ORIGINAL ARTICLE

Training and detraining ratios: Optimizing exercise adherence in older adults

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ABSTRACT

Multicomponent training (MCT) has been shown to be beneficial, but more in-depth dose-response analyses are needed, especially in the long-term, due to low adherence and high heterogeneity among older adults (OA). This study aimed to develop an index to quantify and compare changes following training and detraining, regardless of adherence or follow-up length. This longitudinal, quasi-experimental study included 47 OA who completed one year of a MCT, with 25 continuing for a second year. To assess the impact of the intervention, Daily Training and Daily Detraining Ratios (DTR & DDR), defined as pre-post changes divided by training or detraining days, were used to analyse trainability in strength, cardiorespiratory fitness, agility, and executive function. Both ratios were converted into z-scores and graphically plotted. Considering the number of days trained and detrained, both physical and cognitive function improved significantly. Strength and cardiorespiratory fitness worsen largely during the second detraining, whilst agility declined more steadily. Inhibition remained stable or even improved during detraining. Noteworthy, physical function was more sensitive to training and detraining than executive function, and mobility enhancements confirmed helping to maintain cognition. Standardization and homogenization address adherence issues and allow comparisons of exercise programs that differ in nature and duration.
Keywords: Performance analysis, Executive function, Strength training, Physical fitness, Detraining, Trainability.

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INTRODUCTION

Research efforts in healthy older adults (OA) seek to show which is the best type of physical exercise intervention, which ideally means to be cost-effective, with larger functional and quality of life benefits, and smaller needs of time and psychophysiological demands for this population. Research interests are also focused on finding out the best dose-response strategies, the adherence generated by each type of exercise program, the already accepted need to tailor it, or above all, the need to analyse any improvement in the short, medium, and long term. Indeed, retention after physical-exercise cessation is a concern that has led to an increasing number of publications related to detraining (Grgic 2022; Leitão et al. 2023; Leitão et al. 2022; Modaberi et al. 2021; Venturini et al. 2022; Yang et al. 2021).

In this scenario, we find large discrepancies among different physical exercise training programs (PETPs), since there are wide ranges of age in the participants (Hakkinen et al. 2000; Toraman 2005), gender differences (Gretebeck et al. 2017), or differences in the training load parameters -i.e., intensity, volume and, mainly, frequency and duration- (de Jesus Almeida et al. 2020; Harris et al. 2007). The effect size is the statistic tool mostly proposed to compare their effects. However, PETPs are different in nature and duration, and up to our knowledge, effect size does not consider the frequency of training or detraining, nor the adherence. Similarly, the percentage of change (the delta) is always illuminative, but again it can lead to misunderstanding because it also discards duration and individual frequency of training.

Unfortunately, adherence has not been considered a relevant variable since short-term interventions always get a high rate. Notwithstanding, long-term programs hinder this rate because elderly people have commitments (medical care, family care, etc.) and adherence is known to decline over time (Mack-Inocentio et al. 2022; Picorelli et al. 2014). In fact, Gray et al. (2018) found a 45% dropout rate in a resistance training program of 48 weeks. Lower adherence as people increase their age and physical exercise programs lengthen, has devastating effects due to increases in immobilism and rate of functional impairment with aging (Farrance et al. 2016). Therefore, individual differences in the days of effective training (and detraining length) should be considered in the analyses to standardize the outcomes and avoid misinterpretations.

Hence, it is worthwhile to explore how long PETP's benefits remain, and which is the time-course of their training and detraining effects. Currently, meta-analysis can examine which PETP is effective using different statistical approaches. However, a recent study has highlighted the importance of how engagement, persistence and adherence influence cognitive effects after exercise interventions. Among their results, they concluded that adherence was a variable rarely reported in training programs despite being very important (Li et al., 2024). For this reason, the evolution of differences regarding the real time of individuals' training and adaptations (adherence) is a concern, so developing new index such as the *Daily-Training Ratio* (DTR), or the *Daily-Detraining Ratio* (DDR), which are defined as changes between sample moments divided by training or detraining days respectively, might be helpful or even a need.

