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High-intensity interval training using TRX lower-body exercises improve the risk of falls in healthy older people

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Abstract

The objective of this study was to compare the effects of high-intensity interval training (HIIT) and moderate intensity interval training (MIIT) programs, both with a suspension training system, on several fall risk factors in healthy older adults. A total of 82 participants (68.49 ± 5.18 years) were randomized to HIIT ($n=28$), MIIT ($n = 27$), or control ($n = 27$) groups. Balance confidence (Activities-specific Balance Confidence Scale), fear of falling (Falls Efficacy Scale International), dynamic balance (Timed Up and Go Test) and gait analysis (OptoGait optical detection system) were assessed. Statistical analysis showed improvements after the intervention in HIIT group compared with MIIT and control group regarding the fear of falling ($p < .05$ and $< .01$ respectively), gait (both $p < .05$), and dynamic balance ($p < .05$ and $< .01$ respectively), while both HIIT and MIIT improved balance confidence compared to group control ($p < .01$ and $p < .05$ respectively). We can conclude that HIIT has significant beneficial effects of fall risk in older adults.

Key words: HIIT; TRX; Risk of falls; Older adults.

Introduction

Worldwide, the number of people over 60 is growing faster than any other age groups (WHO, 2007). Aging is generally associated with, neuromuscular impairment and gait and balance disorders, loss of mobility and an increased rate of falls and fractures (Muhlberg & Sieber, 2004).

Unintentional injuries are the fifth leading cause of death in older adults (American Geriatrics Society and British Geriatrics Society, 2011). Approximately 20% of accidental falls require medical attention and 5% lead to a fracture or other serious injuries (Kannus et al., 2005). From a social point of view, falling generates psychological problems such as fear of falling, depression, and apprehension about physical activity (American Geriatrics Society & British Geriatrics Society, 2011; World Health Organization, 2007). Some of its negative results include functional deterioration and loss of confidence (American Geriatrics Society and British Geriatrics Society, 2011). All this generates health costs that can be preventable (Kumar et al., 2014) with appropriate interventions and can help attenuate the negative impacts of falls in older adult people at risk (Gillespie et al., 2012).

There are several risk factors for falls, which can be classified as either extrinsic or intrinsic. Three of the most common intrinsic risk factors for falls are muscle weakness, balance deficit, and gait instability (American Geriatrics Society and British Geriatrics Society, 2011; Granachet et al., 2011). In recent years, numerous randomized controlled trials on risk factors for falls have been published (Blank et al., Gillespie et al., 2012; Tinetti, & Kumar, 2010). Several studies have revealed a relationship between low speed and its relationship with falls in the older adult (Chang, Chen, & Chou; 2016, Viccaro, Perera, & Studenski; 2011). It has been show that some exercise programs, when properly structured, planned, and repeated, can modify these intrinsic risk factors (Nemoto et al., 2007).

One of the main barriers to the habitual practice of physical exercise in adults is "the lack of time" (Stutts, 2002). With this in mind, high-intensity interval training (HIIT) was developed with low-volume exercises. Furthermore, HIIT has been described to be perceived as a more satisfactory activity than continuous exercise of moderate intensity (Bartlett et al., 2011). Safety in a HIIT program is of paramount importance, especially in at-risk populations, but several studies have shown that HIIT training is safe and well tolerated by healthy participants in different populations (Kessler, Sisson, & Short, 2012) as well as by patients with some clinical conditions such as heart disease (Rognmo et al., 2012). García-Pinillos et al. (2017) studied the effects of HIIT on physical performance in healthy older adults, but to the best of our knowledge there are no studies focused on fall risk factors such as the fear of falling, dynamic balance or gait speed in this population.

We hypothesized that a twelve-week high-intensity interval training program (HIIT) with a suspension training system (TRX) would provide several benefits over a moderate intensity interval training (MIIT) and over the results of a group that does not perform any type of exercise. Among such benefits we included a decrease in the risk of falls and improvements in fear of falling, dynamic balance, and gait speed for people 60 and older. The main objective of this randomized controlled trial was to analyze the effects of a HIIT vs. MIIT, both using TRX, on fall risk factors such as balance confidence, fear of falling, dynamic balance and gait in healthy older people.

