

MODERATE INTENSITY IS A BETTER STIMULUS TO INDUCE QUADRIPECS FEMORIS POWER IN ELDERLY ADULTS



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INTENSIDADE MODERADA É O ESTÍMULO MAIS ADEQUADO PARA INDUZIR POTÊNCIA DE QUADRICEPS EM IDOSOS

INTENSIDAD MODERADA ES EL MÁS ADECUADO PARA INDUCIR POTENCIA DE QUADRICEPS EN ANCIANOS

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ABSTRACT

Introduction: The best strategy for improving knee extensor power, a major functional capacity indicator in older adults, is power training. Nonetheless, the training intensity required to induce optimal gains is yet to be found. **Objective:** Our purpose was to compare knee extensor peak power responses between low, moderate, and high intensity load conditions (30%, 50% and 70% of 1RM). **Methods:** Thirteen sedentary elderly women performed six knee extensions in each load condition, calculating knee extensor mechanical work/power output and knee extension peak angular velocity. **Results:** No difference in peak power was found between the high (207.0 ± 68.1 W) and moderate (206.1 ± 71.6 W) load conditions ($p = 0.994$), and both had higher values ($p \leq 0.004$) than the low intensity condition (135.6 ± 56.3 W). **Conclusion:** Moderate load at 50% of 1RM appears to be the preferred strategy for inducing knee extensor power output because in contrast with the high intensity condition, the moderate load yielded higher angular peak velocity, which is also a functional indicator. **Level of Evidence II; Therapeutic studies - Investigating treatment results.**

Keywords: Quadriceps femoris; Resistance training; Aging.

RESUMO

Introdução: A melhor estratégia para melhorar a potência dos extensores do joelho, principal indicador da capacidade funcional em idosos, é o treinamento de força. No entanto, a intensidade do treinamento exigida para induzir a maiores benefícios ainda não é conhecida. **Objetivo:** Nosso objetivo consistiu em comparar as respostas de potência máxima dos extensores do joelho entre as condições de carga baixa, moderada e de alta intensidade (30%, 50% e 70% de uma repetição máxima). **Métodos:** Treze mulheres idosas sedentárias realizaram seis extensões de joelho em cada condição de carga, sendo calculado o trabalho mecânico/débito de força e a velocidade angular máxima (ou pico) dos extensores do joelho. **Resultados:** Não houve diferença significativa na potência máxima entre as condições de carga alta ($207,0 \pm 68,1$ W) e moderada ($206,1 \pm 71,6$ W) ($p = 0,994$), e ambas apresentaram valores maiores ($p \leq 0,004$) do que a condição de baixa intensidade ($135,6 \pm 56,3$ W). **Conclusão:** A carga moderada a 50% de 1RM parece ser a estratégia preferida para induzir o débito de força dos extensores do joelho, uma vez que quando comparada com a condição de alta intensidade, a carga moderada apresentou um pico de velocidade angular maior, o que também é um indicador funcional. **Nível de Evidência II; Estudos terapêuticos – Investigação dos resultados do tratamento.**

Descritores: Quadríceps femoral; Treinamento de resistência; Envelhecimento.

RESUMEN

Introducción: La mejor estrategia para mejorar la potencia de los extensores de la rodilla, principal indicador de la capacidad funcional en personas de la tercera edad, es el entrenamiento de fuerza. Sin embargo, la intensidad del entrenamiento exigida para inducir a mayores beneficios aún no es conocida. **Objetivo:** Nuestro objetivo consistió en comparar las respuestas de potencia máxima de los extensores de la rodilla entre las condiciones de carga baja, moderada y de alta intensidad (30%, 50% y 70% de una repetición máxima). **Métodos:** Trece mujeres de la tercera edad sedentarias realizaron seis extensiones de rodilla en cada condición de carga, siendo calculado el trabajo mecánico/débito de fuerza y la velocidad angular máxima (o pico) de los extensores de la rodilla. **Resultados:** No hubo diferencia significativa en la potencia máxima entre las condiciones de carga alta ($207,0 \pm 68,1$ W) y moderada ($206,1 \pm 71,6$ W) ($p = 0,994$), y ambas presentaron valores mayores ($p \leq 0,004$) que la condición de baja intensidad ($135,6 \pm 56,3$ W). **Conclusión:** La carga moderada a 50% de 1RM parece ser la estrategia preferida para inducir el débito de fuerza de los extensores de la rodilla, dado que cuando comparada con la condición de alta intensidad, la carga moderada presentó un pico de velocidad angular mayor, lo que también es un indicador funcional. **Nivel de Evidencia II; Estudios terapéuticos – Investigación de los resultados del tratamiento.**

Descriptores: Cuádriceps femoris; Entrenamiento de resistencia; Envejecimiento.