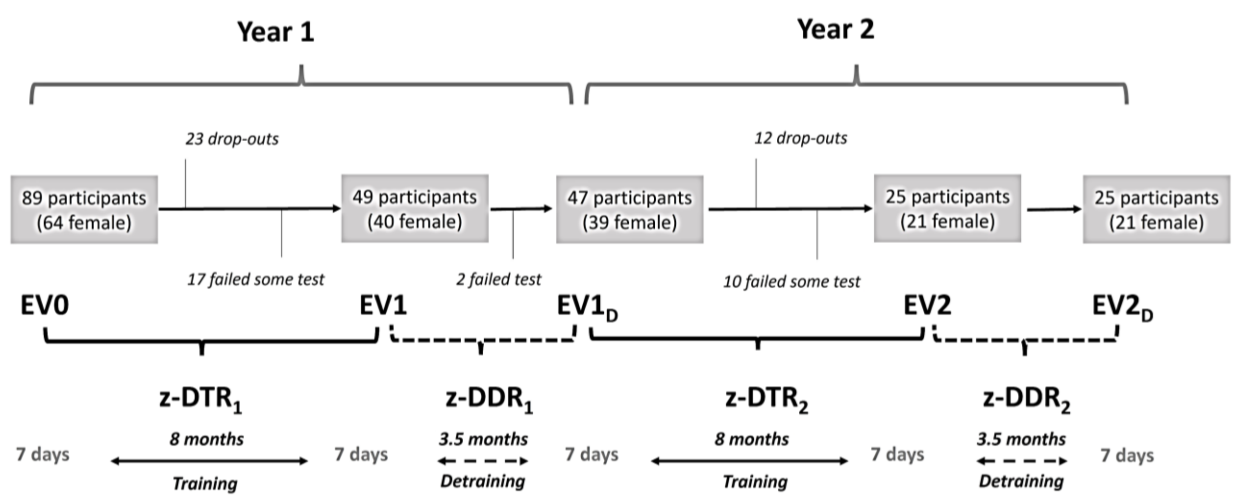
The aim of this study is to propose both ratios as a complementary tool to quantify trainability -changes through training or detraining- following two years of a multicomponent PETP tailored for OA. We hypothesize that quantifying changes in training and detraining regarding adherence (i.e. DTR and DDR), and its further standardization in z-scores (z-DTR and z-DDR), will give light to the real impact of the intervention on this population. Moreover, this method will allow to compare outcomes of different nature (e.g., neuromuscular, cardiovascular, and cognitive outcomes), as well as periods of training with different lengths, whatever the individual's adherence.

MATERIAL AND METHODS

Participants and experimental procedure

Since the starting of the EFAM-UV© (Blasco-Lafarga et al. 2016) project, many healthy OA have participated in this multicomponent training program developed in the sports facilities of the University of Valencia. Every year, physical and cognitive function assessments are conducted at the beginning and at the end of the program (October to May), resulting in 8 months for training and 3.5 for detraining, plus 15 days for testing (7 days in September and 7 days in June). Along the training periods, the program stops only one week for Christmas and one more for Easter to keep the rigour of the process and ensure physical exercise effects.

As already described Blasco-Lafarga et al. (2020), eighty-nine of these healthy OA were invited to participate in the present study and started training. Forty-seven subjects completed training and the whole evaluation on their first year in the program (39 women and 8 men, 71.02 ± 5.75 years; G1), that is, the pre-post training assessments (EV0 & EV1) and a third assessment after the corresponding detraining period which was the pre-training evaluation of the second year ($EV1_D$). Twenty-five of them (21 women and 4 men, 70.82 ± 5.18 years; G2) finished the second year in the program and completed its whole evaluation, again including the assessments after training (EV2) and detraining ($EV2_D$), which was the pre-training assessment on their third year in the program. Mean of adherence was 71% and 72% for the first and second year of the follow-up respectively. After a first traditional analysis considering the two years, but also training and detraining effects in each outcome separately (Blasco Lafarga et al. 2020), data have now been reanalysed by means of these two news standardization ratios. Two z-DTR and two z-DDR resulted from the 5 assessments as displayed in Figure 1.