Material and Method

Experimental approach to the problem

The present study analyzed the effects of a TRX-based HIIT and MIIT programs on balance confidence, fear of falling, dynamic balance and gait in healthy older people. In order to achieve these objectives 73 older adults (68.49 ± 5.18 years, 76.7% women) were assessed.

Study design and participants

This is a randomized controlled clinical trial (RCT) which is part of a research project that analyzed the effects of two different TRX training programs (HIIT and MIIT) on different physical and psychological health indicators in community-dwelling older adults, registered at [clinicaltrials.gov](https://clinicaltrials.gov/ct2/show/NCT03404830) a NCT03404830 (<https://clinicaltrials.gov/ct2/show/NCT03404830>), so there may be some overlap with respect to participants and general methodology.

The recruitment of participants was carried out through the sports service of the Town Hall of “xxxxxx (xxxxxx, xxxxx)” and using its municipal records, local media and social networks. From a total of 90 persons who were initially contacted and screened, 82 met the eligibility criteria and accepted to be enrolled. Participants included in the study were randomly assigned to a high-intensity interval training group (HIIT group), to a moderate intensity interval training (MIIT group), or to a control group in a 1:1:1 ratio using a computer-generated table of numbers. Assignments were kept at a locked location in a sealed, opaque envelope, to be later opened by an independent part not involved in subject selection, evaluation of results, or treatment. A total of 28 people were assigned to the HIIT group, 27 to the MIIT group, and 27 to the control group. These numbers were later reduced to 26 for the HIIT group, 24 for the MIIT group, and 23 for the control group for various reasons, showed in figure 1. In order to participate in the study, participants were required to be over 60 years old and able to understand the instructions, programs, and protocols of this project. An informed written consent was obtained from each participant before enrollment. Exclusion criteria were any condition (i.e. cardiovascular or neuromuscular disease) that contraindicated the exercise program performance, diseases that could alter balance and functional activity (such as auditory or vestibular alterations), central or peripheral neurological disorders, serious psychiatric or somatic diseases or were already included in other training program. Before the beginning of the study, all participants signed an informed consent form after a detailed description of the

that measures the level of concern about falling during social and physical activities inside and outside the home, regardless of whether or not the person actually performs the activity. The Spanish version of the FES-I has been validated in the postmenopausal population (Lomas-Vega et al., 2012). A higher score in the FES-I correlates with a greater FoF.

Dynamic balance

The Timed Up and Go Test (TUG) is a simple, valid, and reliable method to assess functional mobility and dynamic balance, and it has already been used in older adult women (Pisciottano et al., 2014). It is based on every day activities and requires standing from a chair, walking three meters, turning around, and sitting down again (Podsiadlo & Richardson, 1991). The time required by the subject to complete this task is recorded. This has been reported to be a useful tool for identifying community-dwelling adults who are at risk for falls (Okumiya et al., 1998).

Gait analysis

The OptoGait gait analysis system (Microgate Italy, Bolzano-Bozen, Italy), a device consisting of an opto-electrical detection system, was employed for gait analysis. The transmitter bar has 96 light-emitting diodes (LEDs) that communicate in the infrared spectrum. The receiver bar, which is positioned opposite it, has the same number of LEDs. The transmitter and receiver bars of the OptoGait were installed on both sides of a treadmill. Using a data capture rate of 1,000 transmissions/receptions per second, activities such as running, jumping, or the time spent on the ground or in the air can be accurately measured. From these basic data, the software analyzes the data measured in real time in a series of movements. The data collected by the OptoGait uses the differences in gait variables between the left and right legs: the smaller the difference, the greater the stability and balancing ability.

