

BEHAVIOR OF EXTERNAL AND INTERNAL LOAD IN THE EXERCISE TRAINING OF OLDER ADULTS WITH CARDIOVASCULAR RISK FACTORS

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ABSTRACT

Background: Few studies evaluate the behavior of training loads in clinical populations.

Purpose: Analyze the behavior of external and internal load in combined progressive training (aerobic and strength), for nine weeks, in older adults of both sexes with cardiometabolic risk factors, participants in a Cardiorespiratory Rehabilitation Program.

Methods: The program was composed of strong and moderate sessions, divided into three mesocycles composed of three microcycles. Parameters of external load (push-up and squat repetitions and distance covered) and internal load (RPE session) were collected. Data were analyzed using Student's t test for paired samples and one-way analysis of variance, with Tukey's post-hoc. The significance level adopted was 5%.

Results: 31 participants (67.5 ± 5.53 years) were evaluated. Strong sessions presented greater external load ($p < 0.001$) than moderate sessions. Microcycle 3 had a higher number of squat repetitions than microcycles 1 ($p = 0.030$). Mesocycle 3 showed higher values in the two external load repetition variables (push-up, $p = 0.001$; squat, $p < 0.001$). The last strong session showed an increase in external load (push-up repetitions, $p < 0.001$; squat repetitions, $p < 0.001$; distance covered, $p = 0.001$) in relation to the first strong session. Conclusion: There was maintenance or decrease of the internal load and increase of the external training load, which demonstrates the effectiveness of training program in the adaptation and improvement of the physical capacity of trained older adults with cardiometabolic risk factors, being possible for the trainer to check the progression of his students' training.

Keywords: *Physical Exercise; Aging; Rating of Perceived Exertion (RPE).*

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INTRODUCTION

Aging is a physiological process, dynamic and irreversible. The process of human aging is complex and individualized, occurs in the biological, psychological, and social sphere¹; however, it is not always associated with good quality of life. In this process, the natural decline of the maximum strength of the individual stands out, which happens more markedly from the age of 50², and which is considered the main limiting factor in carrying out activities of daily living (ADLs), being directly related to the increase in falls and fractures³. In addition, aging is also associated with the onset of chronic diseases such as cancer, stroke, and dementia, which can also affect the quality of life and functional capacity of the elderly⁴.

On the other hand, the World Health Organization⁵ defines healthy aging as the process of maintaining functional capacity, with physical activity being one of the essential pillars for preserving it and increasing quality of life. Therefore, in aging, the WHO recommends that at least 150 minutes of moderate-intensity aerobic activity per week or 75 minutes of vigorous-intensity activity be performed, along with balance and muscle-strengthening activities at least twice a week⁶. Although this recommendation is related to overall physical activity, that is, any activity produced by the skeletal muscles, which results in energy expenditure above baseline levels⁷, it is known that physical exercise, that is, a planned and systematized physical activity, aimed

at improving one or more components of physical fitness, is an important part of this process of meeting recommendations and achieving healthy aging.

However, for the prescription of physical exercise to be done properly, aiming at the correct progression and optimization of the effects arising from its practice, it is necessary to correctly monitor the training loads (internal and external). Adaptations induced by training result from the level of stress imposed on the body (internal load), and the physiological responses of everyone to the imposed load may also indicate risk of injury, overtraining or insufficient training stimuli. The internal load will be mainly determined by the prescribed training (external load), which, in turn, is related to the quality, quantity and periodization of training⁸. Therefore, measures of external load in strength training can be expressed, for example, considering the load (external resistance) lifted or number of repetitions, and in aerobic training, external load can be described by measures such as displacement speed or the total distance covered. As for internal load, physiological parameters, such as heart rate, and psychophysiological ones, such as subjective perceived exertion (RPE), can be used⁹.

The RPE is a practical and inexpensive method, precisely because it is a visual scale, in which the evaluation of the training session is made from the psychophysiological perception of the individual, which can be related to volume and intensity values, promoting more accurate overload parameters¹⁰. In this sense, despite load control being widely used and studied in the physical training of athletes, with a focus on high-performance sports, there is a lack of studies that address the discussion related to the elderly population, especially with cardiometabolic risk factors.

