Optimization of body balance indices according to Body Mass Index categories during physical education lessons for university students

George D. Mocanu1ABCDE, Gabriel Murariu1ACE, Vladimir Potop23ADE

1 Faculty of Physical Education and Sport, "Dunarea de Jos" University of Galati, Romania
2 University of Pitesti, Romania
3 State University of Physical Education and Sport, Moldova

Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim

Body stability is an important factor in the manifestation of human motor skills. The purpose of the research is to evaluate the efficiency of balance exercises, applied for 28 weeks, with a frequency of one activity / week, on a group of undergraduate students of the "Dunarea de Jos" University of Galați.

Material and Methods

195 subjects participated (99 males and 96 females), divided for analysis into 3 groups (underweight, N = 21, age = 20.16 ± .38, BMI = 17.46 ± .20); (normal weight, N = 111, age = 20.50 ± .21, BMI = 21.70 ± .17); (overweight / obese, N = 63, age = 19.90 ± .18, BMI = 30.69 ± .61). The tests were applied at 3 distinct times: initial T1 at the beginning of the academic year, intermediate T2 towards the end of semester 1 and final T3 at the end of semester 2. 3 static balance assessment tests were used (One leg standing test with closed eyes, Stork test and Flamingo test), respectively 4 tests to evaluate the dynamic balance (Bass test, Functional reach test, Walk and turn field sobriety test and Fukuda test).

Results

ANOVA with repeated measurements and the differences between the test moments highlight in most cases values of F associated with significant thresholds (p <0.05), so there is an improvement in results for all 3 groups. The differences between T1 and T2 tests are larger than those between T2 and T3, so for almost all tests the progress is higher in the first semester, and in semester 2 there is a slight reduction, as a result of adapting to the proposed exercises. Even if they progress significantly, the group of overweight people has obviously weaker average results than normal weight and underweight people, signaling numerous individual cases that have problems in maintaining static balance and commit errors in dynamic balance tests. The better performances of the underweight in 3 cases (One leg standing test, Flamingo test Fukuda test and Walk and turn field sobriety test) cannot be generalized due to their small number compared to the other 2 groups, and this aspect can be considered as a new direction of investigation.

Conclusions

There are premises for a favorable evolution of the balance indices for the group tested in this age group, but it must be taken into account that the low initial fitness level (generated by the lack of concerns for a lifestyle based on physical activities) is a factor that facilitated these less spectacular advances, but still statistically significant.

Keywords: students, static and dynamic balance, assessment, BMI stages, physical activity

Introduction

The balance of the body is important in maintaining different positions and the correct execution of movements, and along with increasing postural muscle strength has a decisive role in the stability of the body of obese people, who have high risks of falling [1, 2, 3]. The sense of balance is fundamental in ensuring the technical correctness of the procedures in sports activities and reducing the risks of injury [4, 5, 6]. The importance of dynamic balance training for young athletes in Malaysia as a factor in injury prevention is highlighted by Lee et al. [7]. The use of balance assessment tests (as elements of the functional fitness battery) may signal possible postural control deficits, induced by the occurrence of muscle fatigue and affecting the efficiency of motor activities [8]. Poor balance values are often correlated with problems and risks of ligament and muscle injuries, requiring actions to improve coordination, which also has beneficial effects on the results of balance tests [9].

The optimal interaction between the vestibular, proprioceptive and visual systems conditions the performance associated with balance, which may be affected by aging [5, 10, 11, 12]. The values of the balance evaluated with the eyes open are higher than the ones evaluated with the eyes closed, aspect confirmed by the testing of the Polish ballerinas, at which better performances are signalled with increasing age, those aged 18 years old having higher results than puberty 14 years old [13]. Postural stability also depends on the information provided...
by the cervical proprioceptors, whose feedback improves the balance on the non-dominant leg of Taekwondo fighters, compared to untrained people [14]. Ways to optimize body stability for different age groups are frequently sought.

The introduction of additional actions with the additional demand for attention can affect the balance. Frequent use of mobile phones for Taiwanese students (texting while walking) affects dynamic balance performance and reduces postural stability, but it has been found that younger subjects can easily prevent falls and adapt more quickly to such tasks, according by Nurwulan et al. [15].

For children and adolescents (9-18 years) there is an improvement in postural balance with increasing age, for groups of athletes aged 9-12 years are found better values for girls, but this difference between genders is no longer reported for the group 13-18 years [16]. The use of hover-boards has beneficial effects on the static balance (One leg standing test and Stork test), respectively dynamic (Balance beam walking test) at the level of young Italian football players, being indicated the use of these devices also in other sports [17]. Playing handball as a recreational sport for postmenopausal women (49-79 years old) facilitates the improvement of postural balance and bone health, reducing the risk of falls and injuries for this category of population [18].

The comparison of performances between athletes (football players) and groups of sedentary students of the same age confirms the significantly better values of athletes, so the involvement in physical activities improves balance [19]. The associations between balance issues and the low level of fitness of African children is highlighted by Verbecque et al. [20]. The authors indicate that there is a high chance of impaired balance with increasing BMI values, so the preventive role of physical activity in maintaining and reducing body weight is vital. The decrease in leg muscle strength and antero-posterior balance performance for pubertal children (overweight and obese classes) is highlighted by Alhusaini et al. [21]. The application and quantification of the results being made up by random selection to ensure numerical balance by gender and divided for data analysis into 3 categories: underweight (N = 21, age = 20.16 ± .38, BMI = 17.46 ± .20), normal weight (N = 111, age = 20.30 ± .21, BMI = 21.70 ± .17), overweight / obese (N = 63, age = 19.90 ± .18, BMI = 30.69 ± .61). Participants do not have constant concerns about performance physical activities, so the influence of this factor on results cannot be taken into account. The study group was informed about the duration, purpose and balance tests applied, ensuring the confidentiality and protection of personal data, in accordance with the Helsinki Declaration [28, 29].

Materials and Methods

Participants.

