BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

Analysis of differences in Muscle Power for female university students majoring in sports according to BMI levels

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Citation: Mocanu G.D. - Analysis of differences in Muscle Power for female university students majoring in sports according to BMI levels.
Balneo and PRM Research Journal **2023**, *14(1): 537*

Academic Editor:
Constantin Munteanu

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 25.02.2023
Accepted: 20.03.2023
Published: 27.03.2023

Reviewers:
Doinița Oprea
Mariana Rotariu

Publisher's Note: Balneo and PRM Research Journal stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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Abstract: Muscle Power (often expressed in terms of explosive strength or explosive force) is required in most sports activities that involve intense and rapid contractions. ***Purpose:*** Identifying the differences and their significance, between the muscle strength values for the female students of the Faculty of Physical Education and Sports, according to their classification by BMI levels. ***Material and method*:** 77 female students of the Faculty of Physical Education and Sport from Galati were evaluated through 6 upper body muscle power tests (30s Plyometric Push-Ups, Shot put, Medicine ball chest throw, Overhead Medicine Ball Throw-forward, Overhead, Medicine Ball Throw-backward, Overhand ball throw) and 7 lower body muscle power tests (Speed Test 10m, Standing Long Jump Test, Vertical Jump Test, 3-Hop Test, 30s Continuous vertical jumps, 30s Lateral double leg hop test, The multiple 5 bounds test). The groups were divided according to BMI levels (underweight 11 cases, normal weight 53 cases and overweight 13 cases). The non-parametric Kruskal–Wallis and Mann-Whitney U tests were used to assess the differences between groups. ***Results:*** Arithmetic average values indicate the superiority of underweight and normal-weight women for lower-body strength and overweight and normal-weight women for upper-body strength, especially for heavy objects throw variants. However, performance differences (assessed by ranks) are in most cases insignificant (Z values correspond to thresholds P>0.05). The only exceptions with significant differences (P<0.05) are for Overhead Medicine Ball Throw-forward (with the superiority of the overweight over the underweight) and Shot put - track and field (with the superiority of the overweight over the underweight). ***Conclusion:*** The constant involvement of female students in curricular and sports physical activities mitigates the differences between the muscle power of the 3 BMI categories. However, the small numerical composition - for the underweight and overweight groups - does not allow the generalization of the results, as studies on larger samples are needed and have common concerns related to the specifics of the sports practiced.

Keywords: students, muscle power, fast movements, sports, BMI levels, differences

1. Introduction

Physically inactive university students and those with a reduced percentage of muscle tissue have poorer vertical jump values compared to those who have higher percentages of muscle tissue and are constantly involved in physical activities. [1–3]. The results of the muscle power tests are affected by the increased percentage of fat, at the level of junior handball players (Qatar) being identified higher values of normal weight compared to overweight ones [4]. At the level of junior Greek basketball players (U-18), normal weight have the best values for horizontal jumps, but a similar performance is found in the Speed Test 10m [5]. Other research identifies negative correlations between Standing long jump test values and body fat level for Croatian teenage girls [6]. These aspects are confirmed by studies on adolescents in Brazil, for which inferior performances are obtained by overweight and underweight in tests of medicine ball throws and horizontal jumps. [7]. Excess body mass reduces the value of motor performance and affects the anatomical systems that have a role in supporting sports and leisure activities [8,9]. Other research on soccer players identifies a higher level of aerobic fitness for players used more in matches, but not for anaerobic strength/jumping tests [10].

A study of children and adolescents from 7 European countries followed the dynamics of SLJ/SBJ performance, highlighting progress with age and gender differences in adolescence in favor of boys. For boys, there is also an obvious increase in values up to 16-17 years [11]. For female university students in Poland (20.01 years), there is a progressive improvement in motor characteristics until 2006, followed by a decline in performance until 2018 [12].

The values of muscle power and strength are variable in ontogeny and they have an important role in the manifestation of speed indices [13]. Research on young elite Slovenian female soccer players (18.56 years) indicates that performance in agility tests is strongly and significantly correlated with short distance sprint and vertical jump, these tests have similar determinants, important aspect in identifying priority aspects in the process of training [14]. Other studies identify the major role of lower and upper body muscle strength in the success of specific high-intensity physical activities for recreationally trained military men (21.2 years), according to [15]. The manifestation of muscle power at the level of the lower body has different values for (elite) handball players, depending on the age category. The U25 and experienced (over 25 years old) teams perform significantly better than the young (U18), according to [16]. The importance of muscle power for Romanian junior handball players is mentioned by [17]. At the level of Slovenian volleyball players (18-38 years old), the explosive strength performances are better for those in the first league compared to the second league. No significant performance differences are noted between different positions/playing positions for women [18]. The analysis of muscle strength performance for young volleyball players indicates significant differences between genders, in favor of men (counter movement jump, squat jump, acceleration on 5 and 10m) and the execution technique of specific procedures depends on muscle power and is correlated with the individual value of players [19–22].