In order to make good prescriptions for this population, the monitoring of loads is of great importance, since low loads may be insufficient to generate or optimize benefits, while excessive loads or improperly distributed in a periodization model can cause harm. The present study aims to analyze the behavior of external and internal load in a progressive combined training program in older adults with cardiovascular risk factors. Our hypothesis is that the external load increases over the mesocycles, while the internal load remains stable or decreases.

METHODS

Experimental Approach to the Problem

The present study is characterized as a short-term longitudinal observational study, observing the behavior of the load training along a training intervention.

Participants

The sample was selected in a non-random manner, voluntarily, and was composed of older adults who met the eligibility criteria for participation in the study, being these: being a member of the Cardiorespiratory Prevention and Rehabilitation Program (PROCOR) for at least three months; have medical authorization to practice physical exercise; having a risk factor for cardiovascular disease (such as high blood pressure and/or diabetes), confirmed by laboratory examination and/or use of medicines; not having musculoskeletal limitations that could impair the execution of the exercises. In addition, all those who agreed to participate in the study signed an Informed Consent Form. The project was approved by the Ethics Committee for Research with Human Being (protocol number: 3.615.659).

Procedures

Initially, an anamnesis was applied to obtain sample characterization data, along with the anthropometric assessment, which was also performed at the end of the intervention. As outcomes of the present study, the number of repetitions of the push-up and squat exercises during each strength training session and the distance covered in aerobic training, as well as the RPE at the end of each session, were monitored.

Anthropometry

Body mass was measured using a Soehnle® scale (Germany) with a resolution of 50 grams, and height was measured using a Sanny® stadiometer (Brazil). From these assessments, the Body Mass Index (BMI) was calculated.

External training load

The measurement of the external load in strength training was given by the number of repetitions in the push-up and squat exercises. In aerobic training, the distance covered was used. Distance performed was registered immediately after sessions.

Internal training load

The internal load of each session was obtained by the RPE method corresponding to the session (RPE-session), by the scale CR10, adapted by Foster et al.¹¹. For this, the questioning was done individually in relation to the intensity of the total training session, and the answer should be a number between 0 and 10, which represent on the scale: 0: rest; 1: very easy; 2: easy; 3: moderate; 4: a little difficult; 5: difficult; 7: very difficult; 10: maximum¹¹. It is important to highlight that the calculation performed to obtain the internal load data consists of multiplying the descriptor indicated by the participant (numbered from one to ten), multiplied by the total duration of the session, generating these values in Arbitrary Units (AU).

Both external and internal load parameters were measured in all training sessions. For calculation and presentation of microcycles and mesocycles data the average load of all sessions of each period was considered.

Training

The present study had as an intervention the training of the PROCOR project, with a frequency of three weekly sessions, on alternate days (Monday, Wednesday and Friday), with combined training (aerobic and strength).

The intervention period consisted of nine weeks of training, divided into three mesocycles of three weeks each. The first mesocycle consisted of two stimulus sessions at moderate intensity and one session at high intensity per week, the second by one session at moderate intensity and two high intensity sessions per week, and the third mesocycle by three weekly sessions at high intensity (Figure 1).

The sessions started with a five-minute standardized joint warm-up, followed by interval aerobics, which could be performed on the athletics track, on the treadmill or on the ergometric bicycle, walking and/or running are preferred. In the aerobic sessions with moderate intensity, four three-minute blocks were performed at intensity 11 on the Borg RPE Scale (6 to 20)¹², alternated with four three-minute blocks at intensity 15. In the strong sessions, four blocks of two minutes at intensity 11 were performed, alternating with four blocks of four minutes at intensity 15. Thus, although both sessions have the same duration (twenty-four minutes), the density of each session is different, that is, the effort:pause ratio for the moderate session was 1:1 and for the hard session it was 2:1, resulting in a longer effort time and a shorter rest time.

After aerobics, strength training was performed, in which exercises were performed with dumbbells, elastic bands or only with body weight, focusing on the work of large muscle groups and consisting of five exercises. On Mondays, the muscles of the upper limbs were exercised, on Wednesdays, exercises for the upper and lower limbs were performed, and on Fridays, only the muscles of the lower limbs were worked.

In sessions with moderate intensity, two series of 30 seconds were performed, while in strong sessions, three series of 20 seconds were performed. Both sessions should be performed at maximum execution speed, with a one-minute interval between series and exercises, and the approximate total duration of strength training was twenty minutes.