The studied group consists of 195 students from “Dunărea de Jos” University of Galați (99 males and 96 females included in the undergraduate study programs of years 1 and 2 of the Faculty of Automation, Computers, Electrical and Electronic Engineering, respectively Medicine and Pharmacy), made up by random selection to ensure numerical balance by gender and divided for data analysis into 3 categories: underweight (N = 21, age = 20.16 ± .38, BMI = 17.46 ± .20), normal weight (N = 111, age = 20.30 ± .21, BMI = 21.70 ± .17), overweight / obese (N = 63, age = 19.90 ± .18, BMI = 30.69 ± .61). Participants do not have constant concerns about performance physical activities, so the influence of this factor on results cannot be taken into account. The study group was informed about the duration, purpose and balance tests applied, ensuring the confidentiality and protection of personal data, in accordance with the Helsinki Declaration [28, 29].

Research Design.

The research took place at the level of the Research Center for Human Performance within the Faculty of Physical Education and Sports in Galați (Romania), respecting the design of longitudinal investigations. The applied tests evaluate the dynamics of static balance indicators (One leg standing test with eyes closed / s, Stork test / s, Flamingo test / number of falls), respectively the evolution of performance at dynamic balance (Bass test / points, Functional reach test / cm, Walk and turn field sobriety test / errors and Fukuda test / degrees of rotation), the application and quantification of the results being exemplified by Walden, Zhang et al. [30, 31, 32, 33]. The batch testing was performed during the academic year 2018-2019, in 3 distinct stages (T1-initial testing, at the beginning of the academic year; T2-intermediate testing, in the 12th week
December, before the winter holidays; T3-final testing, at the end of the academic year). Students who were absent from physical education lessons were not included in the statistical calculation, in order to highlight the efficiency of the motor structures proposed for the development of balance. Participants were advised not to engage in stress-based efforts prior to testing, so that muscle and nerve fatigue does not affect the value of the results.

Training program. The exercise program was implemented over a period of 28 weeks, with a frequency of one activity per week, the structures oriented towards the development of balance being explained and practiced for 15-25 minutes in each lesson, with variable and individualized dosage, according to the effort potential of each participant. Table 1 selectively presents proposed exercises to optimize the level of static and dynamic balance, with the mention that they have been alternated and changed during the activities, in order to avoid capping the results, by adapting the participants to the proposed stimuli.

Table 1. Selection from the variants proposed and applied for the development of balance

| Motor structures proposed for the development of static balance |
|---------------------------------------------------------------|
| • From standing, lunging by making a step back with your palms on your hips and holding the position with your arms up. |
| • From sitting with the palms on the hips, raising the right knee and thigh parallel to the ground, maintaining the position for 5-30 seconds, then the action is repeated for the left leg. Same with lifting a leg outstretched forward / sagittal plane, with the heel at a distance of 10-30 cm above the ground. |
| • From standing on one leg, throwing a tennis ball vertically and holding the arm on the side of the support leg. The same goes for holding the raised leg with the arm. Same with throwing the ball from one hand to the other. |
| • Maintaining balance by flexing and extending the knees from sitting on the platform or balance ball / bosu balance trainer. |
| • From standing on one leg, bending the torso forward and touching the tip of the supporting leg with the opposite arm, the free leg is bent / flexed from the knee and oriented / lifted back. |
| • From standing on one leg, slight half-flexion with return and arms outstretched sideways, vertically or in other planes. |
| • From standing facing the wall, lifting on tiptoes with a slight bend of the torso forward to the limit of imbalance, then balancing by pushing with the palms towards the wall. |

| Motor structures proposed for the development of dynamic balance |
|---------------------------------------------------------------|
| • Moving on various hardness surfaces (soft, semi-hard or hard mattresses), jumping from one foot to the other while maintaining balance. |
| • Successive jumps on one leg, over a drawn line or a cord stretched on the ground, maintaining the position 2-5 sec before the next jump. On return, the detachment leg changes. The same with alternate jumps, from one foot to the other. |
| • From standing sideways to a column of 5-6 bottles, spaced 50 cm apart, jump on one leg next to each bottle, maintaining balance and placing a glass on it. The same with zigzag / snake jumps between bottles. The same jumping back to each bottle. |
| • Running bypassing milestones at 360° alternating the direction of rotation: left / right. |
| • Walking on the narrow side of the gym bench with variable speed, with jumps over various objects and turning at 90, 180, 360°. The same by moving backwards on the gym bench. |
| • Jumps on one leg or from one leg on the other, on different signs / markings drawn on the ground, maintaining the unipodal balance for 1-5 sec. The same with jumps on one leg, in circles arranged under different variants / arrangements on the ground. |

Statistical Analysis.

The statistical calculation was based on the use of Anova parametric techniques with repeated measurements, separately for each subgroup analyzed (underweight, normal weight and overweight / obese). We preferred to include the overweight and obese in a single category, in order to simplify the statistical analysis and reduce the resulting data volume. Data on: Maucly’s Test of Sphericity were synthesized, with the application of the Greenhouse–Geisser correction factors (for ε <0.75) and Huynh-Feldt (for ε > 0.75) when the sphericity could not be assumed, the values of F and associated significance thresholds (sig.), size effect expressed by Partial eta squared (η²p), the differences between the average values between the test moments and their significance, using the Bonferroni correction factor [34, 35]. The confidence interval was set at 5% (p <0.05), according by Murariu, Opariuć [36, 37, 38].
Results

The values of the Anova parametric test with repeated measurements (table 2) indicate significant progress at the level of the 3 groups for most tests (F values correspond to thresholds p < .05), except for the group of underweight in Walk and turn field sobriety test, where p = .329, statistically insignificant value. Partial eta squared scores indicate a strong influence of the applied balance exercise program on the results, with the highest values for all 3 groups in the Bass test and Functional reach test (for underweight, in the Bass test, 81.5% of the variance is explained by the intervention of the proposed program, and for overweight, at the Functional reach test, 81% of the variance is attributed as an effect of the applied program). It should be noted that for the rest of the tests, at the level of the group of normal weight, stronger influences of the program are registered (through the values of $\eta^2_p$) than at the level of the groups of underweight and overweight. The weakest effects of balance exercises are found in the Walk and turn field sobriety test and Fukuda test for underweight and normal weight, but with strong effects on overweight.

