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# Following changes in balance and cognitive performance on healthy middle-aged people: evaluation of the effect of two types of concurrent training



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ABSTRACT
**Purpose.** The study aimed to compare the effects of two different concurrent training protocols applied to healthy middle-aged individuals on balance parameters and cognitive functions.
**Methods.** Thirty-three middle-aged adults voluntarily participated in this study. A randomised, between-group design (Strength+Aerobic Group [SAG] and control group Aerobic+Strength Group [ASG]) was used. After collecting data related to the main characteristics of the subjects (i.e., age, sex, medical history, smoking habits), the following assessments were made: Subjects' physical activity level, balance parameters, and inhibition and attention indicators. The intervention lasted 13 weeks (2 sessions per week, 50 minutes per session).
**Results.** Both protocols (SAG and ASG) significantly improved balance performance. However, as for the group-by-time interaction, no significant difference between the two groups were observed in any of the parameters assessed ($F$(1–31) = 0.843; 0.760; 0.612; 0.656; $p > 0.05$). Thus, it was found that participating in either the SAG or ASG groups had no significant influence on attention accuracy, reaction time, total number of matters processed (participants' psychomotor speed), and non-marked letters (selective attention) (post-test–pre-test difference: $F$(1–31) = 0.239, 0.337, 0.738, 0.414; $p > 0.05$). It was also observed that both training programs resulted in similar improvements in all balance characteristics and cognitive parameters.
**Conclusions.** It was found that the order of strength or aerobic exercises in the concurrent training for improving balance and cognitive parameters in healthy middle-aged individuals is not significant.
**Key words:** exercise, inhibition, attention, proprioceptive

## Introduction

The biological ageing process is distinguished by a multitude of factors leading to morphological and functional alterations [1–3]. Notably, studies have highlighted that the decline in muscle mass commences during middle age and proceeds with incremental pace [4]. This phenomenon is closely linked to a reduction in muscle strength and overall functional capability [5]. Additionally, it is known that with the ageing process, there is a decrease of up to 60% in maximal oxygen uptake ($VO_2max$) in individuals aged 30–70 [6, 7]. Similar to these declines, there can be deficiencies in normal postural control and balance [8]. Another significant health issue that emerges with advancing age is the deterioration of individuals' cognitive functions [9]. To delve deeper, the ageing process is intricately tied to a reduction in physical fitness levels [10–14]. This decline leads to unfavourable consequences, including compromised mobility, heightened vulnerability to falls [15], and a diminished quality of life [16–18]. Previous research has suggested that the degree of physical fitness remains consistent from middle age to older adulthood [19]. This suggests that the physical fitness level during middle age can indicate physical performance in later stages of life, underscoring the potential benefits of early training interventions around the age of 50, which can yield favourable long-term outcomes. Hence, it is crucial to prioritise the maintenance of a high level of physical fitness in individuals who are

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in the middle-aged and older adult populations [20]. The advantages of exercise for adults' overall health are extensive and vary depending on the type of exercise, which can be either short-term or long-term in nature [21–23]. Regular physical activity is regarded as a means to uphold physical capabilities in older individuals, counteract the decline in muscle mass, and preserve functional independence [24]. The existing exercise and physical activity recommendations for older adults encompass endurance training (ET) and strength training (ST) [17, 18, 25]. ST may be effective in slowing or halting the decline in cognitive function in older adults [13, 26]. While the impact of ST on executive function and memory is still debatable, certain reviews have suggested that it may improve some cognitive functions in healthy older adults [27, 28]. Aerobic exercise also appears to have a beneficial impact on cognitive function in older adults [29]. However, a meta-analysis showed that combining aerobic exercise with strength training had a more significant impact on cognition than aerobic exercise alone [30].

Training for both strength and endurance causes different changes in the cardiovascular and neuromuscular systems. In addition to increasing motor unit recruitment capacity and firing rate, strength training also causes muscle hypertrophy [31–33]. These adaptations at the neuromuscular level lead to enhanced muscle strength and power generation [12]. The targeted impacts of strength and endurance training are well-recognised, and it is worth noting that a skilfully structured amalgamation of these two training modalities could potentially alleviate the detrimental effects of ageing to a greater extent compared to their individual applications alone [34]. Consequently, the simultaneous implementation of strength and endurance training, referred to as concurrent training, has emerged as an efficacious strategy for enhancing both neuromuscular and cardiorespiratory functions in adults [35]. This comprehensive approach is adept at preserving functional capacity [36,37], and serves as an optimal means to counteract the adverse effects of ageing.

