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Neuromuscular, acute symptoms and cardiorespiratory responses to progressive elastic resistance training in patients with chronic obstructive pulmonary disease: cross- sectional study

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Research Article

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Abstract

Purpose: To evaluate neuromuscular, acute symptoms and cardiorespiratory responses during progressive elastic resistance training in patients with chronic obstructive pulmonary disease (COPD).

Methods: 14 patients diagnosed with moderate-very severe COPD performed knee extensions at different elastic resistance levels. Normalized Root Mean Square (nRMS) was measured for the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM), together with rate of perceived exertion (RPE), perceived quadriceps fatigue, dyspnea, oxygen saturation and heart rate.

Results: For the VL, a nRMS increase was evident from a two-level increment when using the red color. When using the green and blue colors, four and three level increments were needed to increase nRMS, respectively. For the VM, there were no nRMS progressions. For the RF, a nRMS increase was evident from a two-level increment when using the red color and after one-level when using the green color. Dyspnea, quadriceps fatigue and especially RPE increased in a dose-response fashion and were correlated (p<0.01) with the relative resistance (i.e., % of the maximum resistance), resistance level (i.e., color) and nRMS at the three muscles.

Conclusions: Heavy elastic resistance training is feasible in COPD patients, without excessive dyspnea and with stable cardiorespiratory response.

Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a common, preventable, and treatable disease that is characterized by airflow limitation and persistent respiratory symptoms caused by significant cigarette smoke or noxious particles exposure ¹. It has been estimated that COPD will be one of the top causes of death worldwide in 2030 ^{2,3}.

The main symptom of COPD is chronic and progressive dyspnea ⁴. Still, several systemic manifestations as cardiovascular disease or limb muscle dysfunction have been reported to produce an important worsening in quality of life ⁵ and increased mortality ⁶. Limb muscle dysfunction is characterized by a decreased proportion of type I muscle fibers and oxidative capacity, and reduced cross-sectional muscle area, strength, and endurance ⁶. Peripheral muscle weakness, particularly of the large quadriceps muscles, due to its vital role in activities of daily living, is an essential target of comprehensive disease management ⁷. The weakness of quadriceps is prevalent in approximately 50% of patients with severe/very severe COPD ⁸, and is associated with low exercise tolerance ⁹, reduced quality of life ¹⁰, increased use of health resources ¹¹, and higher mortality risk ¹². In consequence, quadriceps muscle training needs to be included in every well-designed rehabilitation program.

Quadriceps muscle training has been typically performed with the own body weight as a load or with traditional weight machines. In addition, elastic resistance is another portable, cheap and safe alternative. Importantly, the few experimental studies using elastic resistance to train the quadriceps among COPD patients reported effectiveness to improve functional capacity, muscular function ^{13–15}, and inflammatory and metabolic markers ¹⁶. Exercise intensity prescription and progression with the elastic bands differs between studies, likely due to a more challenging objective load quantification. Typically, a change from one color to another results in increased resistance of 20 to 30% ¹⁷. However, there are no previous studies corroborating the number of resistance increments needed during a typical COPD rehabilitation exercise to obtain a real muscle activity increase. Furthermore, achieving sufficient neuromuscular stimulus can be difficult among COPD patients since ventilatory limitation, dyspnea ¹⁸ or muscle fatigue ¹⁹ can occur before. Dyspnea or muscle fatigue, which also are highly variable on an individual basis ²⁰, are a usual cause limiting or stopping exercise practice in these patients ¹⁹. Due to this delicate balance between the neuromuscular response and the acute severity of these symptoms and other variables that may limit exercise practice such as the rate of perceived exertion (RPE), oxygen saturation or heart rate, new studies combining both types of variables are warranted. This would help to design proper exercise progressions to optimize and individualize quadriceps muscle training while improving adherence.