INTRODUCTION

Sarcopenia is a major public health concern characterized by a gradual structural loss in the musculoskeletal system. Such loss is explained by a decrease in the number of muscle fibers as well as their size, particularly fast twitch muscle fibers.¹ De Vito et al.² assign muscle power loss due to aging to a decrease in muscle contraction speed rather than to the ability to generate maximal muscular strength. Muscle power reduction has been pinpointed as the best functional deterioration predictor.^{3,4} The ability to promptly generate knee extensors' torque seems to be vital to an independent life. It is a basic skill for the majority of the daily activities such as walking, standing from a seated position, climbing and, specially, descending a stair.⁵ Indeed, Bassey et al.⁶ found a positive association between those tasks and knee extensors' power. Toraman and Yildirim⁷ identified quadriceps muscles strength and power losses as fall risk factors in elderly people.

These functional losses induced by aging can be mitigated by physical exercise. Nevertheless, there is not a consensus on the best method to achieve this goal, although strength training and, particularly, power training have been shown to be suitable.⁸ Indeed, Tschopp et al.⁸ found both strength and power training to be an effective strategy to reverse senescent functional decline. The authors, however, elect power training as the best method because similar results can be achieved with 20% less training volume. It is suggested that high-speed training promotes a greater type II fibers recruitment, leading to increased rate of force development.⁹

No recommendations are given regarding the training load, therefore, it is commonly chosen arbitrarily.¹⁰ With this conduct, it is easily seen power training protocols for older adults with loads ranging from 20% to 80% of 1RM.¹¹⁻¹⁵ The determination of an optimal intensity training is essential to ensure adequate stimulus for neuromuscular gain compatible with the losses found in this phase of the human life.

Kaneko et al.¹⁶ showed that, for young people, the training load that allows greater mechanical power output is the most effective strategy to increase maximum muscle power. The authors also confirmed this strategy as ideal to increase muscle power over a wide range of loads.

It is known that an ideal training load to maximize mechanical power output is task-dependent and, thus, no single optimal load is applicable to all gestures.¹⁷ In fact, the meta-analysis presented by Soriano et al.¹⁸ showed three optimum range intensities for athletes: light loads (i.e. $\leq 30\%$ of 1RM) for jump squat; moderate loads (i.e. from $> 30\%$ to $< 70\%$ of 1RM) for squat exercise; heavy loads (i.e. $\geq 70\%$ of 1RM) for power clean and hang power clean. Nevertheless, Kawamori and Haff¹⁷ indicate light loads (30-40% of 1RM) as ideal to develop muscle power in single-joint exercises, in untrained subjects.

Finding the optimal load intensity and being able to provide the ideal stimulus to promote older adults' knee extensors power is vital to increase their independency, reducing the risk of falls and improving their gait, contributing to a higher quality of life. Therefore, this study's purpose was to investigate the stimulus intensity that allowed promoting higher knee extensors power output in older adults.

MATERIALS AND METHODS

Thirteen elderly women (69.3 ± 4.1 years; 68.1 ± 18.4 Kg; Body Mass Index: 26.1 ± 2.5 Kg/m²) took part in the study. All participants were considered sedentary by the modified Baecke questionnaire for older adults¹⁹ and reported absence of musculoskeletal problems like knee or hip osteoarthritis. The participants were previously informed of all operational procedures and gave their written consent informing that their involvement in the study was voluntary. The study was approved by the university ethics committee (protocol number 31199114,0,0000,5391).

The knee extension tests were conducted in a conventional knee extension machine (Gervasport Fitness Equipment - Pleven, Bulgaria). Initially,

a standard warm-up session was performed: 10 minutes walking in a self-selected pace and 2 sets of 10 repetition with a load equivalent of 30% and 50% of the participant's body mass, with a rest interval of 3 minutes between sets.

Five minutes after the warm-up, a sub-maximal test was performed to estimate the participants' knee extensors one repetition maximum (1RM). Participants sat in the knee extension machine with their trunk and thigh immovable and the knee axis aligned with the machine's axis. It was instructed to perform as many repetitions as possible with a load of 60% of their body mass. The number of valid repetitions (full knee extension) and load were used to estimate 1RM according to Brzycki.²⁰ If more than ten repetitions were needed, a 10 minute rest was given and the test was repeated. In these cases, the number of repetitions and the load of the first attempt were used to estimate 5RM for the second attempt. None of the participants needed a third attempt.