Several investigations have acknowledged the potential advantages of integrating strength training (ST) and aerobic training (AT) within the same session, with a particular emphasis on the order of these exercises, revealing that certain benefits are associated with one sequence over the other [38, 39]. Notably, Makhlouf et al. [40] observed that performing ST before AT improved dynamic muscle strength more than the reverse training order. This discrepancy could be attributed to AT-induced fatigue, which may impact neuromuscular activation and diminish muscle firing frequency. Conversely, Wilhelm et al. [41] reported that, irrespective of the sequence, combining endurance and strength training conferred beneficial effects on strength and power output in older adults. Thus, existing studies present contradictions, and only a limited number of systematic investigations have been conducted to explore the benefits of different concurrent training sequences to address practical training needs and enhance training outcomes [26].

More evidence is needed to determine how the concurrent training sequence may impact balance factors [42]. In addition, while a growing body of research evidence from epidemiological, cross-sectional, and neuroimaging studies highlights the benefits exercise has on cognition, results from randomised controlled trials paint a more nuanced picture with less consistent findings [43]. Given the relatively limited pool of studies that have directly compared the impacts of varying sequences of concurrent training on both balance and cognitive function, and considering the insufficient supporting evidence, our hypothesis posited that both exercise orders (i.e., strength-endurance and endurance-strength) would yield comparable improvements in the balance and cognitive parameters of middle-aged adults with sound health.

## Material and methods

### Experimental approach to the problem

This study investigated the 13-week effects of two distinct concurrent training procedures on balance and cognition in healthy middle-aged individuals. Thirty-three healthy middle-aged individuals were evaluated using a randomised, between-group design (Strength+ Aerobic Group [SAG] and control Aerobic+Strength Group [ASG]).

### Subjects

This study encompassed 33 middle-aged adults (age = 42.93 ± 8.86 years), with 24 females and nine males who took part voluntarily. A visual representation of the participant flow can be seen in Figure 1. Inclusion criteria comprised: (a) age above 40 years; (b) absence of cardiovascular or neuromuscular disorders; (c) absence of orthopaedic disorders; and (d) absence of neurologic disorders. Exclusion criteria involved: (a) having an artificial prosthesis; (b) engagement in any structured training program; (c) presenting symptoms identified by a medical examiner as grounds for exclusion; (d) presence of conditions precluding exer-