The purpose of the study was to evaluate neuromuscular, acute symptoms and cardiorespiratory responses to progressive elastic resistance training in patients with chronic obstructive pulmonary disease. As a secondary objective, we evaluated the correlation between these variables. We hypothesized that different elastic resistance progressions would be needed to increase quadriceps muscle activity and that acute symptoms but not cardiorespiratory responses would increase.

Methods

Participants

During November 2018 to May 2019, patients over 40 years of age, diagnosed with moderate-very severe COPD, stage II-IV according to GOLD criteria ¹ and stable (i.e., no exacerbations or medication changes within four weeks before the study) at a local Hospital (BLINDED) were candidates for the present study. The exclusion criteria were: having musculoskeletal, rheumatic, cardiac or neurological disorders that might affect exercise performance, previous lung or cardiac surgery, long-term oxygen treatment, and participating in a resistance training program during > 2 times/week, within six months before starting the study.

All the participants were informed about the objective of the study and, in this way, we obtained their respective informed consents. This study was approved by the Northern Metropolitan Health Service of Santiago (Chile), and conducted in agreement with the Declaration of Helsinki.

Procedures

The following clinical variables and symptoms were collected from patients' medical histories: sex, age, anthropometric characteristics (weight, height and body mass index [BMI]), GOLD classification ¹, forced expiratory volume during the first second, in absolute value and percentage of predicted value based on global lung initiative (GLI) reference values ²¹, dyspnea measured through the modified medical research council ²², the physical capacity measured through the six-minute walk distance ²³, the quality of life measured with the COPD assessment test (CAT)²⁴ and Saint George respiratory questionnaire (SGRQ)²⁵ and the comorbidities measured by the Charlson index ²⁶.

Each participant carried out one experimental session. The participants were not allowed to eat, drink or take stimulants (such as caffeine) 2 h before the session and were not allowed to perform more intense physical activity than daily life activities 24 h before the measurement. They were also recommended to sleep a minimum of 7-8 h the night before the assessments. All measurements were made by the same two researchers and were conducted in the same facility at the Hospital.

The surface electromyography (sEMG) protocol started with the preparation of participants' skin, followed by electrode placement, maximum voluntary isometric contractions (MVIC) and the performance of the different exercise conditions. Hair was removed from the skin overlying the muscles of interest, and the skin was then cleaned by rubbing with cotton wool dipped in alcohol for the subsequent electrode placement. Electrodes were placed on the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM) muscles on the dominant leg following the SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) recommendations ²⁷. The dominant side was determined by the question: "Which leg do you prefer to hit a ball with?" Specifically, electrodes for the RF were fixed at 50% of the distance between the anterior superior iliac spine and the superior part of the patella in the same direction of that line. For the VM, the electrodes were placed at 80% of the line between the anterior superior iliac spine and that line. For the VL, the electrodes were located at two-thirds of the line that connects the anterior superior iliac spine with the lateral side of the patella following the orientation of the muscle fibers. Pregelled bipolar silver/silver chloride (Ag/AgCl) electrodes (Kendall Medi-Trace Mini ECG Electrodes, Neurotronics, Randwick, NSW, Australia) with an electrode size diameter of 3.0 cm were placed with an inter-electrode distance of 2 cm. One reference electrode was positioned a finger-length from the other electrodes for the RF muscle and above the patella for the VL and VM muscles, according to the manufacturer's specifications.

Using commercial hardware and software, sEMG was recorded (MyoSystem DTS, Noraxon USA., Inc., Scottsdale, CA, USA), with a sample rate of 1500 Hz. To normalize sEMG amplitude, the maximal voluntary isometric contraction was assessed before starting with the exercise performance. Patients were asked to complete two MVICs with a 1 min rest between trials. They performed a 2 s progressive contraction and then maintained a maximum contraction for the next 3 s. Verbal encouragement was provided to motivate all participants to reach their maximal effort. The position during the evaluation of the MVICs was based on standardized muscle testing procedures ²⁸ and performed against manual resistance. Specifically, the knee extension was performed with the participant seated with 90° of knee flexion and approximately 110° of hip flexion. Besides, patients maintained neutral dorsiflexion of the ankle at 90°.