Note. EVO: baseline; EV1 and EV2: assessment after the first (1) and second (2) training period; $EV1_D$ and $EV2_D$: assessment after first (1) and second (2) detraining period. z-DTR: z-score from Daily Training Ratio; z-DDR: z-score from Daily Detraining Ratio. Upper lines and call texts describe the participants flow, from the initial 89 to the final 25 who completed the whole testing along the two years (from EVO to $EV2_D$). Continuous lines refer to the training period and dashed lines, to the detraining period.

Figure 1. Experimental procedure and flow chart.

All individuals were fully informed and signed their written consent to participate in the study approved by the ethic committee of University of Valencia (Certificate: H1363126067752).

Performance outcomes
According to Rikli and Jones (1999), physical function testing included the six-minute walking test (6MWT) to assess cardiovascular fitness; the 30s-chair stand test (CST) to test lower limbs strength; and the 8-feet timed up-and-go test (TUGT) to evaluate agility. Executive function (EF) was assessed through the Stroop test (Comalli Jr. et al. 1962), where the score obtained after 45 seconds was registered in each sheet. Only the sheet C was considered for further analysis, to assess the inhibition capacity (STROOP).

Body composition measures, executive function, agility and strength (in this order) were obtained during the first testing day, while blood pressure and cardiovascular fitness was assessed 48 h later in a second day to avoid interferences -see Blasco-Lafarga et al. (2020) for more details-.

Exercise training program
According to their investors (Blasco-Lafarga et al. 2016) EFAM-UV© methodology is based on a six-domain taxonomy, progressing in two levels. Starting from the retraining of the more basic motor skills (BS), which include improving gait pattern and postural control while moving forward, backward and laterally, tasks and constrains evolve to include manipulative skills like handling, transporting, passing, catching or throwing, as well as cognitive demands to improve executive function, memory, etc., which are consider complementary in the first level of motor literacy. Later on, the program integrates all the first level domains and introduces rhythm and complex functional motor skills to improve motor control as well as physical fitness in the participants. EFAM-UV© also evolves trough the physical exercise continuum from strength to bioenergetics, with cognition as a permanent target, supervised, tailored, and periodized (Figure 2). To see more details about this physical exercise intervention see Blasco-Lafarga et al. (2020).

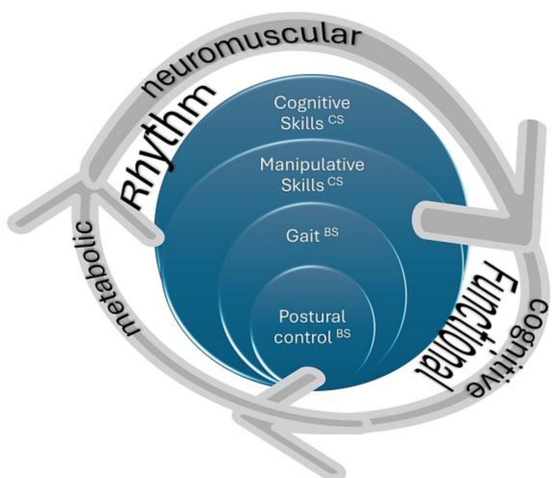


Figure 2. Taxonomy of the EFAM-UV© methodology (Blasco-Lafarga et al. (2020)), a multicomponent cognitive and neuromuscular orientation program specific for older adults

Ratios calculation
With the aim of homogenizing and later standardizing the individual performance, whatever the % of attendance to the training sessions and length of the program (and detraining period), the new ratios DTR and DDR were calculated (Figure 1). These ratios can be expressed as:

$$R = \frac{\Delta y}{t} \tag{1}$$

Where y refers to the name of the outcome; Δy is the change (positive for the gains and negative for the losses) in y between two periods, and t is the number of days of effective training for the DTR, and the total number of non-training days, for the DDR.