Ten minutes after the 1RM estimation, the power tasks were executed. The participants performed three sets of six knee extensions with load of 30%, 50% and 70% of the estimated 1RM, with a precision of 1 Kg. Participants were instructed to execute the concentric phase of all repetitions as quickly as possible. The sets were executed in a random order, with 10 minutes rest interval between them and 20 seconds of interval between each repetition.

The knee extensors peak power was calculated according to Pinho et al.²¹ For this purpose, the knee extension machine's resistance torque was previously determined based on the machine's geometry (a function of the angular position due to an eccentric cam). The inertial properties of the participant's shank were estimated using Dempster anthropometric model.²² Kinematic data was obtained using a digital video camera (Casio EX-ZR10, Shibuya, Tokyo, Japan) with a sample rate of 240Hz, a shutter speed of 1/2000s and a resolution of 432x320 pixels. Reflexive markers (14mm) were attached to the machine's axis and feet support; and in the participant's lateral malleolus. The Ariel Performance Analysis System (Ariel Dynamics, Amherst, Massachusetts, USA) was used to digitize the three markers and an 8Hz low-pass Butterworth filter was applied to smooth the raw spatial coordinates. The coordinates of these points were used to determine the angular position, velocity and acceleration. Using these data, a biomechanical model²¹ estimated the peak power output based on Newton mechanic laws as a function of: the task's kinematic, the machine's resistance torque and the participants' shank's resistance torque. The mechanical work was calculated as the integral of the power curve over time. All the analysis procedures were executed in MatLab 2009b (Mathworks, Inc).

Statistical analysis

Peak power output, peak angular velocity and mechanical work of each repetition were calculated and the mean value of the six repetitions of each load was used for the statistical analysis. Four one-way repeated measures analysis of variance (ANOVA) were used to compare the absolute load, peak power, peak angular velocity and mechanical work between the three conditions (30%, 50% and 70% of 1RM). When necessary, a Tukey post-hoc test was used to identify the differences of the means. Dunlap's effect size (d) with a 95% confidence interval (CI95%) was calculated to compare the magnitude of the differences between conditions. Cohen's effect size benchmark of trivial ($-0.2 \leq d \leq 0.2$), small ($-0.5 \leq d < -0.2$ and $0.2 < d \leq 0.5$), moderate ($-0.8 \leq d < -0.5$ and $0.5 < d \leq 0.8$) and large ($d < -0.8$ and $d > 0.8$) was employed. SigmaStat 3.5 (Systat, Inc) was used for all statistical analysis and the adopted significance level was set in 0.05.

RESULTS

The three load conditions were found to be statistically different from each other ($F_{(2,22)} = 53.234$ with $p < 0.001$). The repeated measures analysis of variance (One-way ANOVA), performed with a power of 1.000,

showed that 70% of 1RM (34.3 ± 16.1 Kg) was higher than 50% of 1RM (24.6 ± 11.6 Kg), with $p < 0.001$; and higher than 30% of 1RM (14.7 ± 6.8 Kg), with $p < 0.001$; and that 50% of 1RM was higher than 30% of 1RM, with $p < 0.001$. Figure 1 shows the main results of the three one-way repeated measures ANOVA's for peak power output, mechanical work and peak angular velocity in the three load conditions.

The ANOVA for peak power output, performed with a power of 0.935, revealed a statistical significance ($F_{(2,22)} = 8.949$ with $p = 0.001$). 30% of 1RM (135.6 ± 56.3 W) was found to elicit lower peak power output when compared to 50% of 1RM (206.1 ± 71.6 W) and 70% of 1RM (207.0 ± 68.1 W) with $p = 0.004$ and $p = 0.003$, respectively, in the post hoc analysis. 50% and 70% of 1RM was found to produce similar knee extensors peak power output ($p = 0.994$).

The ANOVA for the knee extensors mechanical work, performed with a power of 1.000, also revealed a statistical significance ($F_{(2,22)} = 41.730$ with $p < 0.001$). 70% of 1RM (82.1 ± 28.2 J) was found to produce higher mechanical work than the 30% of 1RM (55.2 ± 17.5 J) condition ($p < 0.001$); and higher than 50% of 1RM (73.5 ± 25.0 J) condition ($p = 0.024$). 50% of 1RM produced higher knee extensors mechanical work than 30% of 1RM ($p < 0.001$).

