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Evaluating Human Balance Following an Exercise Intervention in Previously Sedentary, Overweight Adults

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Abstract: Previous research suggests that an improvement in body composition could potentially lead to improvement in balance performance in previously overweight individuals. The purpose of this study was to evaluate if an exercise intervention without any specific balance training can lead to an improvement in standing balance. Fourteen overweight, but otherwise healthy adults (nine females, six males) (mean age: 23.5 years; mean height: 1.70 m, mean starting body mass: 94.1 kg) participated in this study. Balance performance was assessed with sensory organization test (SOT) and motor control test (MCT) on the NeuroCom[®] Equitest[™], prior to and after a 10-week exercise intervention. Results revealed significant improvements in the following balance parameters following exercise intervention: eyes open, sway-referenced visual surrounding and platform condition ($p = 0.033$) for SOT equilibrium scores; SOT center of pressure (COP) sway in the eyes closed condition for anterior-posterior sway velocity ($p = 0.006$) and in the eyes open sway-referenced condition ($p = 0.048$). The results of the current study suggest that improved balance performance can result from an exercise intervention without any specific balance directed exercises, but that the results may be limited to the conditions where the somatosensory system plays a larger role in balance maintenance.

Keywords: obesity; exercise training; functional health; motion analysis

1. Introduction

In addition to the structural and injury issues that may be related to wear and tear on the joints or other anatomical structures as a result of excess weight, there is potentially increased risk of experiencing a fall. Obese and overweight individuals often experience daily postural perturbations to a greater degree than normal weight individuals due to balance issues that could be experienced from the potential of a higher weight distribution which could elevate the center of mass (COM) [1]. Experiencing an increased number or degree of perturbations as a result of increased weight and a higher COM could potentially lead to declines in overall balance leading to falls [1,2]. Hue et al. [3] and Hita-Contreras et al. [4] reported that an increased body weight is strongly correlated to declines in balance. A decline in balance could lead to decreased overall confidence in stability which may

then result in a person being less likely to choose to be physically active or challenge their body to exercise [5]. As weight is gained or remains high, the poor balance ability of an obese person may actually exacerbate the problem of a sedentary lifestyle [5]. Potentially, weight loss could lead to improvements in these factors which could lead to not only gained confidence in the activity but also promotion of increases in activity [6].

There are a number of studies that have evaluated balance differences and similarities between normal weight and overweight individuals. Hue et al. [3] reported that when evaluating standing balance, a regression analysis showed that 52–54% of the variance in postural stability can be accounted for by body mass. This research suggested that as body weight increases, postural stability and overall balance declines [3]. Similar results and suggestions have been reported elsewhere [7–9]. McGraw et al. [5] conducted an assessment of differences in balance for obese and non-obese boys and determined that center of pressure (COP) displacement in response to perturbations was greater for the obese boys. McGraw et al. [5] reported that balance instability was much larger in the sagittal plane rather than the frontal plane and concluded that differences in postural stability were more related to body weight than some other underlying postural instability related to vestibular or visual issues.

Menegoni et al. [10] reported finding statistically significant differences in COP sway in both the medial-lateral and anterior-posterior directions in obese men compared to non-obese men, while obese women only experienced significantly different sway in the anterior-posterior direction compared to non-obese women. Amount of sway was reported to be moderately correlated with overall body weight [10]. Any movement of the COM away from the ideal alignment could place additional stress on the joints (in particular the ankles) and cause postural alterations before any perturbation actually occurs [1,11]. Matrangola and Madigan [12] expressed agreement with this theorized response, but in contrast also suggested that the increased inertia that is experienced by a heavier weight may provide an obese individual with an increased ability to resist perturbations that were not of a sufficient velocity to cause a loss of balance. This would support previously published findings by Błaszczyk, Cieślinska-Świder, Plewa, Zahorska-Markiewicz, and Markiewicz [13].