Comparison and analysis of average differences in pairs at the level of the underweight (Table 3) indicates in most cases significant progress (p < .05), except for the Walk and turn field sobriety test (where errors are missing in the intermediate and final tests), respectively in the Fukuda test (where no significant progress is found between intermediate and final testing). With the exception of One leg standing test, where slightly higher progresses are found between intermediate and final tests, for the other data pairs there are larger differences between initial and intermediate tests compared to those between intermediate and final tests, which confirms the higher progress in the first stage of preparation / semester 1, the adaptation to the stimuli / exercises in the program generating a lower improvement of the results in semester 2.

The situation is similar for the group of normal weight (table 4) with larger differences for the first semester of preparation and smaller for the second, but significant for most data pairs. In the case of the Walk and turn field sobriety test, only for the initial test-final test pair there is significant progress (so at

---

Table 2. ANOVA results with repeated measurements on BMI steps (1 = underweight, 2 = normal weight, 3 = overweight)

| Test                      | Lot | Mauchly’s Test of Sphericity | Correction factor | df   | Error df | F    | Sig. | Partial eta squared ($\eta^2_p$) |
|---------------------------|-----|-----------------------------|-------------------|------|----------|------|------|----------------------------------|
| One leg standing          | 1   | 0.000 0.595                | Greenhouse-Geisser | 1.191 | 23.811   | 22.371 | 0.000 | 0.528                            |
|                           | 2   | 0.000 0.656                | Greenhouse-Geisser | 1.312 | 144.367  | 173.947 | 0.000 | 0.613                            |
|                           | 3   | 0.000 0.658                | Greenhouse-Geisser | 1.317 | 81.630   | 55.441 | 0.000 | 0.564                            |
| Stork                     | 1   | 0.000 0.532                | Greenhouse-Geisser | 1.065 | 21.266   | 19.095 | 0.000 | 0.488                            |
|                           | 2   | 0.000 0.734                | Greenhouse-Geisser | 1.469 | 161.587  | 229.964 | 0.000 | 0.676                            |
|                           | 3   | 0.000 0.688                | Greenhouse-Geisser | 1.376 | 85.289   | 86.992 | 0.000 | 0.584                            |
| Flamingo                 | 1   | 0.000 0.769                | Huynh-Feldt        | 1.538 | 95.363   | 57.571 | 0.000 | 0.481                            |
|                           | 2   | 0.000 0.742                | Greenhouse-Geisser | 1.485 | 165.345  | 137.559 | 0.000 | 0.555                            |
|                           | 3   | 0.000 0.769                | Huynh-Feldt        | 1.558 | 96.586   | 193.259 | 0.000 | 0.481                            |
| Bass                     | 1   | 0.005 0.702                | Greenhouse-Geisser | 1.405 | 28.083   | 88.068 | 0.000 | 0.815                            |
|                           | 2   | 0.002 0.919                | Huynh-Feldt        | 1.809 | 198.952  | 410.853 | 0.000 | 0.789                            |
|                           | 3   | 0.000 0.779                | Huynh-Feldt        | 1.558 | 96.586   | 193.259 | 0.000 | 0.757                            |
| Functional reach         | 1   | 0.001 0.669                | Greenhouse-Geisser | 1.357 | 26.740   | 45.000 | 0.000 | 0.692                            |
|                           | 2   | 0.000 0.719                | Greenhouse-Geisser | 1.438 | 158.150  | 213.035 | 0.000 | 0.659                            |
|                           | 3   | 0.051 0.941                | Sphericity Assumed | 2    | 124      | 264.773 | 0.000 | 0.810                            |
| Walk and turn            | 1   | - 0.500                    | Greenhouse-Geisser | 1.000 | 20.000   | 1.000  | 0.329 | 0.048                            |
|                           | 2   | 0.000 0.797                | Huynh-Feldt        | 1.576 | 173.349  | 6.424  | 0.004 | 0.055                            |
|                           | 3   | 0.055 0.932                | Huynh-Feldt        | 1.863 | 115.529  | 33.036 | 0.000 | 0.348                            |
| Fukuda                   | 1   | 0.768 1.000                | Sphericity Assumed | 2    | 40       | 8.138  | 0.001 | 0.289                            |
|                           | 2   | 0.000 0.536                | Greenhouse-Geisser | 1.072 | 117.948  | 5.201  | 0.022 | 0.045                            |
|                           | 3   | 0.000 0.836                | Huynh-Feldt        | 1.671 | 105.633  | 29.853 | 0.000 | 0.325                            |
the level of the entire study stage / academic year), but without significant accumulations per semester (p > 0.05). A particular situation is encountered at the Fukuda test level, where there is a slight decrease in performance for intermediate testing (several degrees of rotation), but without the difference between the initial and intermediate testing being significant. The situation is remedied by the better performance from the final testing, which generates significant progress between the level of semester 2 and the entire stage of implementation of the proposed program (p < 0.05).

The overweight group made significant progress on almost all data pairs associated with the tests (Table 5), with the exception of the Walk and turn field sobriety test, between intermediate and final testing. For One leg standing test and Stork test, however, greater progress is found for semester 2, so adapting overweight and improving performance in these 2 tests are slower, but this is not confirmed for other situations, where the biggest differences are still between initial and intermediate tests. For the Fukuda test, the average performance is poor (around 30 degrees), which is the threshold for the manifestation of vestibular disorders on the side of body rotation.