To compare among periods and outcomes the ratio was divided by the standard error of the corresponding mean i.e.:

$$\frac{\overline{R}}{s/\sqrt{n}} \tag{2}$$

with $\overline{R}$ being the sample mean of the studied Ratio (DTR or DDR), s being the sample standard deviation and n the given sample size. Notice that this is a z-score highlighting the differences with respect to a non-effect situation, making it comparable across times and outcomes.

$$z = \frac{\overline{x} - \mu}{SE} \tag{3}$$

Regarding notation DTR_1 (DTR_2) and DDR_1 (DDR_2) denoted the ratios for the first (second) year of training and detraining, respectively. A z- was added to the above notation to refer to the z-scores (i.e. z-DTR_1).

Statistical procedures

Statistical analyses were conducted with using R version 3.4.2 (2017-09-28). After testing for normality (Shapiro-Wilk test), and given the samples sizes, normality of all means was considered and, hence, t-tests were performed with a .05 significance level for determining unilateral regions of acceptance-rejection for the z-scores (see Figure 2 for results).

In particular, a null hypothesis of no effect (negative or 0 for the training periods and positive or 0 for the detraining periods) was tested against an alternative hypothesis indicating a significant positive (negative) effect in the DTR (DDR).

The acceptance-rejection regions were stablished according to the 0.05 quantile (with positive and negative signs) of a t-student distribution. Since the sample size differs for each outcome and period (from 22 to 47) the degrees of freedom of the t-Student distribution and the correspondent critical values also varied (from 1.68 to 1.72). With illustrative purposes a common acceptance-rejection region with 1.7 as the threshold value was stablished. This means that, for the training period a significant effect was considered if the corresponding z-score was larger than 1.7. Equivalently, for the detraining periods, a significant (negative) effect would be represented by a z-score lower than -1.7.

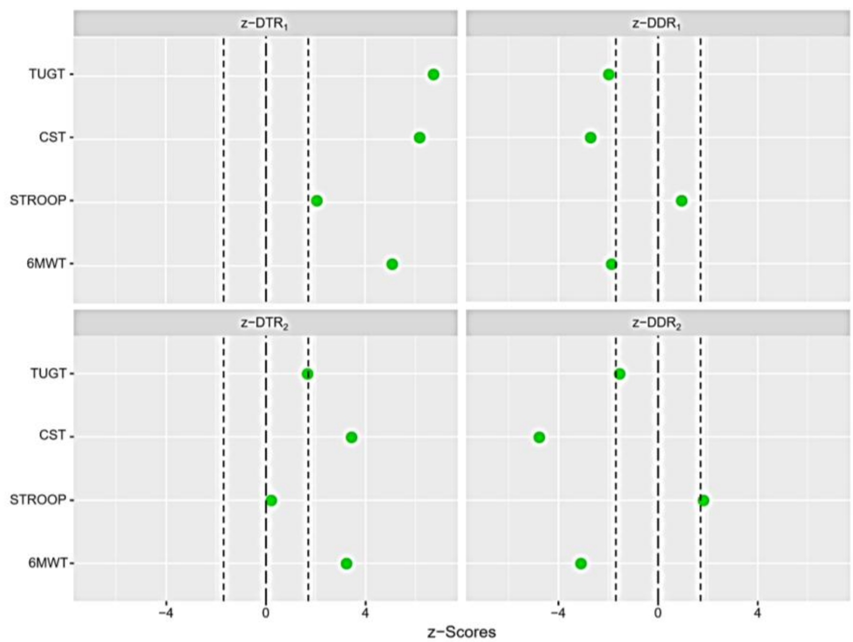
RESULTS

Table 1 shows raw data for physical and executive function variables for G1 (47 participants) and G2 (25 participants).