The OptoGait bars were assembled on both sides of a treadmill. The width of the step is the distance between two successive steps (between two X's). To assess the gait analysis, the "Treadmill Walking 3 mph or 5 km/h" test was used, which involves walking for 30 seconds on the walking belt, while gait parameters were collected by the photocell system at a constant speed of 3.5 km/h both in the walking belt and in the computer system. Two familiarization and five experimental trials with a rest interval of 1 minute between trials were performed. Gait parameters were: Step length (cm): distance between the first contact of one foot and the first contact of the opposite. Double support (s): period of time when both feet touch the ground. Step time (s): time between the first contact of one foot and the first contact of the opposite foot. Stride length (cm): distance between the tip of two subsequent footprints of the same foot or the distance between the heels of two subsequent footprints of the same foot. Gait speed (m/s) and distance (cm) covered during the test.

Training programs

Participants assigned to the MIIT and HIIT groups performed lower-body exercises with a TRX, for four weeks (twice a week) before the beginning of the intervention, to become familiar with this type of training. Participants in the control group attended two 90-minute health education classes focused on health promotion during the study period. The instructors provided participants with information regarding exercise and healthy diets, although no specific information or recommendations regarding cognitive health were given. The research staff made additional contact with participants during the study period via telephone to promote adherence to the education programme and retention of information.

Subjects allocated to both HIIT and MIIT groups received two sessions per week of TRX for twelve weeks. In the HIIT group, each session was divided into three periods: warm-up (10 minutes), main squat activity with the system in suspension divided into four four-

minute intervals at an intensity of 90-95% of the maximum heart rate (HR), followed by active rest intervals of three minutes at 50-70% of the maximum HR (25 minutes), and a cool-down period (10 minutes). Maximum HR was calculated according to Ellingsen et al., (2017). In the MIIT group, the same protocol as the HIIT group was followed, but with lower intensities: 70% of the maximum HR for the main squat activity with TRX, and 50-55% of the maximum HR for the active rest intervals. The training intensity was individually controlled by an HR monitor (V800, Polar Electro, Kempele, Finland). The intensity was individually tailored to HR at moderate or vigorous efforts, ensuring that their HR was kept in the range determined according to each participant's age and their assigned group. The training sessions were directed by a well-trained sports instructor. As a participant resource, and to ensure the consistency of the training, a videotape with the correct executions of the exercises was provided, and instructors were supervised by physical therapists who supported each class. The sessions were held at the same time (10:00-11:00 a.m.) and with a 24h-rest between sessions, on Tuesday and Thursday (HIIT) and Monday and Wednesday (MIIT). Participants were excluded if more than five sessions were lost during the twelve-week intervention. During the intervention, injuries or other effects reported by the participants were collected.

Statistical analyses

Data were analyzed using SPSS v.21.0 for Windows (SPSS Inc., Chicago, USA) and the level of statistical significance stood at $p < .05$. Descriptive statistics are shown as means and standard deviations. The chi-squared test was used to compare sociodemographic variables between groups. The analysis of variance of a single factor was used to verify the non-existence of statistically significant differences in the pre-intervention measures. Likewise, a 3x2 mixed covariance analysis was used, considering as intergroup variable the type of intervention received (group to which the participant was assigned) and as the intrasubject variable the

measurement time (pre- and post-intervention) for each of the dependent variables (ABC, FES-I, TUG, and gait speed). The covariate considered was the BMI of the participants. The analysis of possible interactions was carried out by analysis of variance and *t* tests for repeated measures. Finally, the magnitudes (effect size) of the differences between values were interpreted using Cohen's *d* statistic (Cohen, 1988). An effect size <0.2 reflects a negligible difference, ≥ 0.2 but ≤ 0.5 a small difference, ≥ 0.5 but ≤ 0.8 a moderate difference, and ≥ 0.8 a large difference.

Results

Participants showed high adherence to the exercise training programs, completing at least 83 % of the sessions. No injuries or adverse effects were observed during the intervention.