Graph 1 shows the average performance values of the 5 batches at the final tests. Overweight people have the weakest results in tests to assess static and dynamic balance, but their progress (statistically confirmed) does not allow the approach to the values of normal weight and underweight. They have the shortest holding times at static balance, the lowest score on the Bass test, they make the most errors on the Flamingo test and the Walk and turn field sobriety test, and they have the highest rotation scores around the body axis on the Fukuda test. It is interesting that the underweight group has results close in value to that of the normal weight in most tests and even slightly better than them in One leg standing test, Flamingo Fukuda test and Walk and turn field sobriety test, which requires checks by studies on larger groups in this category, in order to generalize these results.

**Discussion**

Our study identifies the effectiveness of the diversified exercises proposed to optimize the level of balance, an aspect confirmed by other similar research.

Applying core training on unstable surfaces for 18–25-year-olds in Turkey generates gender
Table 4. The results for differences of normal weight average values (N=111)

| Test                  | Mean   | Std. deviation | Std. error | T1-T2     | Sig.b | T1-T3     | Sig.b | T2-T3     | Sig.b |
|-----------------------|--------|----------------|------------|-----------|-------|-----------|-------|-----------|-------|
| One leg standing T1   | 6.320  | 6.098          | 0.579      | -0.160*   | 0.000 | -0.291*   | 0.000 | -0.131*   | 0.000 |
| One leg standing T2   | 6.480  | 6.106          | 0.580      |           |       |           |       |           |       |
| One leg standing T3   | 6.610  | 6.135          | 0.582      |           |       |           |       |           |       |
| Stork T1              | 4.298  | 3.855          | 0.366      |           |       |           |       |           |       |
| Stork T2              | 4.419  | 3.837          | 0.364      | -0.121*   | 0.000 | -0.200*   | 0.000 | -0.079*   | 0.000 |
| Stork T3              | 4.498  | 3.838          | 0.364      |           |       |           |       |           |       |
| Flamingo T1           | 6.378  | 3.482          | 0.331      |           |       |           |       |           |       |
| Flamingo T2           | 5.603  | 3.151          | 0.299      | 0.775*    | 0.000 | 1.279*    | 0.000 | 0.505*    | 0.000 |
| Flamingo T3           | 5.099  | 2.954          | 0.280      |           |       |           |       |           |       |
| Bass T1               | 69.360 | 12.137         | 1.152      |           |       |           |       |           |       |
| Bass T2               | 71.549 | 12.380         | 1.175      | -2.189*   | 0.000 | -4.279*   | 0.000 | -2.090*   | 0.000 |
| Bass T3               | 73.639 | 12.584         | 1.194      |           |       |           |       |           |       |
| Functional reach T1   | 40.076 | 6.035          | 0.573      |           |       |           |       |           |       |
| Functional reach T2   | 41.247 | 5.785          | 0.549      | -1.171*   | 0.000 | -1.874*   | 0.000 | -0.703*   | 0.000 |
| Functional reach T3   | 41.950 | 5.630          | 0.534      |           |       |           |       |           |       |
| Walk and turn T1      | 0.234  | 0.485          | 0.046      |           |       |           |       |           |       |
| Walk and turn T2      | 0.189  | 0.457          | 0.045      | 0.045     | 0.074 | 0.072*    | 0.013 | 0.027     | .250  |
| Walk and turn T3      | 0.162  | 0.437          | 0.042      |           |       |           |       |           |       |
| Fukuda T1             | 20.891 | 24.770         | 2.351      |           |       |           |       |           |       |
| Fukuda T2             | 21.477 | 26.628         | 2.527      | -0.586    | 1.000 | 1.964*    | 0.000 | 2.550*    | 0.040 |
| Fukuda T3             | 18.927 | 23.760         | 2.255      |           |       |           |       |           |       |

*The mean difference is significant at the .05 level; b. Adjustment for multiple comparisons: Bonferroni.

differences for dynamic balance (Y test), but not for the rest of the fitness components [39]. In order to reduce the risk of injury, for American football players are recommended exercises for vestibular, proprioceptive, neuromuscular, with eyes closed and open, respectively on various surfaces - stable and unstable [40]. The use of unstable surfaces improves the values of dynamic balance and reduces the static postural balance for 7-year-old gymnasts [41]. Exercises performed on stable ground are less effective than the variant of unstable surfaces, for women of the 3rd age (60-80 years), by applying a program of this type (12 weeks, with 2 workouts of 45 min./week and 25 minutes oriented to equilibrium structures) progress is achieved, according by Matla et al. [42]. Our program also included this kind of exercises, and the significant progress at the level of the 3 categories confirms their viability.

The variants proposed by specialized studies for balance optimization are extremely varied. An improvement of the results by applying a Tabata training program (for young football players / ages = 23 years) is obtained for the Flamingo test, but without statistical significance, according by Ceylan et al. [45]. Other research highlights the role of various physical activity programs (combat sports, pilates) on increasing balance values and reducing the risk of falls in different categories of the population [2, 3, 6, 44, 45]. The type of sport practiced influences the values of balance. Higher values in the balance tests of young Turkish athletes who are involved in individual sports (karate, gymnastics, judo, table tennis) compared to those involved in team games (basketball, volleyball, handball), as well as the increase the performance of the dynamic balance as age increases are identified by Turkeri et al. [46]. A program of balance exercises applied to children (10-12 years), for 8 weeks x 3 sessions per week generated superior performance in the Flamingo test, but also the speed and agility tests [47]. For teenagers in Kosovo, in the Flamingo test, girls perform better only for the 14-15 years old age group, then boys get superior performance [48]. Balanced values between Montenegrin and Kosovo teenagers in the Flamingo test are obtained by Morina et al. [49]. Long-term application of fitness programs (5 years x 3 sessions / week x 90 min) and their combination with diet positively influences the performance of fitness tests, including the Flamingo test, for boys aged 8-11 years [50]. We obtained in this test the best results for underweight, followed by normal weight, overweight having the lowest performances.
Table 5. The results for differences of overweight average values (N=63)