Similarly, the ANOVA, performed with a power of 0.981, for knee extension peak angular velocity revealed a statistical significance ($F_{(2,22)} = 11.334$ with $p < 0.001$). Performing the test with 70% of 1RM (74.3 ± 17.3 °/s) significantly reduces the peak angular velocity when compared to the 30% of 1RM (95.0 ± 17.4 °/s) condition ($p < 0.001$) and the 50% of 1RM (89.1 ± 14.4 °/s) condition ($p = 0.009$). No statistical differences was found between 30% of 1RM and 50% of 1RM conditions ($p = 0.396$).

In Figure 2 the magnitude of the differences (g effect size and respective 95% confidence intervals) between the three load conditions for peak power output, mechanical work and peak angular velocity are shown.

DISCUSSION

The main finding in our study suggests 50% of 1RM as an ideal stimulus to develop knee extensors power output in older adults.

Although knee extensors peak power with 50% and 70% of 1RM did not display significant nor meaningful differences (trivial effect size), we believe that higher peak angular velocity at 50% of 1RM could bring further benefits to the elderly population. Indeed, a large effect was found when comparing the peak angular velocity produced by 50% of 1RM and by 70% of 1RM, favoring the first condition. Supporting this assumption, Van Roie et al.²³ elect maximum unloaded knee extension velocity as the best functional capacity predictor in elderly people. These authors reiterate the urgent need for knee extensors power development suggesting load conditions that allows the highest angular velocities as the best stimulus.

An additional advantage in using 50% of 1RM rather than 70% of 1RM is the lower mechanical load on the musculoskeletal system, namely on the articular system (cartilage and ligaments). This issue becomes even more relevant in individuals already with some articular dysfunction such as knee osteoarthritis. Prescribing excessive loading to this limited function structure may enhance the problem.²⁴

Notwithstanding, the 70% of 1RM stimulus may offer an advantage over a lighter condition. The statistically significant difference, but small effect, found between 50% and 70% of 1RM conditions in the knee extensors mechanical work, favoring the second, may increase the possibility of a muscle hypertrophy response to training. Thus, if substantial muscle hypertrophy is expected with loads no lighter than 65% of 1RM,²⁵ the high intensity condition may provide a better way to induce this much needed improvement.

De Vos et al.²⁶ found no difference in the total power output of five exercises (leg press, leg extension, leg flexion, chest press and seated

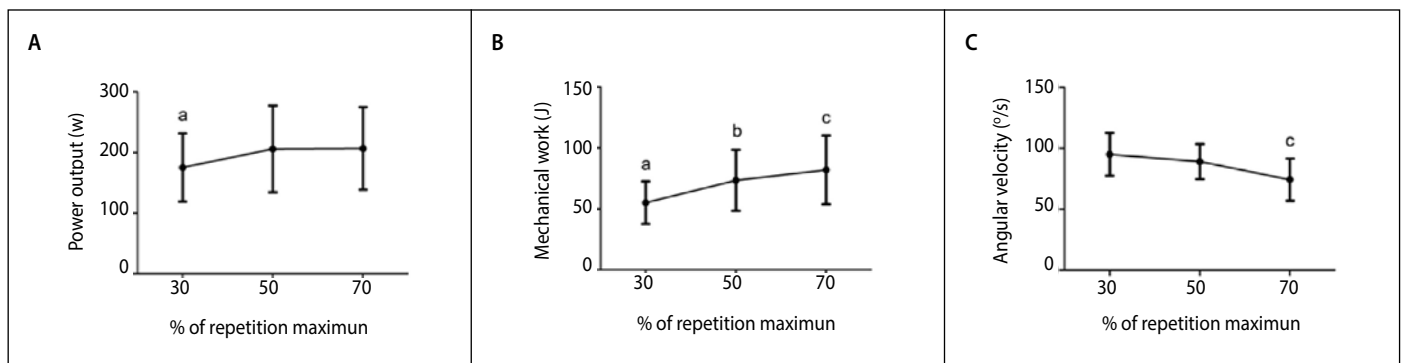


Figure 1. Mean and standard deviation of knee extensors peak power output (1A) and mechanical work (1B) as well as knee extension peak angular velocity (1C) in the three experimental conditions: 30%, 50% and 70% of 1RM. a significantly different from 50% of 1RM and 70% of 1RM, b significantly different from 30% of 1RM and 70% of 1RM, c significantly different from 30% of 1RM and 50% of 1RM.