Baseline measures

There were no differences between groups in the distribution of men and women, $\chi^2(2) = 5.70$, $p = .06$, as well as in the participants' reports of having suffered a fall in the last twelve months, $\chi^2(2) = 4.59$, $p > .05$, depending on the condition to which the participant was assigned. In the examination of anthropometric measurements, statistically significant differences were observed in the variable body mass index, $F(2, 70) = 4.58$, $p = .01$. This last factor was used as a covariate in subsequent analyses. No statistically significant differences were observed in any of the dependent variables examined in the baseline or pre-intervention measurements, depending on the group to which the participant was assigned. More information about participants is shown in Table 1.

Changes from baseline

Balance confidence and fear of falling

A 3x2 ANOVA was performed using as a dependent variable the score obtained in the post-treatment ABC test. This revealed a main effect of the intervention group variable, $F(2,$

69) = 7.13, $p = .002$, $\eta^2 = .17$, as well as a statistically significant interaction of group x measurement time, $F(2, 69) = 4.45$, $p = .04$, $\eta^2 = .10$. The measurement time variable, $F(1, 69) = .22$, $p > .05$, was not statistically significant. The detailed analysis of the interaction showed the existence of statistically significant differences between both measurement times for the control group, $t(22) = 3.18$, $p = .004$, $d = .63$. Likewise, statistically significant differences were found in the post-treatment measures between the control group and the MIIT groups, $t(45) = 2.16$, $p = .04$, $d = .63$ and HIIT, $t(47) = 3.98$, $p < .001$, $d = 1.12$, respectively.

When the dependent variable was the post-intervention score obtained in the FES test, the ANOVA showed the existence of a main effect of the intervention group variable, $F(2, 69) = 6.68$, $p = .002$, $\eta^2 = .16$, as well as a statistically significant interaction of group x measurement time, $F(2, 69) = 8.62$, $p < .01$, $\eta^2 = .20$, statistically significant. The measurement time variable, $F(1, 69) = .19$, $p > .05$, was not statistically significant. The analysis of the interaction revealed the existence of statistically significant differences between both measurement times in the HIIT group, $t(25) = 3.95$, $p = .001$, $d = 1.06$. Likewise, statistically significant differences were found in the post-treatment measures between the HIIT group and the two remaining groups, $t(48) = -3.30$, $p = .002$, $d = .92$, for MIIT and $t(47) = -4.58$, $p < .001$, $d = 1.27$, in relation to the control group. Figure 2 shows more information about fear or falling.

Dynamic balance

Figure 3 shows significant changes in the Timed Up and Go Test (Tug Test). The analysis conducted for the variable time spent in the Timed Up-and-Go test showed the existence of a main effect of the intervention group variable, $F(2, 69) = 4.32$, $p = .017$, $\eta^2 = .11$, as well as a statistically significant interaction of group x measurement time, $F(2, 69) = 3.75$, $p = .028$, $\eta^2 = .10$. The measurement time variable, $F(1, 69) = 3.90$, $p = .052$, was not statistically significant. The detailed analysis of the interaction revealed the existence of

Discussion

The aim of the present study was to analyze the effects of a HIIT vs. MIIT, both using TRX, on some important fall risk factors. Our analysis showed that balance confidence significant improved in both HIIT and MIIT programs, whereas compared with the other two groups, HIIT had better results in the fear of falling, gait analysis and dynamic balance.

To the date, very few studies with suspension training have been performed in older adults, aiming at body composition or muscle strength (Gaedtke & Morat, 2015; Campa, Silva & Toselli, 2018). Nevertheless, there is extensive clinical trial literature concerning fall risk prediction regarding several types on intervention. An example is the study by Ullman et al. (2010), in which they developed a five-week intervention of balance and mobility in older adults which showed significant improvements in predicting the risk of falls with the ABC questionnaire (Ullman et al., 2010). Similarly, compared with control group, in the present study significant improvements were observed in balance confidence assessed by the ABC total score in MIIT ($d = 0.63$) and especially in HIIT ($d = 1.12$) groups. Other studies conducted in older adults with different interventions such as Pilates (Cruz-Diaz et al., 2015) and tai chi (Mortavazi et al., 2018), showed significant improvements in the risk of falls as measured through the FES-I questionnaire, with data similar to the ours, where HIIT participants had significant improvements in the fear of falling compared to MIIT ($d = 0.92$) and control ($d = 1.27$) groups.