To end the sessions, stretching exercises were performed, followed by individual RPE verification with the CR10 Scale by Borg¹³ modified by Foster et al.¹¹, in relation to the entire training session performed. All subjects were previously familiar with the two scales used.

Statistical analyses

The continuous variables characterizing the sample are presented in mean and standard deviation, while the categorical variables are presented in absolute frequency (n). Outcomes were described using mean and standard deviation and data normality was verified using the Shapiro-Wilk test.

Comparisons of external and internal load data, before and after the training period, were performed using Student's t test for paired samples. Data comparisons at different moments of the training period were performed by one-way analysis of variance, with Tukey's post-hoc. The significance level adopted was 5% and all analyzes were performed using the statistical package R, version 3.5.3.

RESULTS

Thirty-one older adults of both sexes participated in this study, all with cardiovascular risk factors, with arterial hypertension being the most prevalent disease. The characterization of the sample is described in Table 1. Table 2 presents the mean values of the external and internal load variables for moderate and strong sessions. There was a significant difference only in the repetitions, both in squat ($p < 0.001$) and in push-up ($p < 0.001$), being identified the highest values in the strong session, with 47.23 repetitions in the squat and 41.51 in the push-up exercise.

The average number of repetitions in push-up and squat exercises, the distance covered, and the internal load referring to the three microcycles of the training program are presented in Table 3. The number of squat repetitions showed a significant difference only when comparing microcycle 1 (40.49 ± 6.74) with microcycle 3 (45.20 ± 6.69), being greater in microcycle 3 ($p = 0.030$).

The comparison between the averages of all sessions of each mesocycle are presented in table 4. The push-up ($p = 0.001$) and squat ($p < 0.001$) repetition variables showed a significant difference in all comparisons, increasing the values at each mesocycle. No statistical difference was observed in the variables distance covered and internal load.

Table 5 presents the mean values of the variables for the first strong session and the last strong session and the comparison between them. A statistical difference can be observed in the number of squats ($p < 0.001$), push-ups ($p < 0.001$) and the distance covered ($p = 0.001$), being greater in the last session. However, no difference was observed in the internal load variable.

Figure 2 illustrates side by side the prescribed intensity and the intensity performed in the training periodization, from the mean values of internal load for each training session.

Table 1: Sample characterization (n = 31).

Age (years)	67.5 ± 5.53
Sex (M/F)	18/13
Height (m)	1.65 ± 0.11
Body mass (kg)	80.16 ± 14.51
BMI (kg/m ²)	28.92 ± 4.69
<i>Cardiovascular risk factors, n</i>	
Arterial hypertension	20
Dyslipidemia	15
Type 2 diabetes	6

m: meters; kg: kilograms; kg/m²: kilogram per square meter. Continuous data are presented as mean and standard deviation; Categorical data are presented in absolute frequency (n sample).

Table 2: Repetitions in the push-up and squat exercises, distance covered and internal load (perceived exertion x session duration) between strong and moderate sessions

Variable (n)	Moderate session	Strong session	P-value
Rep. squat (30)	40.31 ± 6.95	47.23 ± 6.34	<0.001
Rep. push-up (31)	35.65 ± 5.72	41.51 ± 6.38	<0.001
Distance covered – m (22)	1858.26 ± 393.77	1914.88 ± 368.96	0.228
Internal Load - AU (30)	190.01 ± 48.62	184.40 ± 46.83	0.354

n: number of individuals; Rep: repetitions; m: meters; AU: arbitrary units.

Data are presented as mean and standard deviation of all sessions in each referred intensity.

Table 3: Repetitions in the push-up and squat exercises, distance covered and internal load (perceived exertion x session duration) between microcycles.

Variable (n)	Microcycle 1	Microcycle 2	Microcycle 3	P-value
Rep. squat (29)	40.49 ± 6.74 ^a	43.33 ± 6.62 ^{ab}	45.20 ± 6.69 ^b	0.030
Rep. push-up (28)	37.79 ± 6.59	38.02 ± 6.33	39.91 ± 6.37	0.402
Distance covered – m (20)	1957.54 ± 370.41	1946.84 ± 346.89	1940.98 ± 374.92	0.989
Internal Load – AU (31)	204.08 ± 49.14	185.09 ± 49.41	176.94 ± 48.80	0.085

n: number of individuals; Rep: repetitions; m: meters; AU: arbitrary units.