After a 2 min break, the knee extension exercise was performed in the same place and with the same position above described, with six different elastic resistance levels (red, green, blue, black, silver and gold; Thera-Band CLX; The Hygenic Corp, Akron, OH, USA), performed at this order and separated by 2 min of rest between them. According to the elastic band's manufacturer, there is 20% resistance difference between the different bands, except between the two hardest levels (silver and gold), where there is an increase of 30% resistance. Specifically, the different resistances according to the elastic band's manufacturer at 100% elongation are 1.67 kg, 2.09 kg, 2.63 kg, 3.31 kg, 4.63 kg and 6.44 kg for the red, green, blue, black, silver and gold bands, respectively. The band length was 1.9 m, and they were pre-stretched to 50% of their size before performing the exercise to achieve an appropriate intensity.

The exercise was performed with the participant's available range of motion. Participants were asked to move their body and trunk as little as possible and to perform the exercise smoothly without stops or accelerations. For this purpose, a metronome was used with a speed of 1.5 seconds for concentric contraction and 1.5 seconds for eccentric contraction, with a beep sound at the change of each phase. If they were not able to perform the exercise with the correct technique, the attempt was cancelled and repeated. If the patient was not able to reach the three repetitions during a certain condition, the experimental session finished. After performing each condition, a researcher showed the Borg CR10 scale ²⁹ to the patients, and they had to report their RPE, dyspnea and perceived quadriceps fatigue (quadriceps fatigue). Then, oxygen saturation and heart rate were measured with a pulse oximeter (Mindray, model Umec 10, Shenzhen, China).

sEMG processing

sEMG data processing was performed using custom-made algorithms implemented in MATLAB software (version R2015a; The MathWorks, Inc, Natick, MA, USA) and in accordance with a previous study ³⁰. For the analysis, all raw sEMG signals, obtained during the exercises, were digitally filtered with Butterworth fourth-order high-pass filtering at 10 Hz and a moving root-mean-square (RMS). The RMS routine was performed using a smoothing filter/window of 500 milliseconds (250 milliseconds backward and 250 milliseconds forward from each data point) across the entire signal (i.e., across all contractions)³⁰. In each of the muscles and for each level of exercise intensity, an RMS peak from each of the contractions was obtained (i.e., a total of three RMS peaks)³⁰. These three RMS peaks were averaged, and the value obtained was then normalized to the maximum activation value reached at the MVICs, obtaining the normalized RMS (nRMS)³⁰.

Statistical analysis

Simple correlations analyses were performed calculation Pearson's r (correlation coefficient). The association between resistance level and each of the physiological outcome variables were modelled using general linear models (Proc GLM, SAS). Results from these analyses were reported as least square means at each intensity and differences of least square means between intensities with corresponding 95% confidence intervals.

Results

We included 14 patients (9 male), diagnosed with moderate-very severe COPD with a mean age of 67.9 ± 4.3 y, with a FEV₁ of 47.3 ± 19.3 % of predicted value. The Table 1 showed the demographic and clinical data of the participants.

Table 2 shows the acute symptoms of the participants during the different resistance levels. Table 3 shows nRMS Least Squares Means of the different elastic resistances. In general, the red color reported the lowest numerical Mean nRMS values, while the gold color reports the highest.

Table 4 shows the Differences of Least Squares Means between the different elastic resistances.

For the VL, a nRMS increase was evident from a two-level increment when using the red color. When using the green color, a four-level increase was needed to increase nRMS. When using the blue color, a three-level increase was needed to increase nRMS. There were no nRMS differences when the black, silver and golden colors were used.

For the VM, there were no nRMS increases when the resistance level progressed. Only a borderline significant result was found when a five-level increase was performed when using the red color.