There have been a number of published studies that have suggested that a loss in excess body weight could potentially lead to a substantial improvement in overall balance in previously obese and overweight individuals [2,5,14,15]. Despite these suggestions by those comparing obese versus non-obese individuals, very few studies have actually compared balance of a person before and after weight loss. Maffiuletti et al. [15] had their obese individuals participate in a 3-week body weight reduction program that involved an intervention consisting of caloric restriction, moderate physical activity, and nutritional/psychological counseling. In addition, a comparison was made between those that participated in six sessions of balance training versus those that did not [15]. Results showed that both obese groups improved balance as they lost weight following the three-week intervention, and that the group including balance training improved their time of balance maintenance and reduced their trunk sway to a greater degree than the body weight reduction intervention alone [15]. To date, this is the only study that has evaluated standing balance before and after weight loss which has employed any type of exercise to elicit the weight loss. However, the 3-week intervention period is considered a very short-term weight loss intervention and it will be important in future studies to evaluate if a longer term and greater degree of weight loss can lead to even greater improvements in balance.

Two particular studies by Teasdale et al. [16] and Handrigan et al. [14] have evaluated balance ability before and after weight loss resulting from bariatric surgery. Teasdale et al. [16] reported that following a caloric restriction intervention in obese men and weight loss surgery in morbidly obese men that substantial weight loss (average of about 12.3 kg for obese and 71.3 kg for morbidly obese) led to significant improvements in balance parameters. Teasdale et al. [16] also reported that the extent of weight loss was significantly correlated ($r = 0.806$) with the magnitude of improvement in balance. Both of these studies [14,16] concluded that amount of weight loss, not necessarily improvements

in relative strength, was the primary contributor to improvements in balance for overweight and obese adults.

The findings of the three-week intervention of the Maffiuletti et al. [15] study should be improved upon to closely resemble a typical exercise prescription for weight loss. Del Porto et al. [6] reported that there currently does not exist a consensus opinion on the best exercise intervention technique for balance improvement. While traditionally it can be expected that an improvement in the ability to produce muscular force can lead to improvements in the ability to maintain balance, very little information has been gathered on the potential relationship between improvements in body composition and aerobic fitness as they relate to improvements in balance. Therefore, it is possible that if participants experience any improvement in body composition along with improvements in muscular fitness, that this may allow them to perform better in a balance evaluation. The purpose of this study was to evaluate if an exercise intervention centered on aerobic exercise can lead to a substantial improvement in body composition and therefore improvement in standing balance.

2. Materials and Methods

2.1. Participants

The research was approved by the Institutional Review Board committee at the University of Mississippi (Protocol #14-035, approved on 02/05/2014) for the use of human subjects and informed consent was obtained from each participant prior to participation. The desired participant population was sedentary and overweight, but otherwise healthy adults between the ages of 18–44 years (males) and 18–54 years (females). An *a priori* analysis was conducted using G*Power 3.1.7 (University of Düsseldorf; Düsseldorf, Germany) to estimate necessary sample size using RM-ANOVA within-between interaction. Of the 21 participants initially enrolled in the study, six did not finish the intervention and/or complete the post-testing evaluations and were therefore not included in any statistical analysis. The drop-out rates and reasons for each individual drop out are explained elsewhere [17]. The total sample size analyzed was 15 participants (nine females, six males). The Physical Activity Readiness Questionnaire (PAR-Q) [18] was employed during the screening process in order to evaluate for any potential contraindications to exercise. In order to determine physical activity status, participants completed a 7-day physical activity questionnaire [19]. Each participant's body composition was evaluated using dual energy X-ray absorptiometry (DXA) as measured by a Hologic Delphi, QDR series (Bedford, MA, USA) apparatus, and height and body mass were measured by standard scales upon arrival. Body fat percentage ranges for consideration in the study followed previously published recommendations with regards to gender and age [20]. Males were included in the study if their body fat percentage was greater than 22% and females were included in the study if their body fat percentage was greater than 32% [20].