Data are presented as mean and standard deviation. Different letters mean statistical difference.

Table 4: Repetitions in the push-up and squat exercises, distance covered and internal load (perceived exertion x session duration) between mesocycles

Variable (n)	Mesocycle 1	Mesocycle 2	Mesocycle 3	P-value
Rep. squat (28)	39.28 ± 6.47 ^a	43.63 ± 6.46 ^b	48.21 ± 6.96 ^c	<0.001
Rep. push-up (29)	35.91 ± 6.09 ^a	38.42 ± 6.33 ^b	41.99 ± 6.41 ^c	0.001
Distance covered – m (20)	1928.25 ± 350.89	1910.85 ± 344.10	2024.83 ± 404.49	0.575
Internal Load - AU (29)	184.06 ± 56.18	190.21 ± 37.37	181.57 ± 46.92	0.776

n: number of individuals; Rep: repetitions; m: meters; AU: arbitrary units.

Data are presented as mean and standard deviation. Different letters mean statistical difference.

Table 5: Repetitions in the push-up and squat exercises, distance covered and internal load (perceived exertion x session duration) between the first strong session and the last strong session.

Variable (n)	First strong session	Last strong session	P-value
Rep. squat (17)	41.38 ± 6.25	47.56 ± 9.36	<0.001
Rep. push-up (19)	36.79 ± 7.13	41.29 ± 7.22	<0.001
Distance covered – m (11)	1940.91 ± 421.84	2119.09 ± 487.72	0.001
Internal Load – AU (16)	189.87 ± 45.62	162.37 ± 64.62	0.067

n: number of individuals; Rep: repetitions; m: meters; AU: arbitrary units.

DISCUSSION

This study aimed to analyze the behavior of training variables during progressive combined training in middle-aged and older adults with cardiovascular risk factors. From the monitoring of these variables, it is noted that the main result obtained was the significant increase in the external load over time, especially in the variables associated with strength training. In view of this, there was also maintenance of the internal load, indicating positive adaptations resulting from the training program.

When comparing the averages of the variables of the strong sessions with the averages of the moderate sessions, it is noticed a greater amount of repetitions of push-ups and squats and a trend of greater distance covered. In addition, a similar internal load is observed. This may be associated with the fact that the proportion of moderate-intensity sessions was higher at the beginning of the program, which ended with only high-intensity sessions. Thus, at the beginning of the program, despite the predominance of sessions of moderate intensity, the subjects presented a greater perception of effort, precisely because they were not adapted to training. However, as the weeks progressed, the subjects obtained enough adaptations to reduce the perception of exertion, especially for sessions of strong intensity, which resulted in a reduction in the mean RPE. This similar internal load to greater external loads over time indicates positive adaptations to the prescribed stimuli, as it is understood that from the effects of the proposed training, both at the neuromuscular and cardiorespiratory level, the subjects become physiologically more "economical" for the same physical work profile¹⁴⁻¹⁶.

It is also noticed, from the stability of the variables in general, that the weekly loads remained constant throughout the training program. In addition, there was a tendency for the internal load to decrease over the three microcycles. It is understood that each first microcycle represents a break in homeostasis in the training loads, which is the possible explanation for the mean of the internal load variable being higher in the first microcycle than in the two subsequent ones. Regarding external load, while push-up repetitions and covered distance were maintained, squat repetitions were increased along microcycles. Analyzing both external and internal load behavior, it is understood that three weeks/microcycles of the same structure is a suitable period for mesocycles composition.

It is noted, from the present study, a significant difference between the variables of repetitions in the push-up and in the squat when comparing the mesocycles,

being that the loads carried out by the subjects in the training, increased more, going according to the prescribed periodization. In this way, it is observed that the model of undulating the intensity distribution of the sessions seemed efficient, since there was a greater accumulation of work along the mesocycles - $1 < 2 < 3$, as expected for significant gains to occur, such as, for example, of muscle strength. However, for aerobic training, this model does not seem to have been sufficient, but for strength training, these findings highlight how relevant training periodization is for greater gains in strength, muscular endurance, among other physical training variables for practitioners^{17, 18}.