For the RF, a nRMS increase was evident from a two-level increment when using the red color and after one-level increment when using the green color. There were no nRMS differences when the blue, black, silver and golden colors were used. Pearson correlation coefficients showed that the resistance level (1 = red, 6 = gold) was positively and significantly (p < 0.01) associated with RF nRMS (r = 0.46), VL nRMS (r = 0.34), RPE (r = 0.79), dyspnea (r = 0.40) and quadriceps fatigue (r = 0.62). The relative resistance (% of the maximum resistance) was positively and significantly (p < 0.01) associated with RF nRMS (r = 0.39), VL nRMS (r = 0.30), RPE (r = 0.72), dyspnea (r = 0.45) and quadriceps fatigue (r = 0.57). The VL nRMS was positively and significantly (p < 0.01) associated with RPE (r = 0.51), dyspnea (r = 0.48) and quadriceps fatigue (r = 0.50). The VM nRMS was positively and significantly (p < 0.01) associated with RPE (r = 0.33), dyspnea (r = 0.32) and quadriceps fatigue (r = 0.37). The RF nRMS was positively and significantly (p < 0.01) associated with RPE (r = 0.54), dyspnea (r = 0.47) and quadriceps fatigue (r = 0.52). Dyspnea was positively and significantly (p < 0.01) associated with RPE (r = 0.70) and quadriceps fatigue (r = 0.66). RPE was positively and significantly (p < 0.01) associated with RPE (r = 0.70) and quadriceps fatigue (r = 0.66). RPE was positively and significantly associated with quadriceps fatigue (r = 0.84).

Discussion

The main finding was that heavy elastic resistance training induces a normal physiological response and is safe in COPD patients. In most of the cases, at least a two-level resistance increase was needed to obtain a significant nRMS increase during knee extensions in COPD patients. In fact, a real nRMS increase was only evident at the VL and RF, revealing that in spite of increasing the elastic resistance, the VM was not further stimulated.

The nRMS changes were mostly observed during low-moderate resistance levels, while during the three heaviest elastic resistances (black, silver, gold colors) there were no changes, in contrast with a similar previous study in patients with haemophilia ³⁰. In fact, the greatest between-resistance mean differences in our study were found during the first resistance level. This might be explained by a greater opportunity window for increasing nRMS during the lower resistances and lower accumulated neuromuscular fatigue. Differences in muscle strength between the investigated patient groups can thus affect the increase. In addition, intrinsic muscle changes in COPD patients due to early metabolite accumulation ³¹ and reduced fiber conduction velocity ³² while exercising may have caused early fatigue and reduced the possibility of increasing nRMS after this point. It must also be considered that the firing rates and motor-unit recruitment thresholds may occur below 100 % of the MVIC ³³, which would also be difficult to achieve further nRMS increments.

It is worth mentioning that some differences across the quadriceps muscles were noted. For instance, it seems that the VL needs a greater resistance increment than the RF to increase its nRMS. Conservely, the VL increased its nRMS during the knee extension with the blue color (4th heaviest resistance) while nRMS at the RF was no further increased after the green color (5th heaviest resistance). In line with our findings, a recent similar study conducted among patients with severe haemophilia reported that increasing 2–3 elastic resistance levels was needed to increase nRMS in the quadriceps muscle ³⁰. Unfortunately, there are no similar studies conducted among COPD patients.

Another between-muscle difference was that VL and VM had greater general nRMS than RF. Comparable results have been found in patients with COPD during an isometric knee extension ³⁴ or in healthy adults during dynamic knee extensions ³⁵. This greater muscle activation at least at the VL could be partially explained by a stronger force-generating capacity ³⁶. Specifically, it was estimated that the VL and VM had a contribution of 40% and 25% of the quadriceps strength respectively, while the RF and vastus intermedius contributed 35% ³⁶. This, in conjunction with the more linear EMG/force relationship at the VL compared with the RF and VM ³⁷ might explain why this muscle was the only one showing some differences between the heaviest elastic resistance levels. In addition, a shift from fiber type I to II in the VL is a typical skeletal muscle alteration among COPD patients ³⁸. Moreover, the VL has reduced pennation angle and muscle thickness in these patients when compared with age-matched healthy people ³⁹ and is more affected than the VM by age-related fiber atrophy ⁴⁰ or muscle disuse after short immobilization ⁴¹. Hence, if any of these aforementioned events would be present in our patients, it could be plausible that the VL would need a greater extent of nRMS to overcome the same relative resistance than the other quadriceps muscles. All these findings highlight the need for tailored quadriceps training. To our knowledge, this is the first study demonstrating specific nRMS values for different quadriceps muscles during a typical rehabilitative exercise with progressive resistance, which may help to individualize exercise dosing.