| Test               | Mean  | Std. deviation | Std. error | T1-T2   | Sig.b | T1-T3   | Sig.b | T2-T3   | Sig.b |
|--------------------|-------|----------------|------------|---------|-------|---------|-------|---------|-------|
| One leg standing T1| 4.959 | 2.907          | 0.366      |         | -0.157*| 0.000   | -0.353*| 0.000   | -0.196*| 0.000 |
| One leg standing T2| 5.116 | 2.935          | 0.370      | -0.157*| 0.000 |         | -0.353*| 0.000   | -0.196*| 0.000 |
| One leg standing T3| 5.312 | 2.990          | 0.377      | -0.082*| 0.000 | -0.177*| 0.000 | -0.094*| 0.000 |
| Stork T1           | 2.695 | 1.220          | 0.154      |         |       |         |       |         |       |
| Stork T2           | 2.777 | 1.256          | 0.158      | -0.082*| 0.000 | -0.177*| 0.000 | -0.094*| 0.000 |
| Stork T3           | 2.871 | 1.245          | 0.157      |         |       |         |       |         |       |
| Flamingo T1        | 10.571| 4.599          | 0.579      |         |       |         |       |         |       |
| Flamingo T2        | 10.047| 4.681          | 0.590      | 0.524* | 0.000 | 0.905* | 0.000 | 0.381* | 0.000 |
| Flamingo T3        | 9.666 | 4.700          | 0.592      |         |       |         |       |         |       |
| Bass T1            | 58.523| 13.023         | 1.641      |         |       |         |       |         |       |
| Bass T2            | 60.571| 12.630         | 1.591      | -2.048*| 0.000 | -3.714*| 0.000 | -1.667*| 0.000 |
| Bass T3            | 62.238| 12.708         | 1.601      |         |       |         |       |         |       |
| Functional reach T1| 38.941| 8.292          | 1.045      |         |       |         |       |         |       |
| Functional reach T2| 40.238| 8.129          | 1.024      | -1.297*| 0.000 | -2.107*| 0.000 | -0.810*| 0.000 |
| Functional reach T3| 41.047| 7.778          | 0.980      |         |       |         |       |         |       |
| Walk and turn T1   | 1.000 | 0.879          | 0.111      |         |       |         |       |         |       |
| Walk and turn T2   | 0.619 | 0.658          | 0.083      | 0.381* | 0.000 | 0.429* | 0.000 | 0.048  | 0.964 |
| Walk and turn T3   | 0.571 | 0.734          | 0.095      |         |       |         |       |         |       |
| Fukuda T1          | 31.952| 30.571         | 3.852      |         |       |         |       |         |       |
| Fukuda T2          | 31.000| 30.526         | 3.846      | 0.952* | 0.000 | 1.714* | 0.000 | 0.762* | 0.000 |
| Fukuda T3          | 30.238| 29.899         | 3.767      |         |       |         |       |         |       |

* The mean difference is significant at the .05 level; b. Adjustment for multiple comparisons: Bonferroni.

Figure 1. Presentation of the average values of the performances of the 3 lots at the final tests

A decrease in performance in balance tests is reported after the age of 50, and for the interval 20-49 years similar results are recorded, overweight women obtaining lower scores than normal weight [51]. The differences between obese and normal weight for One leg standing test and dynamic balance assessment tests are also reported among Chinese children aged 8-10 years [52]. Young obese
people (21.7 years) have the poorest results in bipodal and unipodal balance tests, compared to normal weight and underweight, according by Ku et al. [53], aspect similar to our research. Young people (ages = 21 years) with concerns related to physical activities (moderate to vigorous intensity) have a lower balance area and implicitly a better balance, with higher values for testing with eyes open [54].

Comparisons between static balance values between female dancers with at least 7 years of activity and sedentary ones (18-23 years) indicate higher balance values for dancers and superior postural control [55]. An exercise program applied 5 weeks, to influence the dynamic balance in elderly and overweight women is proposed by Bellafiore et al. [56]. In this case, performance improvements are obtained for most of the people involved, as a result of the efficiency of the muscular structures and the visual system, which ensures the postural balance. The use of DCE / dynamic core exercise in the warm-up part of physical education lessons for children at the beginning of puberty (10-11 years), for 6 weeks has favorable effects on balance and flexibility [57]. Other authors propose exercises with elastic cord at the level of elite gymnasts’ girls (14 years), through an applied program 12 weeks x 18 hours per week + 2 hours dedicated to exercises with elastic cord, which generate favorable effects on body balance [58]. There are also researches that demonstrate the effectiveness of applying oriental techniques (Yoga asanas) for obese young people (21-25 years), for a period of 4 weeks x 3 sessions per week x 45 min / session. Significant improvements are found in the Functional reach test and One leg standing balance test [59]. Our study confirms the effectiveness of programs based on balance exercises for the age category investigated, even if it was applied with a frequency of one session / week, being in accordance with the other research previously analyzed, through the beneficial effects found.

Conclusions
The application of balance exercises generates performance optimization in the tests applied to all groups investigated, so they are prerequisites for increasing body stability in static and dynamic actions for university students. The progress made is not spectacular, but the fact that they are statistically significant is still a positive aspect. It should be noted that for most tests there is more progress between the initial and intermediate tests, and slightly less between the intermediate and final tests, as a result of a possible adaptation to the exercises proposed in the second part of the program implementation. Even if the group of overweight progresses significantly, its results are weaker than those of normal weight and underweight; this category having the biggest problems in maintaining the body in different positions, but commits most errors and has poor scores in dynamic balance tests. The fact that underweight people get results close to those of normal weight and for 3 even better tests (One leg standing test, Flamingo test Fukuda test and Walk and turn field sobriety test) must be interpreted with some reservations, their weight / representation in the study group requiring the repetition of the research on a much larger sample at the level of underweight. Favorable results can also be explained by the low initial fitness level of the group (without concerns about sports activities), which facilitated the progress made.