Concerning dynamic balance, it has been argued that numerous training sessions in a larger population reduce the execution time in the TUG test, with this being one of the greatest functional predictors for risk of falling (Kojima et al., 2015). Studies from Onambélé-Pearson et al. (2010) that most resembles our research is the one carried out by who compared high and low intensity continuous lower-body strength-training program, obtaining similar improvements in the execution of the TUG test. We could find large improvements ($d = 1.67$)

in dynamic balance after HIIT, similar to previous studies that have employed high intensity training (Globas et al., 2012) or HIIT (Garcia-Pinillos et al., 2017) in chronic stroke survivors and healthy older people respectively.

Cruz-Jentoft et al. (2010), also observed that the adult population suffered a decrease in muscle mass, which is associated with low levels of muscle strength and poor physical performance, measured using gait speed (< 80 cm/s) and the TUG test. In our study, gait analysis was performed through a photoelectric cells system and participants who performed HIIT showed improvements regarding distance and total double support but not in gait speed. At this respect, Globas et al. (2012) found improvements in gait velocity after high intensity aerobic exercise in chronic stroke survivors with residual hemiparetic gait, and Kim et al. (Kim et al., 2017) is similar population yielded similar results to those of our study regarding the double support variable, which was significantly reduced in the post-training data of both studies.

Since the first studies were published, HIIT has been repeatedly shown as a strong predictor of functional performance (Knowles et al., 2015; Nemoto et al., 2007) in the older adult population. As a result, the most commonly used treatments for the older adult in the last three years have focused on training with cycloergometers, with differences concerning only the details of the work protocols (Bell et al., 2015; Bruseghini et al., 2015; Jabbour et al., 2017; Knowles et al., 2015; Maillard et al., 2016; Mandrup et al., 2017; Mejías-Peña et al., 2016). In contrast, our study contributes an innovative approach, with a pioneering use of HIIT training based on the load proposed by Ellingsen et al. (2017), which suggested four blocks of four minutes (90-95% max. HR), but with TRX for older adults such as the one described by Gaedtke & Morat (2015).

Improvements in fear of falling, dynamic balance, and gait provide a precise picture of the changes induced by the type of training conducted in this research. Our findings also

support the different effects between HIIT and MIIT training types. We could observe that after the intervention period, HIIT participants showed a significant improvement compared with MIIT in the fear of falling ($d = 0.92$), as well as in the TUG test time ($d = 1.41$), with the mean post-intervention HIIT in our research being $6.82 \text{ s} \pm 0.87$, unlike the results described by Onambelé, Breen & Stewart, (2010) which showed a post-intervention mean of $10.82 \text{ s} \pm 0.82$.

In conclusion, the results of the present study showed that both interval training programs (HIIT and MIIT) have beneficial effects on several fall risk factors. More precisely, and compared with control group, both HIIT AND MIIT programs improved balance confidence, while HIIT participants obtained significantly better results than those of the other groups regarding the fear of falling, gait analysis and dynamic balance.

Conflict of Interest

The authors declare no conflicts of interest.