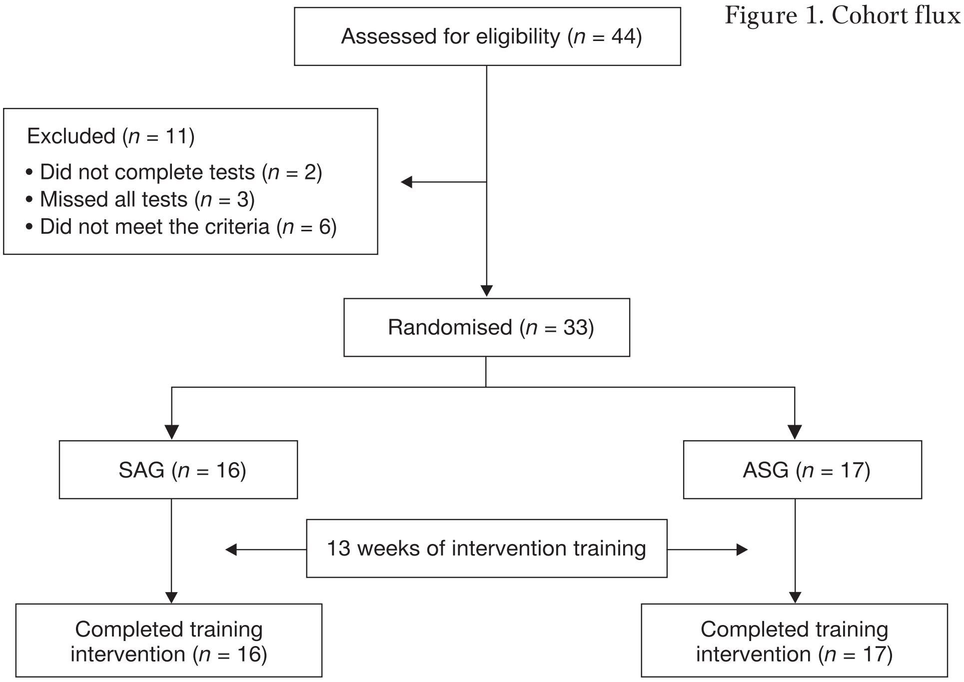


Figure 1. Cohort flux diagram

cise or requiring special care (such as coronary artery disease, thrombosis, moderate or severe bone disease, lung or renal disease); and (e) existence of conditions necessitating the daily use of performance-affecting medications, to prevent any potential impact on the fitness measurements.

Participants were randomly allocated to one of the two groups: SAG ($n$ = 16) or ASG ($n$ = 17). Supplementary information about the participants is provided in Table 1. The participants had not previously participated in any regular aerobic or strength training program and had no practical experience with these exercises. They work as academic and administrative staff at the university. The participants were selected from individuals who had no previous athletic background, showed sedentary behaviour and worked at a desk. Additionally, none of the participants stated that they were using any medication. Participants who expressed willingness to participate in the study adhered to the Declaration of Helsinki and its successive revisions by providing informed consent prior to the study's initiation.

## Procedures

The effectiveness of two distinct concurrent training programs on the parameters of balance and cognitive function in healthy middle-aged adults was compared in a parallel group randomised trial. The evaluations, which took place across two sessions, were disclosed to the participants. Participants' age, sex, medical history, smoking habits, and other characteristics were recorded during the first session. The individuals' level of physical activity was estimated using the seven-day physical activity recall questionnaire (7 Day PARQ), which was administered during a 10- to 15-minute interview. Prior to the intervention training protocols, all anthropometric measurements were taken, and the participants practiced balance tests. After a 24-hour break, cognitive function was evaluated using a variety of measures. The time intervals between testing sessions, as well as the start and end of the training regimen, were all fixed at 72 hours. The same researchers regularly performed the tests and measures in a standardised sequence. The participants were allowed a conventional warm-up program consisting of 10 minutes of jogging and 5 minutes of dynamic stretching before to the balancing tests. To reduce the impact of circadian rhythms on the study outcomes, all assessments were performed at the same time of day (5:30 p.m. to 7:30 p.m.). The participants were given the option to undertake cool-down exercises following the intervention. The total exercise intervention lasted 13 weeks, with two sessions per week, lasting 50 minutes each.

### *Body composition assessment*

A Mesilife 13539 portable stadiometer with 0.1 cm precision was used to measure the height (m). Body mass (kg), fat percentage, and skeletal muscle mass (kg) were all measured using a stable, eight-polar tactile electrode bioelectrical impedance analyser (Tarti Fast, Japan). The validity of this bioelectrical impedance analyser has previously been reported [44]. Body mass index (BMI) (kg/m$^2$) equals body mass (kg) divided by body height squared (m$^2$).

*Physical activity level*

To measure the physical activity levels of adults between the ages of 15 and 65, the study used the short version of the International Physical Activity Questionnaire (IPAQ) [45]. The validity and reliability of this questionnaire have already been shown among Turkish citizens [46]. Physical activity has to last for at least 10 minutes to meet IPAQ's measuring requirements. The participants were asked how much time they spend on vigorous exercise, moderate exercise, strolling, and sitting each day. The durations of walking, strenuous exercise, and moderate physical activities were converted into basal metabolism units known as MET (1 MET = 3.5 ml/kg/min). Using the collected data, a cumulative physical activity score in MET-minutes per week was calculated. This score represents an individual's total weekly physical activity, taking into account the intensity and duration of various activities.