The limits of the study and new research directions.
The high volume of data did not allow the presentation of differences in gender and between gender tests, or the analysis of the significance of differences between BMI classes / (independent samples), which are the subject of another scientific paper. It would be interesting to analyze the results of the battery of tests for students of the Faculty of Physical Education and Sports and whether reading the practical contents of the curricula generates significant improvements in performance related to balance (these data are already collected and will be statistically processed). The use of modern equipment and technologies (which investigate static and dynamic balance using sensors and baropodometric platforms) would facilitate a more nuanced investigation of the mechanisms that condition body stability and identify factors that reduce the value of performance in balance tests.

Acknowledgement
The authors thank the group of students who participated in this study.
The work of Gabriel Murariu (G.M.) was supported by the “Internal research grant in the field of Environmental Engineering regarding the study of the distribution of pollutants in the South East Europe area”—Financing agreement no. 14886/11.05.2022 University of the Dunarea de Jos University of Galati.

Conflict of interest
No potential conflict of interest that is of any relevance to this study was reported by the authors.
References

1. Clark KN. Balance and Strength Training for Obese Individuals. *ACSM's Health 
   & Fitness Journal*, 2004;8(1):14–20. https://doi.org/10.1097/00135124-200401000-
   00008
2. Dunsky A. The Effect of Balance and Coordination Exercises on Quality of Life in Older Adults: A Mini-
   Review. *Frontiers in Aging Neuroscience*. 2019;11:318. https://doi.org/10.3389/fnagi.2019.00518
3. Gadelha AB, Ricci Neri SG, de Oliveira RJ, Bottaro M, de David AC, Vainselboim B, et al. Severity of 
   sarcopenia is associated with postural balance and risk of falls in community-dwelling older women. 
   *Experimental Aging Research*. 2018;44(3): 258–269. https://doi.org/10.1080/0361073X.2018.1449591
4. Ricotti L. Static and dynamic balance in young athletes. *Journal of Human Sport and Exercise*. 2011;6(4):
   616–628. https://doi.org/10.4100/jhse.2011.64.05
5. Hartley EM, Hoch MC, Boling MC. Y-balance test performance and BMI are associated with ankle 
   sprain injury in collegiate male athletes. *Journal of Science and Medicine in Sport*. 2018;21(7): 676–680. 
   https://doi.org/10.1016/j.jsams.2017.10.014
6. Alhusaini AA, Melam G, Buragadda S. The role of body mass index on dynamic balance and muscle strength 
   in Saudi schoolchildren. *Science & Sports*. 2020;35(6). https://doi.org/10.1016/j.scispo.2019.11.007
7. Lee AC, Sankaravel M, Abadi FH, Zainudin FF. Development of balance training program to improve 
   balance control among Malaysian sports schools athletes. *Pedagogy of Physical Culture and Sports*. 
   2022;26(3):174–81. https://doi.org/10.15561/26649837.2022.0305
8. Zerf M, Kherfane MH. Balance as a postural key component (core) for establishing physical state in 
   school program reports. *Quality in Sport*, 2020;6(2):28–33. https://doi.org/10.12775/QS.2020.009
9. Aloui G, Hermassi S, Hayes LD, Bouhafs EG, Chelly MS, Schwiesig R. Loaded Plyometrics and Short Sprints 
   with Change-of-Direction Training Enhance Jumping, Sprinting, Agility, and Balance Performance of Male Soccer 
   Players. *Applied Sciences*, 2021;11(12):5587. https://doi.org/10.3390/app11125587
10. Celic A, Rojas Ruiz FJ, Cepero González M, Kocej A, Kitano K. Effects of age vestibular and visual systems on 
    the soleus H-reflex. *Journal of Human Sport and Exercise*. 2021;18(1). https://doi.org/10.14198/jhse.2023.181.09
11. García-Línea J, Leirós-Rodríguez R, Romo-Pérez V, García-Soldán JL. Sex differences in 
    postural control under unstable conditions in schoolchildren with accelerometric assessment. *Gait & Posture*, 
    2021;87:81–6. https://doi.org/10.1016/j.gaitpost.2021.04.027
12. Paschaleri Z, Arabatzi F, Christou EA. Postural control in adolescent boys and girls before the age of peak height velocity: Effects of 
    task difficulty. *Gait & Posture*. 2022;92:461–6. https://doi.org/10.1016/j.gaitpost.2021.12.018
13. Fronczek–Wojeceichowska M, Padula G, Kowalska J, Galli M, Livatino S, Kopacz K. Static balance and 
    dynamic balance related to rotational movement in ballet dance students. *International Journal of 
    Performance Analysis in Sport*, 2016;16(3):801–16. https://doi.org/10.1080/24748668.2016.11868929
14. Majcen Rosker Z, Vodicar M. Sport-Specific Habitual Adaptations in Neck Kinesthetic Functions Are Related to Balance Controlling 
    Mechanisms. *Applied Sciences*, 2020;10(24):8965. https://doi.org/10.3390/app10248965
15. Nurwulan NR, Jiang BC, Iridiastadi H. Posture and Texting: Effect on Balance in Young Adults. *PLOS ONE*, 2015;10(7):e0154230. 
    https://doi.org/10.1371/journal.pone.0154230
16. Paniczca M, Wilson KE, Hunt A, Keightley M, Zabjek K, Taha T, et al. Postural Stability in Healthy Child and Youth Athletes: The Effect of 
    Age, Sex, and Concussion-Related Factors on Performance. *Sports Health*, 2018;10(2):175–82. 
    https://doi.org/10.1177/1941738117741651
17. Moffa S, Perna A, Candela G, Cattolico A, Sellitto C, Di Blassis P, et al. Effects of Hoverboard 
    on Balance in Young Soccer Athletes. *Journal of Functional Morphology and Kinesiology*, 2020;5(3):60. 
    https://doi.org/10.3390/jfmk5030060
18. Pereira R, Krusstrup P, Castagna C, Coelho E, Santos R, Helge EW, et al. Effects of recreational team 
    handball on bone health, postural balance and body composition in inactive postmenopausal women — A 
    randomised controlled trial. *Bone*, 2021;145:115847. https://doi.org/10.1016/j.bone.2021.115847
19. Golshaei B. Dynamic and static balance differences based on gender and sport participation. [PhD thesis]. 
    The Graduate School of Social Sciences of Middle East Technical University; 2013.
20. Verbecque E, Coetzee D, Ferguson G, Smits-Engelsman B. High BMI and Low Muscular Fitness Predict Low Motor Competence in 
    School-Aged Children Living in Low-Resourced Areas. *International Journal of Environmental Research and Public Health*, 
    2021;18(15):7878. https://doi.org/10.3390/ijerph18157878
21. Alhusaini AA, Melam G, Buragadda S. The role of body mass index on dynamic balance and muscle strength 
    in Saudi schoolchildren. *Bone*, 2021;145:115847.
22. Celik A, Rojas Ruiz FJ, Cepero Gonzalez M, Kocej A, Kitano K. Effects of age vestibular and visual systems on the soleus H-reflex. 
    *Journal of Human Sport and Exercise*. 2021;18(1). https://doi.org/10.14198/jhse.2023.181.09
23. García-Línea J, Leirós-Rodríguez R, Romo-Pérez V, García-Soldán JL. Sex differences in 
    postural control under unstable conditions in schoolchildren with accelerometric assessment. *Gait & Posture*, 
    2021;87:81–6. https://doi.org/10.1016/j.gaitpost.2021.04.027
24. Handrigan G, Hue O, Simonneau M, Corbeil
P. Marceau P, Marceau S, et al. Weight loss and muscular strength affect static balance control. *Int J Obes.* 2010;34(5):956–42. https://doi.org/10.1038/ijo.2009.300

