.8 ± 14.3 ms; ES: -8.02; $p < 0.05$). Similar results were showed for women (Figure 2B) within (EXP_{Pre}: 511.5 ± 35.4 vs. EXP_{Post}: 287.4 ± 18.4 ms; ES: -6.33; $p < 0.0001$) and between groups (CTRL_{Post}: 498.6 ± 40.0 vs. EXP_{Post}: 287.4 ± 18.4 ms; ES: -5.28; $p < 0.0001$).

However, there was any statistical evidence of sexual dimorphism for MRT in the experimental group (Figure 2D) before (WOMEN_{EXP-Pre}: 511.5 ± 35.4 vs. MEN_{EXP-Pre}: 510.4 ± 48.1 ms; ES: -0.03; $p > 0.05$) or after four weeks of RTR (WOMEN_{EXP-Post}: 287.4 ± 18.4 vs. MEN_{EXP-Post}: 300.8 ± 14.3 ms; ES: 0.72; $p > 0.05$) and this no sexual dimorphism difference before and after was confirmed by ES with trivial and small differences respectively

Discussion

The present study is a pioneer in evaluating the manual reaction time in short-term resistance training. The main findings of this research were four weeks of resistance training with volume and intensity adjusted for hypertrophy, exercise order from large to small and upper to lower muscle groups, were able to promote a significant decrease in MRT. Daily life activities alone do not provide enough stimulus to adapt to neuromuscular circuitry.³ Also, the absence of a regular physical exercise program could not improve MRT, which leads to a decreasing quality of life.

The literature shows that reduction in MRT is directly associated with improvement in daily life activities³ and,

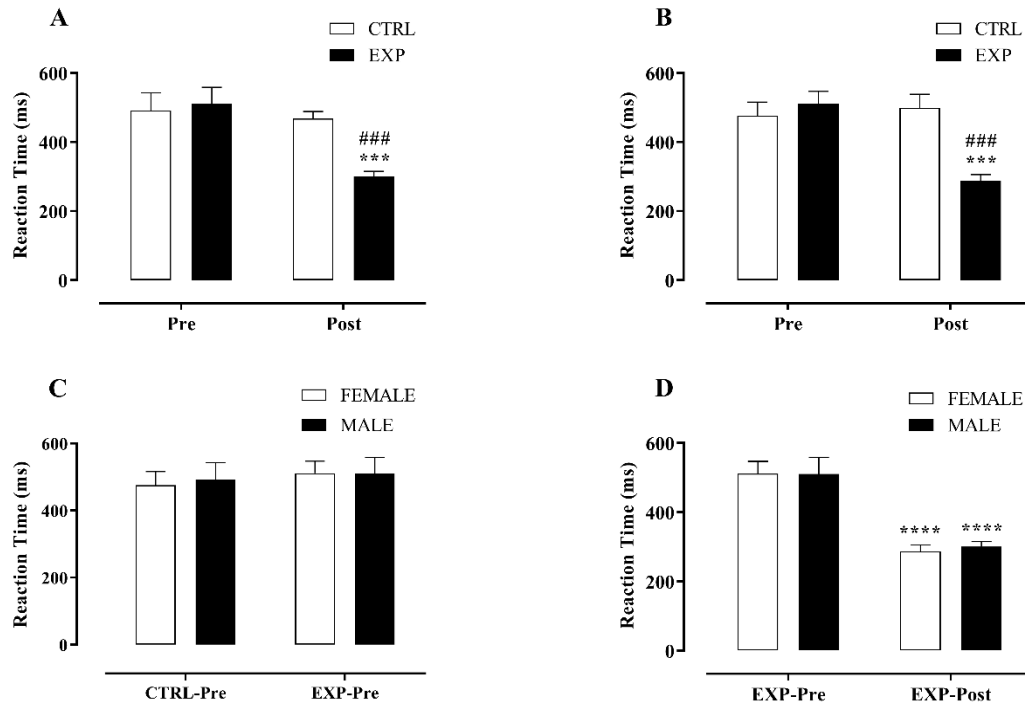


Figure 2. Comparison of manual reaction time, before (PRE) and after (POST), four weeks of resistance training protocol. (A: Male; B: Female; C: Sexual dimorphism between groups; D: Sexual dimorphism within EXP). * Statistical difference within group (PRE vs POST); # Statistical difference between groups (CTRL vs EXP; FEMALE vs MALE). *** $p < 0.001$. ### $p < 0.001$

consequently, on quality of life,² as well as in sports performance of different modalities.^{4,5} Accordingly, exercise training, regardless of type, seems to be fundamental in improving voluntary motor response and quality of life.²⁰