Another relevant finding of our study is the absence of nRMS changes in the VM in spite of the progressive resistance provided, in contrast with a similar article in patients with haemophilia.³⁰ This is likely due to the altered neuromuscular response present in COPD patients and some of the above-mentioned dissimilarities between quadriceps muscles ³². For instance, VL muscle oxygen consumption increased with increasing cadence during constant load cycling, whereas VM remained unchanged ⁴².

Our correlations between the color of the band or the relative resistance and VM nRMS were weak, but moderate for VL nRMS and RF nRMS. Likewise, VL nRMS and RF nRMS were more correlated with RPE, dyspnea and quadriceps fatigue than VM nRMS. This might have relevant clinical implications, especially for those with more advanced disease and less exercise tolerance. For example, in this specific case and muscle, a lower resistance could be used to provide similar nRMS but with lower RPE, dyspnea and quadriceps fatigue, which may facilitate training and adherence. Dyspnea or muscle fatigue usually limit or stop exercise practice among COPD patients before the skeletal muscles are maximally stressed ¹⁹. In our case, dyspnea, quadriceps fatigue and RPE increased in a dose-response fashion while progressing resistance. We found that quadriceps fatigue and especially RPE were more correlated with the resistance progressions than dyspnea, which did not increase to the same extent, suggesting that these variables can especially limit resistance training and should be monitorized. However, achieving a sufficient level of muscle fatigue during training can be relevant, since COPD patients who developed training-induced quadriceps fatigue had greater functional exercise capacity and health-related quality of life than patients without fatigue ⁴³. Interestingly, authors ⁴³ found similar quadriceps force and maximal exercise capacity improvements in

both subgroups. Taking these findings and ours together, it could be suggested that in the absence of nRMS differences and when patients can tolerate it, heavier elastic resistances causing higher muscle fatigue could be desirable to maximize exercise benefits. This shows the relevance of evaluating acute quadriceps fatigue together with dyspnea during the training session to individualize exercise dosing. In addition, RPE could also be relevant during COPD rehabilitation. Based on our results, RPE was the acute symptom with the greatest and more consistent increase likely due to its association with nRMS, dyspnea and especially muscle fatigue. Nevertheless, RPE has demonstrated being associated with other variables in this cohort of patients, such as perceived exercise self-efficacy and exercise capacity ⁴⁴. Despite the absence of similar electromyographical studies among COPD patients, a moderate-very strong association between RPE and nRMS has been reported during shoulder exercises in healthy adults ⁴⁵. Notably, a study among COPD patients reported no cardiorespiratory changes (i.e., blood pressure, heart rate, oxygen saturation, minute ventilation and oxygen uptake) during knee extensions at low and high intensities, but RPE did increase with the latter ⁴⁶. In accordance, we found that heart rate and oxygen saturation were stable during the different resistance levels, whereas the other acute symptoms and especially RPE increased. Interestingly, a recent study suggested that RPE, rather than muscle fatigue and exercise-induced muscle pain, was the main exercise stopper during high-intensity aerobic exercise ⁴⁷. Further studies are needed to understand better those variables limiting exercise practice among COPD and whether RPE correlates with other relevant outcomes.

It must be taken into account that our results cannot be extrapolated to other exercises or exercise variations (e.g., performing knee extensions with both limbs at a time). It also needs to be considered that all the measurements were conducted during three repetitions per condition which may differ when targeting higher volumes. However, this approach is appropriate and is usually used in literature to evaluate nRMS during multiple resistances/intensities to avoid accumulated fatigue ^{28,30,45}, which can be especially relevant in COPD patients ³².