25. Teasdale N, Simoneau M, Corbeil P, Handrigan G, Tremblay A, Hue O. Obesity Alters Balance and Movement Control. *Curr Obes Rep.* 2015;2(3):235–40. https://doi.org/10.1007/s13679-013-0057-8

26. Yamamoto N, Yanagi H, Ito Y, Inoue Y, Tanaka K, Wada T, et al. Dynamic and Static Ability of Balance and Postural Control in Japanese Obese Children. In: Lim CT, Goh JCH, editors. 6th World Congress of Biomechanics (WCGB 2010) August 1-6, 2010 Singapore. Berlin, Heidelberg: Springer; 2010. p. 258–61. https://doi.org/10.1007/978-3-642-14515-5_67

27. do Nascimento JA, Silva CC, dos Santos HH, de Almeida Ferreira J], de Andrade PR. A preliminary study of static and dynamic balance in sedentary obese young adults: the relationship between BMI, posture and postural balance. *Clinical Obesity*, 2017;7(6):577–83. https://doi.org/10.1111/cob.12209

28. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA*. 2015;310(20):2191. https://doi.org/10.1001/jama.2013.281053

29. Sandu AS. *Etica si deontologie profesionale.* [Professional ethics and deontology]. Iasi: Lumen; 2012. (In Romanian).

30. *Balance Fitness Tests* [Internet]. [Internet]; 2022 Jan 27 [cited 2022 Feb 15]. Available from: https://www.topendsports.com/testing/balance.htm

31. *Functional Reach Test (FRT).* *Physiopedia.* [Internet]; 2022 Jan 27 [cited 2022 Feb 15]. Available from: https://www.physio-pedia.com/Functional_Reach_Test_(FRT)

32. Walden T. *Standardized Field Sobriety Testing: Learning from Our Mistakes.* Office of Justice Programs; 1987.

33. Zhang Y, Wang W. Reliability of the Fukuda Stepping Test to Determine the Side of Vestibular Dysfunction. *J Int Med Res.* 2011;59(4):1432–7. https://doi.org/10.1177/03000605103690451

34. Armstrong RA. When to use the Bonferroni correction. *Ophthalmic and Physiological Optics,* 2014;54(5):502–8. https://doi.org/10.1011/opo.12131

35. Weerahandi S. *Generalized Inference in Repeated Measures: Exact Methods in MANOVA and Mixed Models.* John Wiley & Sons; 2004.

36. Murariu G. *Fizică statistică și computațională- Aspecte contemporane și aplicații* [Statistical and computational physics-Contemporary aspects and applications]. Galati: Galați University Press; 2018. (In Romanian).

37. Murariu G, Munteanu D. Lucrări practice de identificare, modelare și simulare a proceselor fizice [Practical works for identification, modeling and simulation of physical processes] Galati: Galați University Press; 2018. (In Romanian).

38. Opriuc DC. Statistica aplicată în stiintele socio-umane. Analiza asocierilor și a diferențelor statistice [Statistics applied in the socio-human sciences. Analysis of associations and statistical differences]. Sibiu: Arhip Art; 2011. (In Romanian).

39. Yapra K, Küçükkubaş N. Gender-related differences on physical fitness parameters after core training exercises: A comparative study. *Progress in Nutrition.* 2020;22(3):e2020028–e2020028. https://doi.org/10.23751/pn.v22i3.9334

40. Ceylan HJ, Günyar AR. Positional differences in anticipation timing, reaction time and dynamic balance of American football players. *Pedagogy of Physical Culture and Sports,* 2020;24(5):227–39. https://doi.org/10.15561/26649857.2020.0503

41. Gonener U, Gonener A. How balance training on different types of surfaces effect dynamic balance ability and postural sway of gymnast children? *Progress in Nutrition,* 2020;22(1-S):151–7. https://doi.org/10.23751/pn.v22i1-S.9806

42. Matla J, Filar-Mierzwa K, Ścisłowska-Czarnecka A, Jankowicz-Szymańska A, Bac A. The Influence of the Physiotherapeutic Program on Selected Static and Dynamic Foot Indicators and the Balance of Elderly Women Depending on the Ground Stability. *International Journal of Environmental Research and Public Health,* 2021;18(9):4660. https://doi.org/10.3390/ijerph18094660