However, our results show that changing in quality of life and sports performance can be acutely, since just four weeks of resistance training reduced MRT in healthy adults. Probably, short-term resistance training was able to promote, in the central nervous system,²¹ several hormonal, structural,²² and mostly functional adaptations in such as speed stimulus processing, motor units activation,²² synchronization²² and consequently, better organized voluntary motor response.²³

The present study also demonstrated an absence of sexual dimorphism influence on MRT before or after four weeks of resistance training, despite gender differences to withstand exercise load, fatigue sensation,²⁴ or hand muscle structure.²⁵ Possibly, because the motor task applied in our study evaluated only the dominant hand to perform it, according to Mickeviciene et al.¹¹ Thus, it is also reasonable to hypothesize that there is sexual dimorphism influence on MRT in performing activities with both hands.¹¹ Despite this hypothesis, there is no evidence about the reaction time of both hand activities and gender differences.

This study has some limitations, since that we did not evaluated the manual reaction time using a gold standard method, and only evaluated total manual reaction time. This study also did not control the menstrual cycle, but it was intentionally to increase its external validity. Future research should focus on differences in volume and intensity of resistance training and overall effect in different sports and rehabilitation therapy. Additionally, it would be essential to evaluate the sexual dimorphism influence in other neural processing moments, such as pre-motor reaction time, muscle contraction time, and motor reaction time for different activities and sports.

In conclusion, our study demonstrated that only four weeks of resistance training was sufficient to promote neural circuitry adaptation accounted for the manual reaction time improvement

despite anatomical, endocrine, and physiological differences between men and women. Thus, short-term resistance training can improve voluntary motor response, and consequently, quality of life. Therefore, physical therapists, coaches, and scientific sports managers should add specific resistance training in their training periodization for untrained and athletes to improve or rehabilitate voluntary motor response. In particular, for activities or sports that required fast voluntary motor response in upper limbs (e.g. daily life activities, soccer, fight sports, baseball, tennis and others).

Authorship. All the authors have intellectually contributed to the development of the study, assume responsibility for its content and also agree with the definitive version of the article. **Conflicts of interest.** The authors have no conflicts of interest to declare. **Funding.** This study was supported by the Brazilian Council for Scientific and Technological Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (CAPES) - financial code 001, the Rio de Janeiro State Research Foundation (FAPERJ). **Acknowledgements.** The authors were grateful for the members of Laboratory of Physiology and Human Performance for the support on data collection. **Provenance and peer review.** Not commissioned; externally peer reviewed. **Ethical Responsibilities.** *Protection of individuals and animals:* The authors declare that the conducted procedures met the ethical standards of the responsible committee on human experimentation of the World Medical Association and the Declaration of Helsinki. *Confidentiality:* The authors are responsible for following the protocols established by their respective healthcare centers for accessing data from medical records for performing this type of publication in order to conduct research/dissemination for the community. *Privacy:* The authors declare no patient data appear in this article.