Figure 3 displays changes in physical (TUGT, CST & 6MWT) and executive function (STROOP), once standardized and converted into z-scores (z-DTR & z-DDR). Since these z-scores consider training and detraining impact -accounting for the time of effective training- on all the subjects who trained for one year in the EFAM-UV© program (z-DTR_1 & z-DDR_1), and on those who trained for two years (z-DTR_2 & z-DDR_2), they allow to compare the trainability and retention of agility, strength, cardiovascular fitness, and inhibition capacity, along two training and two detraining periods.

Table 1. Sample characteristics and raw data for physical and cognitive function along two years of EFAM-UV©, expressed as mean (SD).

	1ST YEAR (N = 47)			2ND YEAR (N = 25)		
	EV0	**EV1**	**EV1D**	**EV1D'**	**EV2**	**EV2D**
Body Weight (kg)	68.14 (12.52)	67.54 (12.45)	67.91 (11.99)	66.48 (9.66)	65.28 (8.85)	66.1 (9.38)
Height (m)	1.57 (0.07)	1.57 (0.07)	1.55 (0.07)	1.54 (0.06)	1.54 (0.05)	1.53 (0.06)
SBP (mm Hg)	133.01 (23.47)	125.83 (15.99)	127.3 (15.99)	122.07 (15.18)	121.57 (13.33)	122.22 (16.7)
DBP (mm Hg)	74.16 (10.66)	68.48 (8.1)	72.04 (9.72)	70.3 (9.82)	70.72 (8.72)	73.57 (11.49)
TUGT (s)	6.85 (1.37)	5.69 (0.82)	5.8 (0.79)	5.7 (0.6)	5.42 (0.7)	5.57 (0.73)
CST (rep)	15.61 (3.08)	18.36 (3.82)	17.31 (3.96)	18.1 (3.68)	20.07 (4.63)	17.12 (3.55)
6MWT (m)	523.51 (64.96)	572.18 (61.92)	558.09 (71.71)	553.12 (71.87)	585.5 (75.13)	558.45 (80.2)
STROOP (u.a. score)	26.22 (8.54)	30.36 (11.08)	29.77 (10.89)	31.52 (10.04)	32.65 (8.3)	35.87 (11.14)



Note. Physical function: 6MWT (6-minute walking test), TUGT (8-feet timed up-and-go test), and CST (30s-chair stand test). Cognitive function: STROOP (Stroop test, inhibition). X axis presents z-scores: z-DTR1 & z-DTR2 (daily-training ratio in the first and second year; left side); z-DDR$_1$ & z-DDR$_2$: daily detraining ratio in the first and second year; right side). Neyman-Pearson significance test approach with a .05 significance level determines unilateral regions of acceptance-rejection when comparing a null hypothesis of no effect (negative or 0 for the training periods and positive or 0 for the detraining periods), against an alternative hypothesis indicating a significant positive (negative) effect in the DTR (DDR). Dashed lateral lines represent the critical values for rejecting the null hypothesis of non-effect, with the threshold value for common acceptance-rejection region at 1.7.

Figure 3. Changes in physical and cognitive function along two years of EFAM-UV©: z-Scores of daily-training and daily-detraining ratios (left and right, respectively).

A significant effect of the first training period was observed for each outcome with TUGT and STROOP showing the largest and lowest improvement, respectively. For the first detraining period, the only variable that did not show a negative z-score was STROOP (in fact it has still a positive value, although inside the rejection area). In the two remaining periods (during the second year) significant training and detraining effects for CST and 6MWT were observed. Meanwhile TUGT stayed in the limit of the rejection area during both periods. Conversely, executive function was almost stationary after the second training period and remained positive (even in the limit of rejection) after the second detraining, showing the inverse effect.