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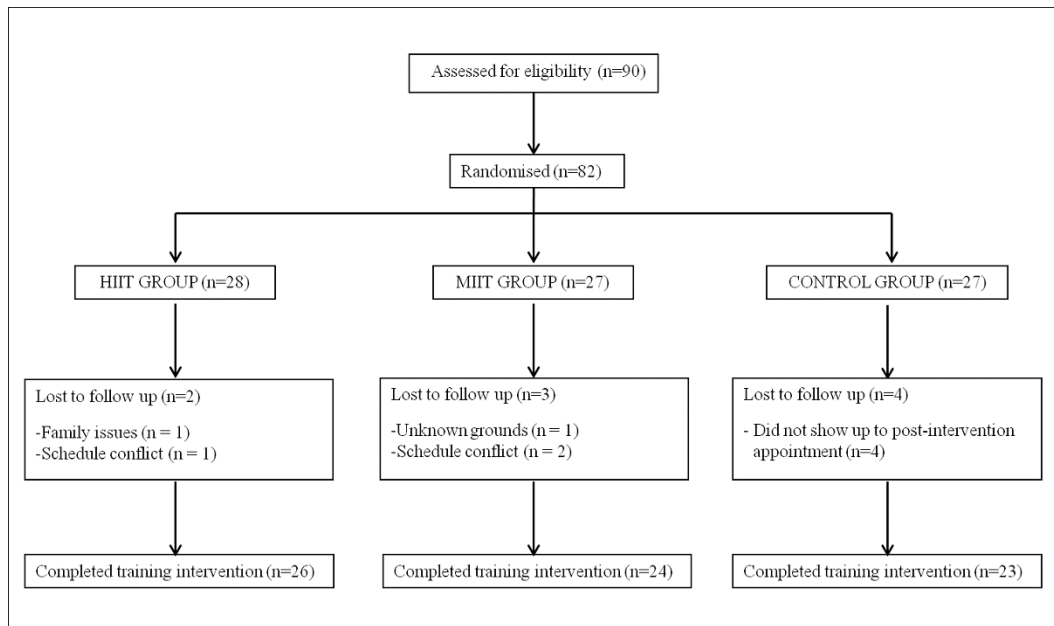


Figure 1: Flow chart of the study participants.