In conclusion, heavy elastic resistance training seems to be feasible in COPD patients, without causing high dyspnea increments and with a stable cardiorespiratory response. In general, COPD patients need to increase at least two elastic resistance levels to obtain a real RF and VL nRMS increase during knee extensions, while there is no nRMS progression for the VM. There is no nRMS progression between the three heaviest elastic resistances, although these levels could be used to increase muscle fatigue or RPE. Dyspnea, quadriceps fatigue and especially RPE increase in a dose-response fashion and are correlated with the relative resistance, the resistance level and nRMS.

Declarations

Author contribution statement

JC, BGG, LLA and CCM conceived and designed study; JC, BGG, CCM, AOV and NSC collected raw data; BGG, LLA and CCM completed all data analyses; JC and RTC wrote the manuscript. All authors discussed the results and contributed to the final manuscript.

Additional information

The authors declare no competing interests.

Abbreviations

chronic obstructive pulmonary disease (COPD); Normalized Root Mean Square (nRMS); rectus femoris (RF); vastus lateralis (VL); vastus medialis (VM); rate of perceived exertion (RPE), surface electromyography (sEMG)

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Tables

Table 1. Baseline characteristics

Variable	
Sex	
Male	9 (64.3%)
Female	5 (35.7%)
Age (y)	67.9 ± 4.3
Weight (Kg)	71.4 ± 13.9
Height (cm)	169 (158-171)
BMI	26.4 ± 5.6
GOLD classification	
I	0 (0%)
II	5 (35.7%)
III	5 (35.7%)
IV	4 (28.6%)
FEV ₁ (L)	1.34 ± 0.57
FEV ₁ (% of predicted)	47.3 ± 19.3
mMRC	
0	1 (7.1%)
1	3 (21.4%)
2	6 (42.9%)
3	2 (14.3%)
4	2 (14.3%)
6MWD (m)	403 ± 110
CAT	22 (15-27)
SGRQ	43 (33-62)
Charlson index	4 (3-5)
Oxygen saturation	95.6 ± 1.8
Heart rate	80.0 ± 17.7

Abbreviations: 6MWD: Six-minute walk distance; BMI: Body mass index; CAT: COPD assessment test; FEV1: Forced expiratory volume during the first second; GOLD: Global initiative for chronic obstructive lung disease; mMRC: Modified medical research council; SGRQ: Saint George respiratory questionnaire. The values are expressed in mean \pm standard deviation or median (P25-P75)

Tuble 2: Noute symptoms during the unterent resistance revers											
Resistance level	Rate of		Dyspnea		Quadriceps		Oxygen		Heart		
	perceived exertion				fatigue		saturation		rate		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Red	1.3	1.2	1.3	1.7	1.0	1.5	95.1	2.4	80.2	17.9	
Green	3.2	1.8	1.8	1.9	2.4	2.4	95.2	2.2	81.1	17.6	
Blue	4.1	1.7	2.6	2.3	3.4	2.6	95.1	2.8	81.2	18.1	
Black	5.6	1.9	3.4	3.0	5.3	2.4	95.6	2.1	81.7	18.8	
Silver	6.7	1.7	3.5	3.2	6.1	2.7	95.5	2.1	84.7	19.7	
Gold	7.9	1.7	4.7	3.3	6.2	3.1	95.4	2.1	83.9	20.6	

Table 2. Acute symptoms during the different resistance levels

67.0	93.6
76.8	103.4
80.5	107.1
88.6	115.3
84.7	113.3
96.7	127.2
76.1	108.4
77.4	109.7
88.3	120.6
90.8	123.1
92.6	127.6
89.7	127.3
48.6	74.5
56.6	82.5
71.2	97.1
71.3	97.2
80.3	108.3
82.7	112.7
2	30.3 32.7