*Balance performance*

A portable platform (Sensbalance MiniBoard; Sensamove®, Utrecht, the Netherlands) that acted as an interactive teaching tool was used for the balance evaluation. Each participant performed two separate balance tasks that were each subject to a different set of rules, and these evaluations were carried out twice. The Sensbalance MiniBoard used cutting-edge, noninvasive technology to make it easier to collect data in real time when conducting balance checks. Furthermore, the device had the option of storing obtained data in a variety of forms, including Notepad data files, Excel spreadsheets, and graphics files. According to Liviu, Ilie, and Fernando's study [47], the measurement system used in this study allowed the researchers to perform tests focusing on static and dynamic balance as well as ankle joint mobility. However, the current study focused primarily on evaluating the individuals' static and proprioception balance assessments.

*Inhibition*

The Go/No-Go Task serves as a cognitive evaluation designed to gauge response inhibition, encompassing the suppression of well-established responses [48]. Although diverse iterations of this task exist, it has not been standardised within the Turkish population thus far. In this investigation, a computer-based Go/No-Go task was employed, utilising X and O images as stimuli. Participants received instructions to promptly click the left mouse button on the appearance of the target stimulus (X image), while refraining from clicking when the non-target stimulus (O image) was presented. The task encompassed a total of 200 stimuli, evenly split between target and non-target stimuli. Each stimulus was exhibited for 50 milliseconds, succeeded by a 1,450--millisecond display of a black screen before the subsequent stimulus emerged, resulting in a 1,500-millisecond inter-stimulus interval (SOA). The inter-stimulus intervals (ISI) were also set at 1,450 milliseconds. Completion of the task required roughly 5 minutes and 40 seconds. Within the Go task, accurate executions achieved through clicking the left mouse button in response to a target stimulus denoted the correct reaction score. Conversely, the absence of button-clicking on the appearance of a non-target stimulus contributed to the incorrect reaction score. Furthermore, the average response time for accurate reactions to target stimuli was recorded as the correct reaction latency. In the context of the No-Go task, successfully refraining from responses when encountering a non-target stimulus was tallied as the correct reaction score. Conversely, pressing the button following a non-target stimulus added to the incorrect reaction score. The average response time for accurate reactions to non-target stimuli was documented as the incorrect reaction latency.

*Attention*

The participant's attention span, selective attention, and mental concentration levels were evaluated using the D2 attention test. This assessment comprises a front page for recording personal details and outcomes, followed by a trial row. The principal test form ensues, featuring 14 rows per page, each containing 47 letters. These letters are a mix of 'p' and 'd' with various quantities of small markings (one, two, three, or four) adorning them. During the test, participants are tasked with identifying and marking 'd' letters that have two markings, while disregarding other irrelevant letters. A time frame of 20 seconds is allocated to complete each row [49, 50]. The Total Matter Score Processed (TM) serves as a quantitative measure, assessing the performance across all processed items in the D2 attention test, both relevant and irrelevant. The Total Error (E) encompasses letters that were left unmarked (E1) as well as those incorrectly marked (E2). To delve into the qualitative facet of performance, the Error Percentage (E%) is computed, denoting the error rate for all processed items. A lower error rate signifies greater accuracy in the participant's responses, indicative of heightened work quality and attention span.

*1-Repetition Maximum Strength Test*

The indirect 1 repetition maximum (1RM) test is relatively simple, efficient, and safe when used and administered. The formulas for calculating 1RM allow for weightlifting repetitions of less than 20 and a linear or curved relationship between the percentages of 1RM. In order to determine the 1RM values of the study participants, indirect 1RM bench press, leg press, long pulley, leg extension, and overhead press were used. 1RM tests were performed using a weight machine (Technogym Selection 900). The formula for calculating 1RM indirectly is given below [51]:

1RM = (Lifted Weight) / [1.0278 – (Repetition*0.0278)]

*Training program*

The training program included 13 weeks of twice-weekly sessions that took place either in an outdoor athletic field pavilion or an indoor arena. Each training session began with a 5- to 7-minute warm-up phase that included exercises including dynamic mobility, low-intensity walking, and jogging. The sessions were then finished with a 4- to 5-minute cool-down phase that included stretching and relaxation techniques. These sessions lasted roughly 50 minutes, including warm-up and cool-down intervals, for a 105–120-min--ute total weekly duration. Figure 2 presents a thorough summary of the 13-week training course.

Eight seasoned personal trainers oversaw all training sessions. Paired groups were established based on the participants' comparable strength and aerobic fitness levels. Tailored training programs were formulated for each individual, taking into account data derived from strength and aerobic assessments. The resistance training (RT) phase adopted the circular training method, whereas the aerobic training phase incorporated a sequence of moderate to vigorous movements. Both the resistance training and aerobic exercises adhered to the step-loading periodisation principle.