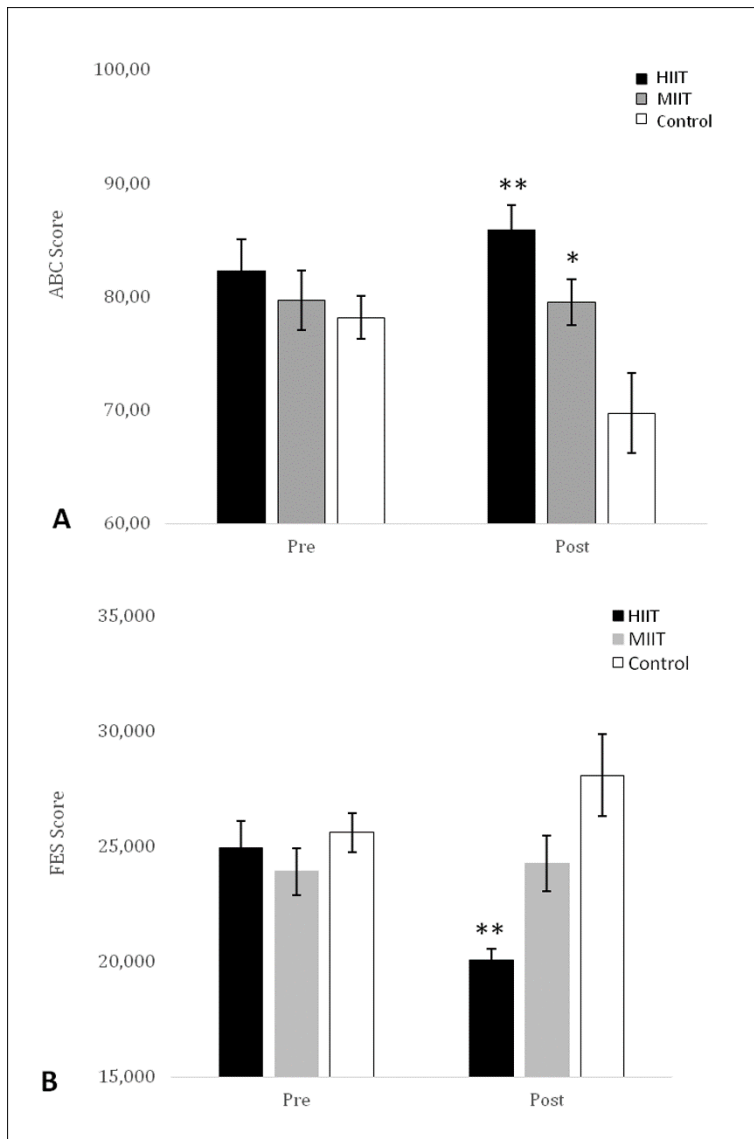


Figure 2: Pre- and post-intervention changes in balance confidence and the fear of falling. ABC = Activities-Specific Balance Scale; FES-I = Falls Efficacy Scale International; HIIT = High Intensity Interval Training; MIIT = Moderate Intensity Interval Training. (A): * $p = 0.04$. ** $p < 0.001$. (B): ** $p = 0.001$.

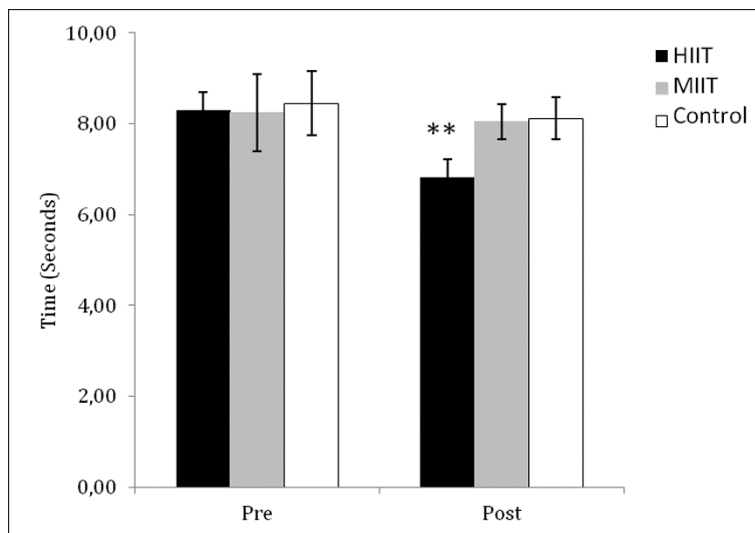


Figure 3: Pre- and post-intervention changes in dynamic balance assessed by the TUG Test. TUG Test = Timed Up and Go Test; HIIT = High Intensity Interval Training; MIIT = Moderate Intensity Interval Training. ** $p = 0.001$.

Table 1: Subject characteristics.

	Total (n = 73)	HIIT (n = 26)	MIIT (n = 24)	Control (n = 23)	<i>F</i> (2,70)	<i>p</i>
Age	68,49 (5,18)	68,23(2,97)	68,75(5,98)	68,52(6,33)	.06	> .05
Weight (kg)	76,51(12.15)	73,75(14,20)	76,48(12,09)	79,65(9.03)	1.46	> .05
Height (cm)	157,00(7,89)	155,65(7,60)	159,13(8,12)	156,3(7,85)	1.35	> .05
BMI	30,59(3,25)	29,48(3,69)	30,33(3,07)	32,13(2,30)	4.58	.01
Falls	0,56(0,87)	0,46(0,99)	0,46(0,72)	0,78(0,78)	1.10	> .05
PA time	1,70(0,54)	1,73(0,45)	1,75(0,53)	1,61(0,66)	.46	> .05
Gender (n, %)					$\chi^2(2)$	
Female	56 (76.7%)	24 (92.3%)	17 (70.8%)	15 (65.2%)	5.70	> .05
Male	17 (23.3%)	2 (7.7%)	7 (29.2%)	8 (34.8%)		

HIIT = High Intensity Interval Training Group; MIIT = Moderate Intensity Interval Training Group; BMI = Body Mass Index; PA time = physical activity time. Values are expressed as mean (standard deviation) and n (%).