Table 3. nRMS Least Squares Means of the different resistance levels

Resistance level Mean nRMS Standard Error Lower Upper

nRMS: normalized Root Mean Square

Muscle

Table 4. Differences of Least Squares Means between the different elastic resistances

				1							-					
Muscle	Vastus lateralis															
Color vs Color	Red	Red	Red	Red	Red	Green	Green	Green	Green	Blue	Blue	Blue	Black	Black	Silver	
	Green	Blue	Black	Silver	Gold	Blue	Black	Silver	Gold	Black	Silver	Gold	Silver	Gold	Gold	
Estimate	-9.8	-13.5	-21.6	-18.7	-31.7	-3.7	-11.8	-8.9	-21.9	-8.2	-5.2	-18.2	3.0	-10.0	-13.0	
Standard Error	6.4	6.4	6.4	6.9	7.4	6.4	6.4	6.9	7.4	6.4	6.9	7.4	6.9	7.4	7.7	
P Value	0.132	0.041	0.001	0.009	<.0001	0.572	0.071	0.206	0.005	0.210	0.456	0.017	0.672	0.181	0.098	
Lower	-22.7	-26.4	-34.5	-32.6	-46.5	-16.5	-24.7	-22.8	-36.7	-21.0	-19.1	-33.1	-10.9	-24.9	-28.4	
Upper	3.1	-0.6	-8.8	-4.8	-16.8	9.2	1.1	5.0	-7.0	4.7	8.7	-3.3	16.9	4.8	2.5	
Muscle	Vastus Medialis															
Color vs Color	Red	Red	Red	Red	Red	Green	Green	Green	Green	Blue	Blue	Blue	Black	Black	Silver	
	Green	Blue	Black	Silver	Gold	Blue	Black	Silver	Gold	Black	Silver	Gold	Silver	Gold	Gold	
Estimate	-1.3	-12.2	-14.7	-17.9	-16.3	-10.9	-13.4	-16.6	-14.9	-2.5	-5.6	-4.0	-3.2	-1.5	1.6	
Standard Error	8.3	8.3	8.3	9.0	9.6	8.3	8.3	9.0	9.6	8.3	9.0	9.6	9.0	9.6	10.0	
P Value	0.873	0.147	0.082	0.051	0.095	0.195	0.113	0.071	0.125	0.767	0.532	0.676	0.726	0.872	0.872	
Lower	-18.0	-28.9	-31.4	-35.9	-35.5	-27.6	-30.1	-34.5	-34.2	-19.2	-23.6	-23.2	-21.1	-20.8	-18.4	
Upper	15.3	4.4	1.9	0.1	2.9	5.8	3.3	1.4	4.3	14.2	12.3	15.2	14.8	17.7	21.6	
Muscle	Rectus Femoris															
Color vs Color	Red	Red	Red	Red	Red	Green	Green	Green	Green	Blue	Blue	Blue	Black	Black	Silver	
	Green	Blue	Black	Silver	Gold	Blue	Black	Silver	Gold	Black	Silver	Gold	Silver	Gold	Gold	
Estimate	-8.0	-22.6	-22.7	-32.8	-36.2	-14.6	-14.7	-24.8	-28.2	-0.1	-10.2	-13.6	-10.1	-13.5	-3.4	
Standard Error	6.6	6.6	6.6	7.1	7.6	6.6	6.6	7.1	7.6	6.6	7.1	7.6	7.1	7.6	7.9	
P Value	0.230	0.001	0.001	<.0001	<.0001	0.032	0.030	0.001	0.001	0.989	0.159	0.080	0.163	0.082	0.670	
Lower	-21.3	-35.9	-36.0	-47.1	-51.5	-27.8	-27.9	-39.1	-43.4	-13.3	-24.5	-28.9	-24.4	-28.8	-19.3	
Upper	5.2	-9.4	-9.5	-18.5	-20.9	-1.3	-1.4	-10.5	-12.9	13.2	4.1	1.7	4.2	1.8	12.5	

Bold color denotes a statistically significant difference