During the RT phase, each session spanned roughly 20–25 minutes and comprised two sets of 8–20 repetitions, interspersed with 1–2-minute rest intervals, in line with the approach proposed by Pescatello et al. [52]. The resistance training program involved either two or three sets, employing the circuit training technique. The intensity was gauged by employing the Borg CR-10 scale [53], commencing at a rating of 2 points and incrementally elevating to 5 points on a weekly basis, as elaborated in Table 1. The RT exercises encompassed a range of movements, including squats, barbell bent-over rows, overhead presses, planks, lat pull downs, triceps push downs, barbell curls, leg extensions, leg curls, lunges, barbell bench presses, and crunches. Notably, hydraulic and roller system fitness machines were preferred for resistance exercises, particularly during the initial four weeks of the training protocol. Subsequently, from the fifth week onward, free weights such as dumbbells and barbells were integrated as the exercise loads progressed. All training sessions were conducted under the supervision of the researcher who organised the exercise sessions. The researcher facilitated participant motivation, ensured the accurate execution of movements, and prioritised safety considerations.

Table 1. Periodisation of strength training

| Weeks | Intensity (Borg CR-10) | Repetitions |
|---|---|---|
| 1–2 | 2 | 15–20 |
| 3–4 | 3 | 15 |
| 5–7 | 4 | 12–15 |
| 8–10 | 5 | 10–12 |
| 11–13 | 6 | 8–10 |

Intensity was established between 50–65% and 80–85% of HRmax for both groups (SAG and ASG). The HRmax was estimated using Tanaka et al.'s equation (i.e. (208 – age) ∗ 0.7) [54]. The heart rate variables of the participants during aerobic exercise were determined using a heart rate sensor (Polar Verity Sense; Kempele, Finland). The Polar Verity Sense can be connected to a sports watch or app via Bluetooth®, ANT+. Control is provided by Bluetooth transfer to a tablet via Polar Flow program.

Aerobic exercise training was designed to include different aerobic training protocols for each pair. In line with the step loading periodisation principle, an aerobic training program was designed from moderate to vigorous intensity, with HRmax varying between 50 and 85% from the 1st week to the 13th week of participation. The aerobic training program lasted approximately 20–25 minutes. It included walking and running and was carried out on a 400 m outdoor track. In periodisation, especially the 1st to 4th weeks, walking, jogging and running-based exercises were preferred between weeks. In the following weeks, in addition to these exercises, more intense exercises were added to the training program (rope jumping, jumping jacks, burpees, vertical jumping, broad jumping, sliding, and footwork). The training strategy was the same in both groups. However, the strength training was performed first in SAG, followed by aerobic training while in ASG, aerobic training was performed first and then strength training.

Statistical analyses

The data was analysed using the statistical software SPSS v.18.0 for Windows (SPSS Inc., Chicago, USA), with $p < 0.05$ considered significant. The mean (*SD*) was used to convey the descriptive statistics. Prior to the analysis, the Shapiro-Wilk and Levene's tests were used to assess the normal distribution and homogeneity of all the data. The chi-square test and *t*-test were used to compare sociodemographic factors between groups. The dependent variables were submitted to a 2 × 2 analysis of variance (ANOVA) with repeated measures, which included the group and measurement components. Prerequisite conditions were assessed before the ANOVA. Box's Test of Equality of Covariance Matrices was used to ensure that there were no significant differences in covariances between measurement groups for pairwise combinations. It was confirmed that a participant's difference score remained independent of the difference scores of other participants across repeated measures. The magnitudes of variations in values were also assessed using the partial eta squared effect size. Because it is available in statistical software, the partial eta squared coefficient ($\eta_p^2$) was preferred in circumstances where comparisons included more than two groups or more than two measures of a single group [55]. While Cohen [56] categorises partial eta squared as small (0.0099), medium (0.0588), and big (0.1379), findings can be interpreted without such categorisation. The partial eta squared coefficient assumes values between 0 and 1, and when multiplied by 100, it signifies the proportion of dependent variable variance explicable by the independent variable [55].

## Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by Tekirdag Namik Kemal University's Scientific Research and Publication Ethics Committee (approval No: 2021.275.11.19).

## Informed consent

Informed consent has been obtained from all individuals included in this study.

## Results

At baseline (before the training intervention), there were no significant between-group differences ($p > 0.05$)

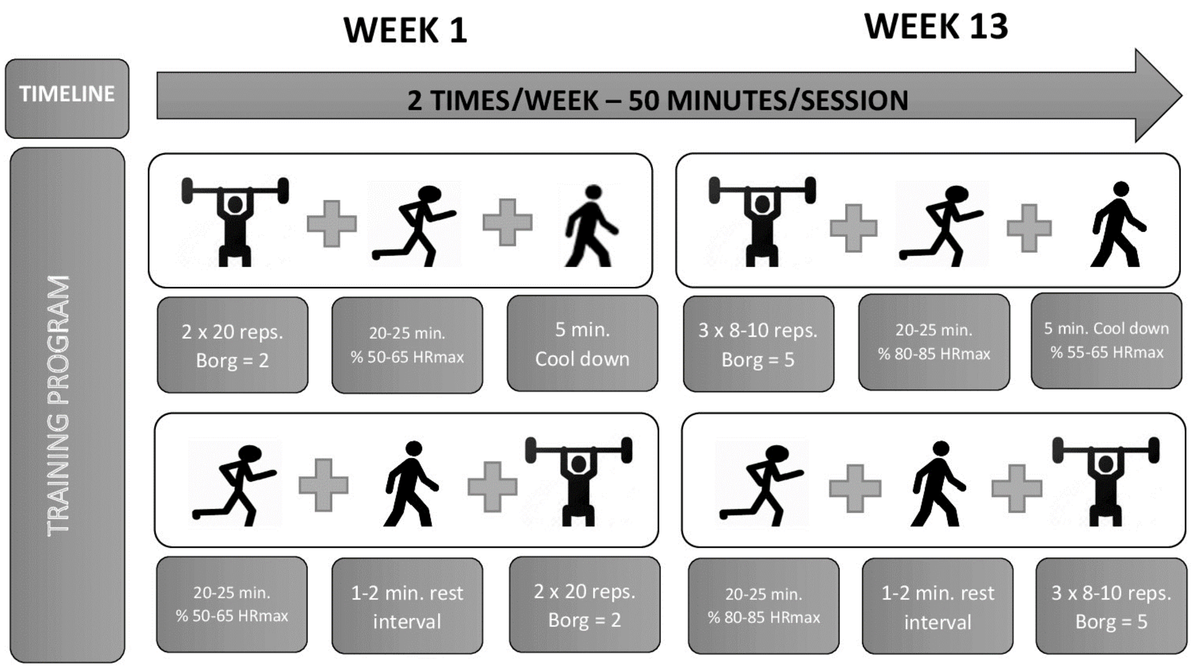


Figure 2. Illustrative scheme of training program across groups

in anthropometric characteristics, sex distribution, physical activity level, or sitting time (Table 2).

According to the two-way ANOVA results for the mixed measurements made to test whether being in SAG or ASG had a significant effect on the parameters that form balance performance, in the group-time interaction, there was no significant difference between the two groups in any parameter (respectively; $F_{(1–31)}$ = 0.843; 0.760; 0.612; 0.656; $p > 0.05$) as shown in Table 3.

It was discovered that participating in either the SAG or ASG groups had no significant influence on ACC, RT, TM or E1 (post-test–pre-test difference, respectively: $F_{(1–31)}$ = 0.239, 0.337, 0.738, 0.414; $p > 0.05$) (Table 4).