A general overview explains the largest effect of training after the first year (Figure 3, left side: z-DTR_1 vs z-DTR_2), while neuromuscular and cardiovascular fitness (CST & 6MWT respectively) showed larger impairments in the second detraining (Figure 3, right side: z-DDR_1 vs z-DDR_2). Executive function improved continuously through the two years.

DISCUSSION

This study proposes a new method to quantify changes through training or detraining ratios following two years of physical exercise participation in the EFAM-UV© program. To the best of our knowledge, z-DTR and z-DDR are the first indicators capable of analysing and comparing performance changes following PETPs, regardless of their nature (strength, endurance, multicomponent, etc.), duration (i.e. the effective duration of training or detraining) or units of measurement (seconds, meters, etc.). Therefore, this approach addresses the issue of individual adherence differences and avoids the confounding influence of varying sample sizes or participant groups. In fact, both "*effect size*" or "*delta*" approaches to mean comparisons analysis, benefit from similar number of participants in all sample conditions to compare differences. Instead, this new measure allows for the use of different n values and different adherence levels (i.e., effective trained or detrained days) because both variables are integrated into the above-mentioned ratios. As hypothesized, z-DTR and z-DDR enable the analysis of short, medium and long-term training or detraining processes, facilitating adjustments to load and dosage in the short-term.

Compared to the analysis reported in the previous article (Blasco-Lafarga et al. 2020), the interpretation of the results has been modified by considering the specific days of training and detraining through to the ratios. The results of the first year of training changed minimally, and only the STROOP displayed significant differences when analysed with the ratios. Nevertheless, greater variations were observed in the subsequent periods analysed. After examining the first detraining, where no significant differences had been found with the traditional analysis (Repeated measures ANOVA), the ratios indicated a significant decline in all physical variables (CST, 6MWT and TUGT). During the second year of training, agility and cardiorespiratory fitness showed significant improvements according to the ratios, in contrast to the traditional analysis. Meanwhile, the CST and STROOP yielded the same results with both types of analysis. Finally, when the second detraining period was analysed using the ratios, the results also changed, revealing a significant worsening in cardiorespiratory fitness but a significant improvement in cognitive function. The changes in the results could be due to the fact that the ratios take into account the specific days of training (and non-training), whereas traditional statistics do not consider this factor and may therefore fail to accurately reflect what is truly happening. Or at least the weight of days of training/detraining underpinning and explaining the changes.

Once the z-DTR calculation was performed, it became easier to compare the dynamics from the outcomes. Conditional capacities (lower limb strength and cardiovascular capacity) confirmed to be highly sensitive to training and detraining, reflecting both short- and long-term changes. This dynamic underscores the importance of training these two capacities after detraining periods, or at least implementing pre-established, even unsupervised strength exercises or routines to maintain the benefits of the physical exercise programs over longer periods -when supervision ceases, as noted by Geirsdottir et al. (2015). Another option is an eight-week retraining phase, as proposed Leitão et al. (2024), in which hypertensive women older adults improved their physical function after a three months of detraining. Since conditional capacities have been identified as two independent health indicators (Lee et al., 2010), their monitoring, maintenance, and improvement should be prioritized due to their behaviour and their close relationship with the functional independence of older adults contributing to a better quality of life in parallel to their increased life expectancy.