43. Ayfö Y, Mulazimoğlu O, Celikbilek S, Dalbudak İ, Kalafat C. The effect of Tabata training program on physical and motoring characteristics of soccer players. *Progress in Nutrition,* 2021;25(52):e2021255–e2021255. https://doi.org/10.23751/pn.v25i52.11885

44. Casonatto J, Yamacita CM. Pilates exercise and postural balance in older adults: A systematic review and meta-analysis of randomized controlled trials. *Complementary Therapies in Medicine,* 2020;48:102232. https://doi.org/10.1016/j.ctim.2019.102232

45. Donatoni da Silva L, Shiel A, Sheahan J, McIntosh C. Six weeks of Pilates improved functional mobility, postural balance and spatiotemporal parameters of gait to decrease the risk of falls in healthy older adults. *Journal of Bodywork and Movement Therapies,* 2022;29:1–9. https://doi.org/10.1016/j.jbmt.2021.06.014

46. Turkeri C, Oztuktur B, Buyuktas B, Ozturb D. Comparison of Balance, Reaction Time, Attention and BMI Values in Individual and Team Sports. *Journal of Education and Learning,* 2019;8(6):119–28. https://doi.org/10.5539/jevl.v8n6p119

47. Acar H, Eler N. The Effect of Balance Exercises on Speed and Agility in Physical Education and SportsPEDAGOGY of Physical Culture and SportsPEDAGOGY. 2019;7(1):74–9. https://doi.org/10.5539/jel.v8n6p119

48. Berisha M, Cilli M. Comparison of Eurofit Test Results of 11-17-Year- Old Male and Female Students in Kosovo. *European Scientific Journal,* ESJ. 2017;13(51): 138. https://doi.org/10.19044/esj.2017.v13n51p138

49. Morina B, Miftari F, Badau D. Fitness Level Differences between Students in Kosovo and Montenegro. *Education Sciences,* 2021;11(3):140.
50. Garcia-Hermoso A, Saavedra JM, Escalante Y, Dominguez AM, Castro-Pinero J. Effects of an exercise program with or without a diet on physical fitness in obese boys: a three-year follow-up. *Progress in Nutrition*, 2018;20(1):94–103. https://doi.org/10.23751/pn.v2011.5836

51. Iverson GL, Koehle MS. Normative Data for the Balance Error Scoring System in Adults. *Rehabilitation Research and Practice*, 2013;2013:e846418. https://doi.org/10.1155/2013/846418

52. Mi HU, Jinjing W, Xu S, Yang Z. Influence of obesity and gender on the dynamic and static balance in children aged 8-10 years [J]. *Chinese Journal of School Health*, 2021; 42(7): 1064-1067,1072. https://doi.org/10.16835/j.cnki.1000-9817.2021.07.024

53. Ku PX, Abu Osman NA, Yusof A, Wan Abas WAB. Biomechanical evaluation of the relationship between postural control and body mass index. *Journal of Biomechanics*, 2012;45(9):1638–42. https://doi.org/10.1016/j.jbiomech.2012.03.029

54. Zhu W, Li Y, Wang B, Zhao C, Wu T, Liu T, et al. Objectively Measured Physical Activity Is Associated with Static Balance in Young Adults. *International Journal of Environmental Research and Public Health*, 2021;18(20):10787. https://doi.org/10.3390/ijerph182010787

55. Kilroy EA, Crabtree OM, Crosby B, Parker A, Barfield WR. The Effect of Single-Leg Stance on Dancer and Control Group Static Balance. *International Journal of Exercise Science*, 2016;9(2): 110–120.

56. Bellafiore M, Battaglia G, Bianco A, Paoli A, Farina F, Palma A. Improved postural control after dynamic balance training in older overweight women. *Aging Clin Exp Res.*, 2011;23(5):378–85. https://doi.org/10.1007/BF03357762

57. Chang N-J, Tsai I-H, Lee C-I, Liang C-H. Effect of a Six-Week Core Conditioning as a Warm-Up Exercise in Physical Education Classes on Physical Fitness, Movement Capability, and Balance in School-Aged Children. *International Journal of Environmental Research and Public Health*, 2020;17(15):5517. https://doi.org/10.3390/ijerph17155517

58. Struhár I, Dovtělová L, Kapounková K. Effect of exercise with elastic cord on postural stability in a group of elite gymnasts. *Journal of Human Sport and Exercise*. 2014;9(1 (special issue)). https://doi.org/10.14198/jhse.2014.9.Proc1.58

59. Jorrakate C, Kongsuk J, Pongduang C, Sadsee B, Chanthorn P. Effect of yoga training on one leg standing and functional reach tests in obese individuals with poor postural control. *Journal of Physical Therapy Science*, 2015;27(1):59–62. https://doi.org/10.1589/jpts.27.59

---

Information about the authors:

**George D. Mocanu;** https://orcid.org/0000-0002-3534-5055; george.mocanu@ugal.ro; Faculty of Physical Education and Sport, “Dunarea de Jos” University of Galati; Galati, Romania.

**Gabriel Murariu;** https://orcid.org/0000-0002-7107-2007; gabriel.murariu@ugal.ro; Faculty of Sciences and Environment, “Dunarea de Jos” University of Galati; Galati, Romania.

**Vladimir Potop;** (Corresponding Author); https://orcid.org/0000-0001-8571-2469; vladimir_potop@yahoo.com; University of Pitesti, Pitesti, Romania; State University of Physical Education and Sport, Chisinau, Moldova.

Cite this article as:

Mocanu GD, Murariu G, Potop V. Optimization of body balance indices according to Body Mass Index categories during physical education lessons for university students. *Pedagogy of Physical Culture and Sports*, 2022;26(4):233–243. https://doi.org/10.15561/26649837.2022.0403

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (http://creativecommons.org/licenses/by/4.0/deed.en).

Received: 25.06.2022
Accepted: 23.07.2022; Published: 30.08.2022