Table 2. Characteristics of participants (mean ± *SD* and *n* [%])

| Variable | Whole group (*n* = 33) | SAG (*n* =16) | ASG (*n* = 17) | *p* |
|---|---|---|---|---|
| Age (y) | 42.93 ± 8.86 | 44.61 ± 6.22 | 41.35 ± 10.73 | 0.293 |
| Height (cm) | 162.32 ± 7.93 | 162.97 ± 6.82 | 161.71 ± 9.02 | 0.655 |
| Body mass (kg) | 70.81 ± 14.77 | 70.70 ± 14.85 | 70.90 ± 15.16 | 0.970 |
| Body mass index ($kg \cdot m^{-2}$) | 26.86 ± 5.26 | 26.65 ± 5.52 | 27.07 ± 5.17 | 0.823 |
| Sex,* *n* (%) | | | | |
| Male | 9 (27.8) | 5 (31.2) | 4 (23.5) | 0.619 |
| Female | 24 (72.2) | 11 (68.8) | 13 (76.5) | |
| PAL (MET-min/week) | 688.42 ± 697.46 | 740.18 ± 758.64 | 639.70 ± 654.32 | 0.686 |
| Sitting time (h) | 8.42 ± 3.92 | 7.81 ± 3.97 | 9.00 ± 3.92 | 0.394 |

* Chi-square test, PAL – physical activity level

Table 3. Balance parameters before (pre-test) and after (post-test) the 13-week training program

| Variables | Groups | Pre-test (mean ± *SD*) | Post-test (mean ± *SD*) | *F* | *p* (group × time) | $\eta_p^2$ |
|---|---|---|---|---|---|---|
| Static balance (sc) | SAG | 87.68 ± 4.84 | 91.00 ± 2.52 | 0.040 | 0.843 | 0.001 |
| | ASG | 86.29 ± 7.64 | 90.00 ± 3.90 | | | |
| Proprioceptive balance (sc) | SAG | 83.50 ± 5.68 | 86.37 ± 4.20 | 0.095 | 0.760 | 0.003 |
| | ASG | 82.29 ± 9.12 | 84.35 ± 6.77 | | | |
| Dynamic balance (sagittal oscillation) (sc) | SAG | 81.00 ± 9.33 | 90.56 ± 7.45 | 0.263 | 0.612 | 0.008 |
| | ASG | 79.05 ± 16.50 | 90.64 ± 8.44 | | | |
| Dynamic balance (frontal oscillation) (sc) | SAG | 88.50 ± 7.08 | 96.25 ± 4.00 | 0.203 | 0.656 | 0.006 |
| | ASG | 88.41 ± 10.52 | 95.17 ± 4.29 | | | |

SAG – strength+aerobic group, ASG – aerobic+strength group; $\eta_p^2$ – partial eta squared, sc – score

Table 4. Inhibition and attention parameters before (pre-test) and after (post-test) the 13-week training program

| Variables | Groups | Pre-test (mean ± *SD*) | Post-test (mean ± *SD*) | *F* | *p* (group × time) | $\eta_p^2$ |
|---|---|---|---|---|---|---|
| ACC (%) | SAG | 95.93 ± 2.81 | 98.31 ± 1.88 | 0.239 | 0.628 | 0.008 |
| | ASG | 94.76 ± 5.44 | 97.70 ± 3.03 | | | |
| RT (ms) | SAG | 235.32 ± 84.57 | 160.91 ± 142.79 | 0.337 | 0.566 | 0.011 |
| | ASG | 232.71 ± 73.81 | 197.31 ± 199.35 | | | |
| TM | SAG | 500.93 ± 109.67 | 499.37 ± 87.88 | 0.114 | 0.738 | 0.004 |
| | ASG | 541.11 ± 69.44 | 548.35 ± 72.70 | | | |
| E1 | SAG | 121.43 ± 65.59 | 36.12 ± 23.18 | 0.687 | 0.414 | 0.022 |
| | ASG | 123.47 ± 43.31 | 52.05 ± 42.61 | | | |

SAG – strength+aerobic group, ASG – aerobic+strength group, $\eta_p^2$ – partial eta squared, ACC – accuracy, RT – reaction time, TM – total number of matters processed (representing participants' psychomotor speed), E1 – non-marked letters (representing the selective attention of the participants)

## Discussion

The research aimed to investigate how two different concurrent training strategies applied to middle-aged sedentary healthy individuals affected improvements or changes in participants' balance and cognitive function variables and to compare these changes in training strategies.