The individualization of force-velocity training in elite female soccer players (23.4 years old) requires their evaluation through sprint and jump tests [23].

The factors that influence muscle power values are extremely varied. Ingestion of caffeine in moderate doses has beneficial effects on physical performance parameters in team sports, with improvements related to repeated sprint ability, repeated jump height and agility tests being observed [24]. Maintaining an optimal level of vitamin D is important in performance of anaerobic muscle power and strength. Studies on university/collegiate athletes in different disciplines (USA) have shown that those with vitamin D deficiency have lower values in the vertical jumps, 3-Hop Test and change of direction tests [25]. The movement pattern specific to each sport influences the manifestation of the muscular strength of the lower extremities: the knee extension force is more important in weightlifting and basketball (due to the vertical movements), and the knee flexion force is more important in soccer (due to the fast movement pattern) , according to [26]. Vertical jump efficiency is better, with improvement in vertical trunk supportability, according to a study on non-sporting Japanese university students (men and women, 19.7 years old), but this beneficial effect is no longer observed after the interruption of training/detraining phase [27]. Optimizing explosive strength performance at the upper body level is related to the fact that the subsequent explosive task and conditioning activity (CA) must be as similar as possible to the movement model/pattern to be executed, in order to maximize and capitalize on post activation performance enhancement (PAPE) [28].

Even if the use of static stretching (SS) is counter-indicated before physical efforts (due to the negative effects on muscle strength performance), research on junior handball female players has demonstrated the beneficial effect of combining SS with dynamic warm-up, thus improving medicine ball throwing performance [29]. Other authors indicate the beneficial effect of static stretching exercises for hip flexors with increased VJT performance in a study of Indian university students majoring in sports [30]. The exclusive use of active static stretching in the warm-up reduces the value of VJT for a group of university students from the Faculty of Physical Education and Sport in Malaysia (18-28 years) compared to a dynamic warm-up based on jumping (without the use of muscle stretching), according to [31].

Sports performances are conditioned by the quality of the musculoskeletal system, physical activities having beneficial effects on the body's systems and functions [32–35]. The large gluteal muscle has an important role in straightening the knee joint and producing a significant and positive mechanical work, which ensures knee extension and implicitly an increased value of repeated vertical jumps, according to a study on Japanese university students (20.7 years), athletics practitioners [36]. For female teenage Brazilian handball players, muscle imbalances (quadriceps stronger than hamstrings), combined with the presence of dynamic postural balance deficits, can favor the occurrence of musculoskeletal injury [37]. Studies of adolescent soccer players indicate strong and significant associations between balance and lower body strength tests: countermovement jump (CMJ), standing long jump (SLJ), and 3-hop jump test. The correlations reported between the tests increase with age and indicate a transfer between these motor skills [38]. Studies on soccer players show the importance of Hop tests (as an indicator of physical performance) for players who have recovered from lower limb injuries and are returning to competitive activity. They show values similar to those of teammates who did not suffer injuries, except for the side hop [39].

Subjects subjected to repeated vertical jump tests modify their jumping technique, reduce force production and muscle activity as an effect of muscle fatigue, and these manifestations are specific to both genders [40]. The onset of the fatigue state (neuronal and contractile) generates decreases in explosive strength values, an aspect confirmed by research on untrained adult men (23.7 years) [41]. The onset of fatigue generates a decrease in performance in tests based on jumps (Continuous Vertical Jump 30 s), stiffness and joint angles being signaled, and changes in intralimb coordination also appear at the end of the effort [42]. In this sense, the continuous vertical jumps 30s test provides useful information related to the level of cardiovascular demand for those evaluated, also allowing the evaluation of other functional aspects in high-intensity efforts, but the superior mobilization of the cardiovascular function is achieved for the variant lasting 50-60s [43].

The usefulness and efficiency of plyometric training in increasing the value of muscle power for different branches and sports events is highlighted by [44–47]. Application of plyometric training for 10 weeks x 2 sessions/week to First League female soccer players (19.3 years) significantly optimized lower body muscle strength performance in sprint, counter movement jump/CMJ and standing broad jump [48]. For Indian cricketers (20-26 years old), using plyometric push-ups is more effective than using swiss ball push-ups in terms of increasing throwing distance, especially when looking to improve performance in a short period of time [49]. Plyometric push-ups have an important role in making adaptations to the type of stretch-shortening cycle stress at the level of the upper body. Push-ups are frequently used in training programs in martial arts, boxing, baseball, military, fitness, etc., with positive effects on muscle power, strength and endurance [50]. For female MMA (Mixed Martial Arts) practitioners, the importance of developing strength, muscle power and endurance is highlighted, HIIT strength exercises specific to this sport being recommended, insisting on the development of explosive strength throughout the body [51].