2.2. Measures and Data Analysis

For balance evaluation, the participant reported to the Applied Biomechanics Laboratory for balance assessments using the NeuroCom[®] Equitest[™] (NeuroCom International, Inc., Clackamas, OR, USA). Participants were instructed to stand as still as possible for balance assessment using a Sensory Organization Test (SOT) as well as a Motor Control Test (MCT). The SOT was performed to evaluate standing balance scores and included the following balance test conditions: (1) eyes open (EO); (2) eyes closed (EC); (3) eyes open sway-referenced vision (EOSRV); and (4) eyes open sway-referenced platform (EOSRP); (5) eyes closed sway-referenced platform (ECSRP); and (6) eyes open sway-referenced vision and platform (EOSRVP). The SOT, as proposed by Nashner [21], uses the sway-referencing capabilities of the visual surrounding structure and the platform to assess the ability of the sensory systems in balance maintenance by selectively disturbing somatosensory and/or visual information. The MCT was performed to evaluate dynamic balance by employing an 18" × 18" dynamic dual force plate, which can create translations in the plate in two different directions both forward and backward.

This then allows the creation of two testing conditions within the two different directions: backward translations (small, (BWS), medium (BWM), large (BWL)) and forward translations (small (FWS), medium (FWM), large (FWL)), for four total testing conditions. A detailed description of each of these balance tests is explained in other locations [21,22]. Each participant completed a familiarization trial of each test prior to any collection of balance data. Following the end of these two tests, the participant was permitted to leave.

COP excursions derived from the Neurocom Equitest were used to calculate sway parameters of average sway velocity (VEL) and postural sway root mean square (RMS) in both medial-lateral and anterior-posterior directions (medial-lateral sway velocity (MLVEL), anterior-posterior sway velocity (APVEL), medial-lateral sway RMS (MLRMS), and anterior-posterior sway RMS (APRMS)) using the Equations (1) and (2) [23–25]. Higher values of sway parameters represent a greater postural sway during the balance tests and indicate decreased balance and postural stability. Equilibrium score (EQ) is an overall representation of the postural stability during the SOT, where higher EQ scores represent less sway and better postural stability. Postural reaction time latencies from the MCT (in milliseconds (ms)) are a measure of the speed of active responses from an individual following a forward or backward perturbation. Lower latencies represent faster reaction times and suggest faster and better balance recovery following external perturbations.

$$\text{SWAY VEL} = \left(\frac{1}{t} \right) \sum_{i=0}^n |\text{COP}_i - \text{COP}_{i-1}| \quad (1)$$

$$\text{SWAY RMS} = \sqrt{\frac{1}{n} \sum_{i=0}^n (\text{COP}_i - \text{COP}_{avg})^2} \quad (2)$$

2.3. Procedures

Indirect calorimetry was used to measure oxygen consumption during treadmill exercise using the ParvoMedics TrueOne 2400 measurement system (ParvoMedics, Sandy, UT, USA). Each participant completed a submaximal treadmill protocol to estimate VO_2 max by employing a modified Balke protocol [20]. Treadmill exercise persisted until the participant's heart rate (HR) reached 60% of heart rate reserve (HRR). Independent regression equations were employed to evaluate the VO_2 -HR association and VO_2 max was projected at the extrapolated HR_{max} .

Participants were prescribed a walking/running for exercise program aimed at producing a weight loss of at least 5% of pre-intervention body mass. The program lasted for 10 weeks which exceeded the recommendations by Bravata et al. [26] for exercise programs employing exercise which was to be self-reported by the participant. All participants were given a weekly amount of walking or running exercise energy expenditure (EE) to complete and were requested to correspond through the use of an online survey (Qualtrics, Provo, UT, USA) to provide their weekly self-reported exercise that had been completed that week. The exercise intervention consisted of an aerobic exercise prescription centered on walking/running exercise that was meant to be accumulated over the week in which it was prescribed. The level of exercise that was prescribed each week was based on current recommendations based on a joint position statement from the American College of Sports Medicine (ACSM) and American Heart Association [20]. The amount of walking exercise that was prescribed initially was low enough for the participants to reasonably handle the increase in activity given that they were all previously sedentary. The weekly increase in exercise was equal to a 10% increase in estimated EE per week, following previously published ACSM guidelines [20]. A detailed description of this intervention is explained elsewhere [17].