References

1. [Garg M, Lata H, Walia L, Goyal O. Effect of aerobic exercise on auditory and visual reaction times: a prospective study. Indian J Physiol Pharmacol. 2013;57\(2\):138-45.](#)
2. [Jakobsen LH, Sorensen JM, Rask IK, Jensen BS, Kondrup JN. Validation of reaction time as a measure of cognitive function and quality of life in healthy subjects and patients. Nut. 2011;27\(5\):561-70.](#)
3. [Jain A, Bansal R, Kumar A, Singh KD. A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. Int J Appl Basic Med Res. 2015;5\(2\):124-7.](#)
4. [Hirose N, Hirano A, Fukubayashi T. Biological maturity and choice reaction time in Japanese adolescent soccer players. Res Sport Med. 2004;12\(1\):45-58.](#)
5. [Emre AK, Settari K. Coincidence-Anticipation Timing and Reaction Time in Youth Tennis and Table Tennis Players. Percept Mot Skills. 2010;110\(3\):879-87.](#)
6. [LaRoche DP, Cremin KA, Greenleaf B, Croce RV. Rapid torque development in older female fallers and nonfallers: a comparison across lower-extremity muscles. J Electromyogr Kinesiol. 2010;20\(3\):482-8.](#)
7. [Wilkerson GB, Training. Neurocognitive reaction time predicts lower extremity sprains and strains. Int J Athl Ther and Train. 2012;17\(6\):4-9.](#)
8. [Caragata GE, Tuokko H, Damini AJA. Adaptation, Aging. Fit to drive: A pilot study to improve the physical fitness of older drivers. Act Adapt Aging. 2009;33\(4\):240-55.](#)
9. [Darby D, Moriarity J, Pietrzak R, Kutcher J, McAward K, McCrory P. Prediction of winning amateur boxers using pretournament reaction times. J Sports Med Phy Fit. 2014;54\(3\):340-6.](#)
10. [Tonnessen E, Haugen T, Shalfawi SA. Reaction time aspects of elite sprinters in athletic world championships. J Strength Cond Res. 2013;27\(4\):885-92.](#)
11. [Mickeviciene D, Motiejunaite K, Karanauskiene D, Skurvydas A, Vizbaraitė D, Krutulyte G, et al. Gender-dependent bimanual task performance. Medicina. 2011;47\(9\):497-503.](#)
12. [Miller AE, MacDougall JD, Tarnopolsky MA, Sale DG. Gender differences in strength and muscle fiber characteristics. Eur J Appl Physiol Occup Physiol. 1993;66\(3\):254-62.](#)
13. [Stenbaek DS, Fisher PM, Budtz-Jorgensen E, Pinborg A, Hjordt LV, Jensen PS, et al. Sex hormone manipulation slows reaction time and increases labile mood in healthy women. Psychoneuroendocrinology. 2016;68\(Núm\):39-46.](#)
14. [Mandolesi L, Polverino A, Montuori S, Foti F, Ferraioli G, Sorrentino P, et al. Effects of Physical Exercise on Cognitive Functioning and Wellbeing: Biological and Psychological Benefits. Front Psychol. 2018;9:509](#)
15. [Lord SR, Ward JA, Williams P, Strudwick M. The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized controlled trial. J Am Geriatr Soc. 1995;43\(11\):1198-206.](#)
16. [Ratamess NA, Alvar BA, Evetoch TK, Housh TJ, Kibler WB, Kraemer WJ, Triplett NT. American College of Sports Medicine Position Stand: Progression Models in Resistance Training for Healthy Adults. Med Sci Sports Exerc. 2009;41\(3\):68e-708.](#)
17. [Ivey FM, Roth SM, Ferrell RE, Tracy BL, Lemmer JT, Hurlbut DE, et al. Effects of age, gender, and myostatin genotype on the hypertrophic response to heavy resistance strength training. J Gerontol A Biol Sci Med Sci. 2000;55\(11\):M641-8.](#)
18. [Gursoy R. Sex differences in relations of muscle power, lung function, and reaction time in athletes. Percept Mot Skills. 2010;110\(3 Pt 1\):714-20.](#)
19. [Rhea M. Determining the Magnitude of Treatment Effects in Strength Training Research Through the Use of the Effect Size. Journal Strength Cond Res. 2004;18\(4\):918-20.](#)
20. [Panton LB, Graves JE, Pollock ML, Hagberg JM, Chen W. Effect of aerobic and resistance training on fractionated reaction time and speed of movement. J Gerontol. 1990;45\(1\):M26-31.](#)
21. [Yarrow JF, White LJ, McCoy SC, Borst SEJNL. Training augments resistance exercise induced elevation of circulating brain derived neurotrophic factor \(BDNF\). Neurosci Lett. 2010;479\(2\):161-5.](#)
22. [Del Vecchio A, Casolo A, Negro F, Scorcelletti M, Bazzucchi I, Enoka R, et al. The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. J Physiol. 2019;597\(7\):1873-87.](#)
23. [Carroll TJ, Selvanayagam VS, Riek S, Semmler JG. Neural adaptations to strength training: Moving beyond transcranial magnetic stimulation and reflex studies. Acta Physiol. 2011;202\(2\): 119-40.](#)
24. [Ansdell P, Thomas K, Howatson G, Hunter S, Goodall S. Contraction intensity and sex differences in knee-extensor fatigability. J Electromyogr Kinesiol. 2017;37:68-74.](#)
25. [Karakostis FA, Zorba E, Moraitis K. Sexual Dimorphism of Proximal Hand Phalanges. Int J Osteoarchaeol. 2015;25\(5\):733-42.](#)