On the other hand, the characteristics of the program (enriched exercises based on the dual-task paradigm and gait pattern involving changes of direction and rhythm) made agility highly susceptible to changes in all periods except for the second detraining phase. This may be due to a greater residual effect derived from training for two consecutive years through complex tasks, changes of direction and decision-making, as established by Donath et al. (2016) to improve this complex capability. Additionally, slower responses in cognition enhancement could explain why executive function was the only variable that exhibited a delayed response, despite training under the dual-task paradigm, as it improved after the second detraining period. These results are aligned with the theory of cognitive reserve, which states that the brain attempts to resist physiological or pathological changes associated with aging through neuroplasticity (Pettigrew et al., 2019). Notably, despite of López-Sáez de Asteasu et al. (2017) suggesting that adherence above 85% is necessary to enhance memory or executive function, EFAM-UV© was able to improve executive function in the long term, without neglecting other abilities that are equally important for the independent living of older adults. The fact that these two variables did not deteriorate during the second detraining period highlights the importance of long-term exercise programs, as their implementation helps preserve acquired benefits, leading to an improved quality of life by enhancing environmental awareness, decision-making, and action execution—thus facilitating daily life activities.

Similar to previous long-term studies (Mack-Inocentio et al. 2022; Oliveira et al. 2017), the sample decreased within periods over the years due to common aging-related issues (higher illness or familiar commitments). However, dropout rates remained within the range proposed by Geirsdottir et al. (2017). Despite being a supervised program, conducted in groups to promote socialization and carried out in a controlled environment -key aspects for maintaining adherence in women (Harris et al., 2020)- the decline in adherence over time could not be avoided.

z-DTR comparisons between physical and cognitive function in our study align with this need of larger adherence or more time of training to ensure cognitive improvements after physical exercise training. Unfortunately, we cannot conclude this based on previous studies, nor compared different trends in trainability, since, up to our knowledge, no previous study standardizes and homogenizes individual performance concerning actual individual participation.

Of uttermost importance, this new index is not particularly useful in the short term, as training days tend to be very similar for all users. But in long-term PETPs, adherence rates typically range between 70% or 85%, and the results obtained could be significantly affected. Thus, these ratios would allow for a more precise analysis of the number of training or detraining days and could even be used to compare differences between participants based on their attendance rates.

This study was not without limitations, primarily the significant reduction in the number of participants during the second year of training. However, recruiting older adults over an extended period (even years) is not an easy task. Further analyses and new research are needed to validate the z-scores, as they appear promising and could help refine in vivo training programs. Additionally, the ability to individually tailor these ratios would allow for the design of personalized programs so that all participants could benefit, despite varying levels of adherence. Moreover, monitoring adherence could help expand our understanding of the psychosocial benefits of long-term programs.

CONCLUSIONS

Summarizing, the ratios are more sensitive to small changes due to the tracking of training and detraining days. As a result, cardiorespiratory capacity, which did not show significant differences with traditional analysis, changed completely in its interpretation when using the ratios. Additionally, the two conditional abilities (CST and 6MWT) showed to be highly sensitive to both training and detraining, highlighting the need to reduce detraining periods or add maintenance exercises during any non-training period. Regarding agility and executive function, the ratios gave light that, thanks to long-term training, improvements showed to be maintained during the second detraining phase.

As a practical application, z-DTR and z-DDR could be proposed as a new method for comparing different programs and determining which is most effective in terms of objectives, pathologies, and adherence rates regarding participants' physical and cognitive conditions. These ratios could be a simple complementary tool for comparing physical exercise interventions by adding a necessary information, such as adherence. This way, policymakers and fitness trainers should recommend or even prioritize PETPs with higher z-DTR and lower z-DDR for specific populations -i.e., those that generate the most significant changes during training and the highest retention rates during detraining. Indeed, these findings and reanalysis helped to confirmed that the physical and cognitive benefits following EFAM-UV© methodology were highly valuable in developing community policies aimed at creating specific physical exercise programs for older adults.

AUTHOR CONTRIBUTIONS

All authors have contributed to the published work and agree to its publication in JHSE. Specifically, conception and design: AC, AF, CBL; training program and collected data: AC, AR, PM; analysis and interpretation of the data: AC, AF, CBL; drafting of the paper: AC, AF, CBL; writing—review and editing: AC, AF, AR, CBL, PM. All the authors approved the final version to be published and agree to be accountable for all aspects of the work.

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No potential conflict of interest was reported by the authors.

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