2.4. Statistical Analysis

The body composition and physical characteristics data, sway parameters, latencies, and all other balance parameters were analyzed using a repeated-measures analysis of variance (RM-ANOVA)

independently for each of the SOT and MCT tests, and potential relationships with changes in body mass were evaluated by employing a Pearson correlation. Post hoc pairwise comparisons using a Sidak correction was performed if main effect significance was found for footwear types. Partial eta-squared (η^2) effect size and F-statistic values are reported. For all analyses, significance was set at an alpha level of $p < 0.05$ and all statistical analyses were performed using the SPSS 21 statistical software package (IBM SPSS® Statistics V21.0, Armonk, NY, USA).

3. Results

3.1. Physical Characteristics of Participants

There were no significant differences ($p > 0.05$) in physical characteristics of the total study sample at baseline or following exercise intervention (age, height, body mass, fat-mass (FM), fat-free mass (FFM), abdominal fat mass (AFM)). The mean age of the participants (in years) was 23.5 ± 4.9 years and the mean height of the participants was 1.7 ± 0.1 m. The mean pre-intervention body mass index (BMI) of the participants was 32.2 ± 5.0 kg/m². The pre- and post-intervention data for the following variables is presented in Table 1: body mass, FFM, FM, AFM, and aerobic capacity (VO₂ max). On average, the sample lost approximately 1.0 ± 4.6 kg of body mass. None of the body mass characteristics of the sample exhibited a significant change from baseline ((body mass, $p = 0.452$), (FFM, $p = 0.877$), (FM, $p = 0.619$), (AFM, $p = 0.474$), (VO₂ max, $p = 0.163$)).

Table 1. Physical Characteristics.

Physical Characteristics		Mean	SD	Min	Max
Body Mass (kg)	Pre	94.1	20.1	61.2	126.9
	Post	93.1	20.7	59.82	122.9
FFM (kg)	Pre	59.6	13.3	38.7	82.1
	Post	59.8	14.3	38.9	81.8
FM (kg)	Pre	33.6	9.0	21.8	51.0
	Post	33.3	9.1	20.9	49.0
AFM (kg)	Pre	11.9	5.0	6.3	22.7
	Post	11.6	4.1	5.7	18.4
VO ₂ max (mL/kg/min)	Pre	34.5	5.8	25.0	43.0
	Post	37.4	7.8	26.3	57.1

3.2. Balance Evaluations

The repeated-measures analysis of variance (RM-ANOVA) revealed a significant main effect difference between pre- and post-intervention for balance sway parameters and balance EQ scores but not for motor control test (MCT) latency scores. Sensory organization test (SOT) EQ scores and MCT latency scores are summarized in Table 2. The results from the SOT EQ scores revealed a significant main effect for intervention in the eyes open sway-referenced vision and platform (EOSRV) condition ($F(1,14) = 5.577, p = 0.033, \eta^2 = 0.285$). Post hoc pairwise comparisons revealed significantly higher EQ scores post-intervention, suggesting improved balance performance. Results for the SOT COP sway parameters revealed significant differences in the EC condition for anterior-posterior sway velocity (APVEL) ($F(1,14) = 10.270, p = 0.006, \eta^2 = 0.423$) and in the eyes open sway-referenced vision (EOSRV) condition for APVEL ($F(1,14) = 4.672, p = 0.048, \eta^2 = 0.250$). Post hoc pairwise comparisons for both of these variables revealed a significantly reduced postural sway in post-intervention evaluation, also suggesting improved balance performance in the post-intervention testing. This data is summarized in Table 3. No other significant differences were exhibited in any of the other balance testing conditions. However, the results herein tend to suggest a trend towards improved balance performance following the completion of the intervention.

Table 2. SOT EQ Scores and MCT Latencies.