Furthermore, this result emphasizes the importance of making efficient progressions throughout the training program so that the internal load can be maintained, and during this period, there was an increase in the work performed and the maintenance of the perception of effort. Given this, it is possible to infer that if the exercise program had been structured without training progression, always maintaining the same number of repetitions performed at the same speed, the internal load could have decreased even more, repressing the adaptations found in this study.

When comparing the last strong session with the first strong session of the program, it is noticed that there was a significant increase in the repetitions in the push-up and in the squat, as well as in the distance covered. On the other hand, although not statistically significant ($p = 0.067$), a trend toward a 15% decrease in internal load was observed, indicating a relative improvement in performance. This means that, at the end of the intervention, the participants were performing greater training loads and had greater tolerance to effort, promoting a certain economy of movement. This decrease in the internal load throughout a training program is in line with the study by Moreira et al.¹⁹, who observed a decrease in the internal training load during 6 weeks of training young athletes. In addition, the increase in the distance covered in aerobic training suggests a possible improvement in functional capacity, cardiorespiratory fitness and aerobic capacity. For McArdle, Katch and Katch²⁰ improving functional capacity and raising aerobic capacity are important factors in an aerobic training program. Both short bouts of repeated exercise (interval training) and continuous efforts of long duration (continuous training) can improve aerobic capacity.

Still, the improvement in functional fitness attributed to the relationship between internal and external load in the present study is corroborated by the findings of Danielewicz et al.²¹, who observed an improvement in functional capacity, more specifically a better score in the "Sit and Stand Up", "8-foot-up-and-go" and "2 min Step Test" tests, with the same sample and intervention as the present study. Furthermore, Dun et al.¹⁶ carried out a study with patients undergoing

cardiac rehabilitation that consists of observing, for eight weeks, the adaptations and cardiorespiratory responses during interval training on the treadmill prescribed from the RPE. As a conclusion of the study, there is an increase in speed with the maintenance of PSE and without an excessive increase in heart rate and blood pressure. In this way, the effectiveness of RPE as a marker of intensity and the adaptations resulting from aerobic training in eight weeks is observed, as well as in the present study.

From the comparison between the figures of prescribed intensity with the trained internal load, it is noticed that there is a drop in the values in the last three microcycles, reinforcing the indications of adaptation of the subjects to the training. Thereby, this could be a favorable period to change some training variable so that the load progression continues, generating overload on the individual and, consequently, new adaptations and functional fitness gains^{18,20}.

As a limitation of the study, there is a lack of another internal load marker and the application of only one RPE collection at the end of the entire session, without the specific identification for each part (aerobic or strength) of the combined training. In addition, there was loss of some records, considering that some ergometers did not record measurements and due to the programmatic nature of the program.

As a strong point of this work, we highlight the pioneering spirit in presenting the monitoring of internal and external load in the clinical setting, which can contribute to prescribing training for older people with risk factors. Another point is to demonstrate that high-cost or difficult-to-access equipment is not necessary to reproduce this study, encouraging the control of variables to optimize the outcomes from training, especially in clinical populations.

training sessions and also monitor the speed and distance covered in aerobic training, which can be done on the treadmill or, if done outdoors, using cell phone apps.

From the obtained results, it is concluded that during a period of nine weeks of combined training, there was maintenance or decrease of the internal load, while there was an increase of the external training load. That is, during the nine weeks, adaptations to training were generated, demonstrating the importance of periodization and training progression for elderly populations, especially with cardiovascular risk factors.

Therefore, the use of RPE scales show promise, both for prescribing and monitoring loads in physical training for older adults. In addition, this method does not depend on costly or difficult-to-handle instruments, it is capable of providing essential data related to overload, which is extremely important in the training of clinical populations.

It is suggested that more research be carried out using the monitoring of the internal load in clinical populations, also considering the elaboration of training programs with longer duration in order to evaluate the behavior of the variables in the long term, considering the relevance of the involvement of this population in physical exercise programs.

CLINICAL RECOMMENDATIONS

It is recommended for the trainer to control the external and internal load variables, since this way it will be possible to verify the progression of the training of their students. In addition, the equipment used in this study is low cost and easily accessible, which facilitates its use. Therefore, it is possible to collect RPE during the session with the Borg RPE Scale (6 to 20) and after the session with the CR10 Scale by Borg, monitor the repetitions of the exercises and/or the load used in the strength

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