Explosive strength tests (SLJ, VJT, short distance runs, shot put, medicine ball throw, etc.) were frequently used to assess the fitness level of Polish university students (1953-2010), but the main independent variable studied was gender and fewer comparisons have been made related to anthropometric parameters, environmental variables and other factors [52].

The purpose of the research is to identify the differences and their significance, between the muscle power values for the female students of the Faculty of Physical Education and Sport, according to their classification by BMI levels.

2. Materials and Methods

2.1. Participants

All female students of the Faculty of Physical Education and Sport in Galati (77 cases) from the 1st and 2nd years of the bachelor's degree, specializing in Physical Education and Sports, were invited to participate in this cross-sectional study, planned in May 2019. After the anthropometric measurements, the group was divided into 3 groups, according to belonging to the 3 BMI classes: underweight (N=11, age=19.818±0.981, BMI=17.354±0.963), normal weight (N=53, age=20.547±1.461, BMI= 20,888±1,560), overweight (N=13, age=20,769±1,165, BMI=26,053±0,766). The anthropometric data and the involvement in curricular and performance physical activities for the 3 groups are summarized in table 1. It is observed that for the groups of underweight and normal weight women there is a balance between the athletes and non-athletes participants, an aspect that is not valid for the group of overweight, where the number of non-athletes is double that of sportswomen. The subjects involved in the study were investigated and obtained a favorable medical opinion to undergo physical tests. All requirements related to the protection of personal data specific to investigations involving human subjects (Declaration of Helsinki) have been complied with [53,54].

Table 1. The distribution of the studied women by groups and the analyzed anthropometric variables

Indicator	No. of subjects	Athletes	Non-athletes	Height	Weight	BMI
Underweight	11(14.29%)	6(7.79%)	5(6.49%)	164.363±8.969	47.000±5.656	17.354±0.963
Normal weight	53(68.83%)	27(35.06%)	26(33.78%)	167.301±6.562	58.537±6.283	20.888±1.560
Overweight	13(16.88%)	4 (5.19%)	9(11.69%)	163.538±7.264	69.846±6.829	26.053±0.766

2.2. The organization of the research

The organization of the evaluation tests was planned in the Research Center for Human Performance, affiliated to the Faculty of Physical Education and Sport in Galati. Upper body muscle power was assessed by 6 field tests (30s Plyometric Push-Ups/repetitions, Shot put/cm, Medicine ball chest throw/cm, Overhead Medicine Ball Throw-forward/cm, Overhead Medicine Ball Throw- backward/cm, Overhand ball throw/m). The muscle power of the lower body was evaluated by 7 field tests (Speed Test 10m/s, Standing Long Jump Test/cm, Vertical Jump Test/cm, 3-Hop Test/cm, 30s Continuous vertical jumps/ number of repetitions , 30s Lateral double leg hop test number of repetitions, The multiple 5 bounds test/cm). Additional information related to the applied set of tests can be found in the source [55]. Student instruction included an explanation of the tests and instructions to avoid high-intensity efforts prior to taking the assessment so that subjects are not tested during muscle fatigue stage. Power tests in endurance mode (repetitive jumps and plyometric push-ups) were done at the end of the assessments.

2.3. The statistical analysis of data

The statistical calculation was performed using the SPSS software (Statistical Package for the Social Sciences/IBM Vers.24 Chicago, IL, USA). The numerically reduced batches of underweight and overweight students, combined with the results of the Shapiro Wilk data distribution normality test, determined the application of non-parametric tests. The Kruskall-Wallis test (the non-parametric equivalent for ANOVA when there are at least 3 independent samples) and Mann-Whitney U (the non-parametric equivalent for the t-test on pairs of independent samples) were used. Chi-Square/$\chi 2$ values, Z values and significance thresholds/Sig were highlighted. For a better understanding of the dynamics of the results on the 3 BMI levels, the average performance values were graphically represented [56–61]. The confidence interval was set at 95% ($P<0.05$).

3. Results

Graphs 1 and 2 indicate the average performance values related to the muscular power of the lower and upper body for the 3 groups analyzed. It is observed that normal weight women have the best scores for SLJ, 3 Hop test, 30s Lateral double leg hop test and 30s Vertical jumps, and underweight women have the best results for VJT, The multiple 5 bounds and Speed test 10m. We note that in all the lower body strength evaluation tests, the overweight group obtains the lowest average results, so excess body mass negatively influences horizontal and vertical jump performances.