EQ Scores	Pre-Intervention	Post-Intervention	Latencies	Pre-Intervention	Post-Intervention
SOT Conditions	Mean ± SD	Mean ± SD	MCT Conditions	Mean ± SD	Mean ± SD
EO	93.6 ± 1.6	92.9 ± 2.6	BWS (ms)	136.7 ± 10.3	134.3 ± 8.6
EC	92.0 ± 2.2	92.0 ± 2.0	BWM (ms)	126.7 ± 12.2	126.3 ± 10.1
EOSRV	92.0 ± 2.4	92.7 ± 2.2	BWL (ms)	120.7 ± 11.0	120.3 ± 12.5
EOSRP	83.0 ± 9.4	81.6 ± 13.7	FWS (ms)	150.7 ± 18.0	149.3 ± 17.3
ECSRP	68.1 ± 10.2	69.9 ± 7.1	FWM (ms)	131.0 ± 14.4	131.3 ± 13.4
EOSRVP	69.8 ± 11.1	72.8 ± 10.0 *	FWL (ms)	125.7 ± 13.7	126.0 ± 11.8
Composite	80.2 ± 6.3	81.1 ± 6.7	Composite (ms)	128.5 ± 9.6	127.7 ± 11.5

Sensory organization test (SOT) Equilibrium (EQ) scores and motor control test (MCT) latencies (ms). SOT conditions include eyes open (EO), eyes closed (EC), eyes open sway-referenced vision (EOSRV), eyes open sway-referenced platform (EOSRP), eyes closed sway-referenced platform (ECSRP) eyes open sway-referenced vision and platform (EOSRVP). MCT conditions include backward small (BWS), medium (BWM), large (BWL) translations and forward small (FWS), medium (FWM), large (FWL) translations. * represents significant post-intervention effect at $p < 0.05$.

Table 3. SOT COP Postural Sway Variables.

SOT Conditions	Pre-Intervention	Post-Intervention	SOT Conditions	Pre-Intervention	Post-Intervention
	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD
EO			EOSRP		
MLVEL (cm/s)	0.74 ± 0.1	0.75 ± 0.1	MLVEL (cm/s)	0.93 ± 0.2	0.91 ± 0.2
APVEL (cm/s)	1.03 ± 0.2	1.06 ± 0.3	APVEL (cm/s)	1.86 ± 0.7	1.64 ± 0.5
MLRMS (cm)	0.15 ± 0.1	0.18 ± 0.1	MLRMS (cm)	0.23 ± 0.1	0.26 ± 0.2
APRMS (cm)	0.32 ± 0.1	0.34 ± 0.1	APRMS (cm)	0.98 ± 0.7	1.11 ± 1.1
EC			ECSRP		
MLVEL (cm/s)	0.82 ± 0.2	0.81 ± 0.2	MLVEL (cm/s)	1.28 ± 0.3	1.24 ± 0.3
APVEL (cm/s)	1.36 ± 0.4	1.23 ± 0.40 *	APVEL (cm/s)	3.40 ± 0.8	3.16 ± 0.7
MLRMS (cm)	0.19 ± 0.1	0.18 ± 0.09	MLRMS (cm)	0.38 ± 0.2	0.38 ± 0.2
APRMS (cm)	0.42 ± 0.1	0.40 ± 0.1	APRMS (cm)	1.69 ± 0.6	1.64 ± 0.5
EOSRV			EOSRVP		
ML EL (cm/s)	0.79 ± 0.1	0.75 ± 0.1	MLVEL (cm/s)	1.07 ± 0.2	1.06 ± 0.2
APVEL (cm/s)	1.20 ± 0.3	1.11 ± 0.2 *	APVEL (cm/s)	2.77 ± 0.6	2.54 ± 0.5
MLRMS (cm)	0.17 ± 0.1	0.15 ± 0.1	MLRMS (cm)	0.29 ± 0.1	0.29 ± 0.2
APRMS (cm)	0.42 ± 0.1	0.37 ± 0.1	APRMS (cm)	1.76 ± 0.8	1.62 ± 0.8

Sensory organization test (SOT) conditions include eyes open (EO), eyes closed (EC), eyes open sway-referenced vision (EOSRV), eyes open sway-referenced platform (EOSRP), eyes closed sway-referenced platform (ECSRP) eyes open sway-referenced vision and platform (EOSRVP). Center of Pressure (COP) postural sway variables include sway velocities (VEL; cm/s) in the anterior-posterior (APVEL) and medial-lateral (MLVEL) directions and postural sway root mean square (RMS; cm) in the anterior-posterior (APRMS) and medial-lateral (MLRMS) directions. * represents significant post-intervention effect at $p < 0.05$.