Our study determined that two different concurrent training programs applied to the participants resulted in improvements in static, dynamic, and proprioceptive balance performance. However, it was found that these improvements did not create a significant difference when comparing the training programs. It has been reported that concurrent training (CT) programs reduce the detrimental effects of ageing and improve neuromuscular responses. Investigating the impact of CT on balance, especially during the training, has been emphasised as it can lead to a better prescription of CT programs for middle-aged and elderly individuals [42]. However, upon reviewing the literature, it was found that there were no studies specifically focusing on middle-aged individuals and only a limited number of studies have been conducted on the elderly population. At this point, Silva et al. [42] stated that in their study involving women and men between the ages of 60 and 75, two different concurrent training strategies did not improve static and dynamic balance levels. However, the existing values were maintained. Wilhelm et al. [41] evaluated the effect of a 12-week CT sequence on the dynamic balance of 36 elderly male participants. The results showed that neither of the training strategies led to an improvement in dynamic balance performance. At this point, the results of the two studies mentioned above indicate that there are no improvements in balance performance, but the existing situation is maintained. There may be many factors that can cause this situation. In particular, the physical activity status and exercise history of the participants in both studies may be effective. Additionally, training program content, intensity, and duration may have affected the research results. No research examining the aspect of proprioception was found in the literature. Therefore, the findings obtained regarding static, dynamic, and proprioceptive balance performance in our study represent a valuable contribution to the field. Furthermore, the positive improvements in overall balance performance for middle-aged individuals observed in both the aerobic+strength and strength+aerobic training strategies indicate that these two different training approaches can be used as exercise methods for middle-aged individuals in their exercise plans.

In the study, accuracy and reaction time improvements were observed, representing the inhibition parameter in both training strategies. However, no significant difference between training strategies was found when comparing these improvements. Additionally, there were low-level improvements in psychomotor speed and selective attention, representing the attention attribute. However, these improvements did not vary significantly between the training strategies. Understanding the role of physical activity in boosting cognitive function in adults and delaying the onset of cognitive decline is becoming more important as age-related cognitive impairment increases [43]. The positive effects of exercise on cognitive health are supported by a growing body of research evidence from epidemiological, cross-sectional, and neuroimaging studies [30, 57–59]. However, no research has been found that explicitly examines which concurrent training strategy may effectively improve cognitive functions in middle-aged individuals. Only limited studies have investigated the impact of concurrent training on cognitive functions, and the number of such studies is quite restricted. Morente-Oria et al. [60] conducted a study in which they implemented an 8-week, 3-day per week concurrent training program involving strength and aerobic exercises in 48 women aged 60. They found improvements in participants' reaction times related to executive function.

As is well known, a decrease in attention can lead to reduced capacity to accomplish more complex tasks [61], and there are various approaches to improve reaction time [62,63]. Therefore, it is deemed highly important to identify exercise strategies that can preserve and enhance cognitive function in individuals from different populations. Indeed, there is strong evidence that regular physical activity enhances various cognitive functions in both healthy individuals and those with certain medical conditions [27, 49, 58, 64–66]. Additionally, scientific research also indicates that inactivity and obesity are associated with cognitive impairments [67, 68]. In this context, our study has identified that the concurrent training strategy presented in two different versions can be used to preserve and enhance cognitive functions in healthy middle-aged individuals.

The present study has some limitations. First, it is essential to acknowledge that the research groups exhibited an unequal ratio of male to female participants, which may limit the generalisability of the study findings. Second, the lack of a control group, in addition to the two exercise groups, may be seen as limiting the study. Additionally, participation in board games, chess, backgammon or electronic games, which could affect participants' daily lives, especially attention and reaction speed, could not be controlled. This is also seen as a limitation of the research. It is recommended for researchers who will conduct research on the subject to do more training sessions. Also, the training strategy designed in the research is considered a very suitable strategy for middle-aged sedentary individuals in terms of intensity, number of sets, number of repetitions and duration. This is one of the strengths of the research. Future researchers can use this training strategy as a reference.

## Conclusions

The effects of two different application stages of the concurrent training program used as the exercise method were examined regarding balance characteristics and cognitive functions in healthy middle-aged individuals. It was found that both training programs resulted in similar improvements in all balance characteristics and cognitive parameters. When comparing the effects of both training strategies on balance and cognitive parameters, no significant differences were observed. Therefore, it was determined that the order of strength or aerobic exercises in the concurrent training is not significant for improving the balance and cognitive parameters in healthy middle-aged individuals.

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## Disclosure statement

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## Conflict of interest

The authors state no conflict of interest.

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