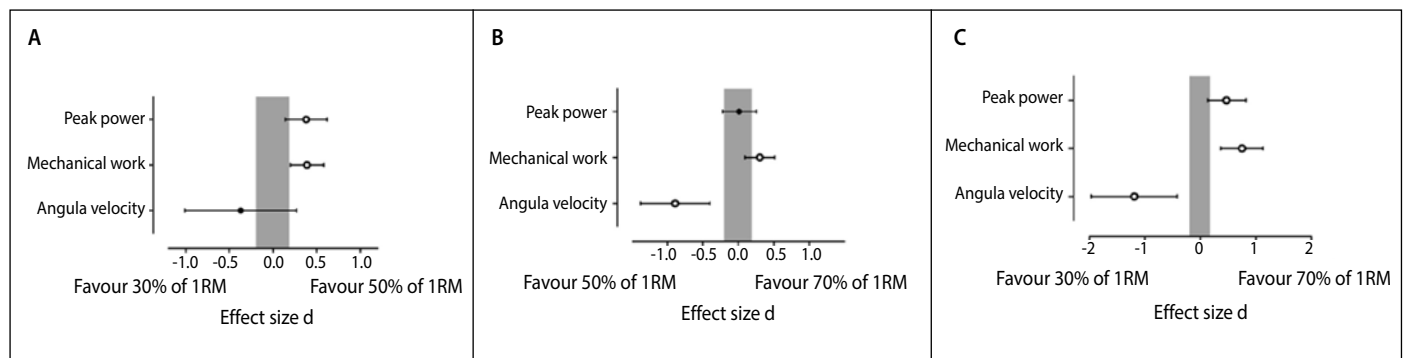


Figure 2. Magnitude of the differences (Dunlap d effect size) with 95% confidence interval in peak power output, mechanical work and peak angular velocity between 30% of 1RM and 50% of 1RM (2A); 50% of 1RM and 70% of 1RM (2B); 30% of 1RM and 70% of 1RM (2C). A blank mark denotes a significant difference ($p < 0.05$) between the two analyzed conditions and a solid mark the absence of significant differences (results from the repeated measures analysis of variance). The shaded area specifies the interval in which the effect size of the difference between conditions is trivial ($-0.2 < d < 0.2$).

row) between the participants in the three groups (20%, 50% and 80% of 1RM) that underwent 12 weeks of power training. Although that study's purpose was to elect an ideal power training intensity, the authors failed to report the test intensity at which the higher power output was obtained at baseline. Furthermore, the authors call peak power to the average power (mean value of 5% to 95% of the concentric portion of the power curve in each of the five exercises). Even so, they neglect to state in which of the ten test conditions (ten loads) the improvements in mean power took place. Thus, the results obtained by them makes the question about what would have happened if the training protocol was performed with an optimal load unanswered. Furthermore, no information is given about the load regime at which power peak is maximal.

Knee extensors peak power was chosen as the guiding parameter to prescribe power training for older adults because it seems to be the best elderly functional capacity indicator.^{27,28} Indeed, Bean et al.²⁸ found significant associations between knee extensors peak power and physical performance tests. They infer peak muscle power as a physiological predictor of functional limitation and disability in elderly population. Furthermore, the isotonic test condition selected (in contrast with isokinetic or isometric tests) carries, in our point of view, higher ecological validity. Human movement is characterized by different accelerations of the body mass and joint net torques must be produced to overcome this constant mass and to maintain progression (walking, climbing a stair, sitting and standing a chair). Thus, we believe the most suitable approach was employed to test knee extensors power in older adults with the intention to prescribe an optimal training intensity.

Our ultimate goal was to provide an optimal intensity stimulus to be applied in power training programs for older adults allowing their maximum power output. Although the concept of an "ideal intensity

stimulus" may be debatable by physicians or physiotherapists of even strength and conditioning coaches, we believe our assumption is quite plausible. Based in the sports performance model premise that there is an ideal intensity in which peak power output is maximized,²⁹ we found no reason to assume different outcome could occur in the elderly population.

Finally, readers must take into account the specificity of our findings. Although an ideal training load for older adults has been found, we believe this optimal stimulus may vary significantly for other type of movements, namely the ones with a multi-joint nature.^{18,29} Therefore, it is reasonable to assume that for other movements besides single joint tasks there could be a different intensity in which higher peak power is achieved.

CONCLUSION

Both 50% and 70% of 1RM were found to elicit the highest knee extensors peak power; however moderate intensity is preferable as the optimal stimulus because it allows knee extension at a higher peak angular velocity with less mechanical load. Notwithstanding, older adults without knee injuries and with previous strength training experience may use 70% of 1RM for knee extensors peak power development as well as a muscle hypertrophy strategy.

This information should be used to prescribe solely the knee extension exercise relative load because one may expect different optimal intensities for other type of movements.

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