In addition, there was shown to be a significant correlation between degree of weight change and the following variables: EOSRV MLVEL ($r = -0.720, p = 0.002$), EOSRV MLRMS sway ($r = -0.634, p = 0.011$), EOSRP MLRMS sway ($r = -0.564, p = 0.029$), EOSRP APRMS sway ($r = -0.515, p = 0.049$), ECSRP MLVEL ($r = -0.712, p = 0.003$), ECRSP MLRMS sway ($r = -0.545, p = 0.036$). Degree of weight loss was given a positive value in that if weight was lost, it represented a positive value. Because a higher value for sway parameters (VEL and RMS) represent a greater degree of sway during the balance tests and represent decreased balance and postural stability, the indirect relationship exhibited in the current data suggest that there was a strong relationship for a number of variables in amount of weight loss and improvement in certain balance parameters. No significant correlations between degree of weight change and any other balance parameters were seen ($p > 0.05$).

4. Discussion

Based on the available evidence, one could reasonably assume that a loss in fat mass could potentially lead to substantial improvements in overall balance. Del Porto et al. [6] reported that a unanimous opinion does not exist on the best exercise intervention technique for balance improvement. The purpose of the current study was to evaluate if an exercise intervention centered on brisk walking

for exercise could lead to a substantial decrease in body weight and also an improvement in standing balance. The current study would support previous reports from Goulding et al. [2], Handrigan et al. [14], Maffiuletti et al. [15], and McGraw et al. [5] that even a slight improvement in body composition can lead to balance improvements, but in addition, potentially define the degree of change that could be experienced with each amount of weight lost. The results of the current study would also support the previous findings of Matrangola and Madigan [12] and Blaszczyk et al. [13] that the increased inertia that is experienced by a heavier weight may provide an obese individual with an increased ability to resist perturbations that are not of a sufficient velocity to cause a loss of balance.

The current study, similar to Maffiuletti et al. [15], exhibited a significant improvement in balance parameters. However, in stark contrast to Maffiuletti et al. [15], the current study did not elicit a significant degree of weight loss (on average 1.0 ± 4.6 kg) compared to their study (on average, 6.1 kg for body weight reduction program (BWR) alone, 7.1 kg for BWR plus specific balance training). This weight change information and method of loss is discussed in more detail elsewhere [17]. What also must be considered is that with the average starting body mass of participants in the current study of 94.1 ± 20.1 kg, this is substantially less than the participants in their study (123.9 ± 22.3 for BWR alone, 133.6 ± 28.9 kg for BWR plus specific balance training) [15]. This is an average difference of 29.8–39.5 kg from the current starting body mass of the current sample [15]. In fact, Maffiuletti et al. [15] note that their participants were all classified as extremely obese based on their BMI. With the mean starting BMI of their participants of 42.8 ± 6.3 (for BWR alone) and 45.8 ± 7.3 (for BWR plus specific balance training), not a single one of the current participants even reached the mean BMI of either of the Maffiuletti et al. [15] groups, and only three even fell within one standard deviation the starting BMI of their participants. While the samples are certainly similar in nature, only three of the current participants could even be potentially considered extremely obese, with the rest classified as either overweight or obese per BMI standards.

Where the comparisons become interesting is that Maffiuletti et al. [15] note that only the BWR plus specific balance training group reached a significant level of improvement in balance parameters, while the BWR alone group did not reach a significant level of improvement despite both groups losing a significant amount of weight. An important finding of Maffiuletti et al. [15] was therefore that the BWR plus specific balance training group led to a significantly improved balance over BWR alone. As previously mentioned, the current participant group did not lose a significant amount of weight (on average 1.0 ± 4.6 kg), but did exhibit a significant improvement in balance performance. It is not surprising that the BWR plus specific balance training group of Maffiuletti et al. [15] saw a significant improvement in balance because they had direct balance training during their intervention. The 3-week intervention period was a relatively short period of time to expect significant improvements in both body mass and balance to happen, but they happened with Maffiuletti et al. [15]. What must be considered is the program that was employed. The BWR intervention employed by Maffiuletti et al. [15] was a relatively aggressive plan including not only physical activity but also psychological counseling, nutritional education, and caloric restriction of 500 kcal under the basal metabolic rate. While that certainly can lead to a substantial loss in weight (as was exhibited in their study), that is not always feasible for every individual who is overweight. Not every person who aims to lose weight is going to have access to the components of the program that was employed by Maffiuletti et al. [15]. The potential strength of the current program was that it was conducted with a modest amount of exercise that was entirely done at the participant's own leisure and self-reported to the researchers. Individuals who are overweight or obese may be more likely to begin with a program such as this one before transitioning to more aggressive programs like the ones of Maffiuletti et al. [15] or the bariatric surgery options discussed by Teasdale et al. [16] and Handrigan et al. [14]. Even without a significant loss of weight, the significant improvement in balance is perhaps an enhancement of the findings of Maffiuletti et al. [15] demonstrating that balance improvements can potentially be experienced prior to any significant loss in weight.

The difference in pre- to post-intervention VO_2 max, with an increase of 3.1 mL/kg/min, while not significant, could also be partially explained by the expression of VO_2 max to body mass. If a decline in body mass is experienced with no change in absolute aerobic capacity, relative aerobic capacity would improve solely as a product of the change in body mass. It is possible that even though the improvement was not significant, a slight increase in VO_2 max could result in improvement of the fitness of the musculature that would also be needed to maintain balance. Several authors have suggested that the ability and efficiency with which to produce muscular force may play an important role as a component of maintaining balance [27–29]. These authors relate their findings to gains in the ability to produce maximal force anaerobically, however, it is possible that improvements to muscular fitness related to aerobic exercise can still lead to similar improvements. Therefore, it is possible that the participants who experienced any slight improvement in body composition also experienced a slight improvement in muscular fitness, allowing them to perform better in a balance evaluation. This would be a potential area of future research in studying potential improvements in fitness of the muscles surrounding the ankle joint in how they may improve balance even from aerobic exercise.

Postural stability is governed by three major sensory systems that include the visual, vestibular, and somatosensory systems [30]. Findings from the current study demonstrate significant improvements in balance performance post-intervention, especially when the individuals had to rely on the somatosensory system heavily in an attempt to remain balanced. This was evident with significantly lower postural sway velocity after the exercise intervention in the EC and EOSRV SOT conditions, where visual feedback is completely absent or incorrect with conflicting feedback and forces the individuals to rely on the somatosensory afferent systems and efferent muscular responses to maintain postural stability. Even though there was no significant differences among the physical characteristics of the study's participants such as FFM or FM, the existing differences could be attributed to the exercise intervention program that helped individuals to have greater balance performance when there is either no feedback or conflicting feedback from the visual system. The SOT EQ scores also revealed improved balance performance post-exercise intervention during the EOSRVP condition, where both the visual and somatosensory systems are challenged and an increased reliance on the vestibular system is required. However, the exercise intervention did not seem to impact the postural response latencies during the MCT when individuals were subjected to forward and backward external perturbations, as no significant differences existed in the MCT latencies.

With a very similar sample size (15 overweight individuals) to the Maffiuletti et al. [15] study (19 extremely obese individuals) and an effect size (η^2) ranging from 0.250–0.423 (implying large effect) for the variables exhibiting a significant balance improvement, it can be reasoned that the current study expands on the current knowledge base that balance improvements can be realized by an overweight individual performing an exercise program without a significant loss in weight. Key in this is that no specific balance training was conducted during this study, suggesting that balance improvements occurred as a result of the exercise and potentially the small loss in weight. Therefore, even though the loss in weight was not considered significant, the exercise program lasted long enough to realize benefits in balance, perhaps related to the loss in weight, as the Pearson r data implies. Future study should aim to evaluate if similar benefits in balance improvement can be realized in resistance training exercise interventions aimed at weight loss in addition to the current evidence of balance improvements related to the aerobic exercise intervention employed with the current study.

5. Conclusions

The overall inability to lose a significant amount of body mass limited potential improvements in balance in the current study. However, the results of the current study suggest that an exercise intervention alone without a significant loss in weight and also without any form of specific balance training can lead to an improved balance performance, but that it may be limited to the conditions where the vestibular system plays a larger role in balance maintenance.

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