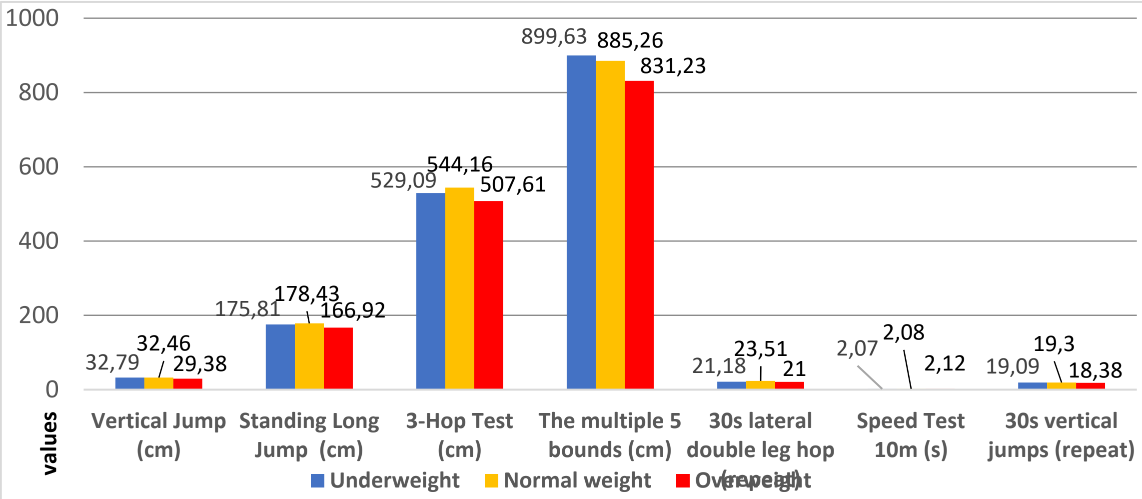

Figure 1. The average performance values in the muscle power tests for the lower body on the 3 BMI categories

However, the dynamics of the results changes between the groups for the strength of the upper body, where we find an obvious superiority of the normal weight and the overweight for most of the tests. In the Shot put test we notice that the overweight group has the best average score, but in the other tests we note that the normal weight group has the best values. Underweights perform worst on medicine ball and shot put tests, so body mass deficits on these assessments are a disadvantage.

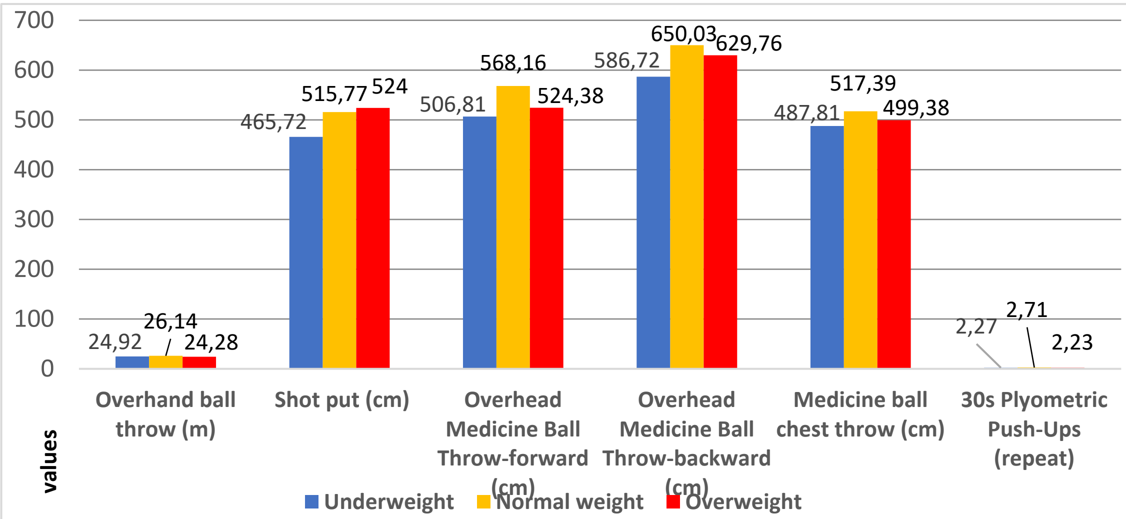

Figure 2. The average performance values of the muscle power tests for the upper body in the 3 BMI categories

Tables 2 and 3 summarize the Kruskall-Wallis non-parametric test values for the 3 groups. We found that the Chi-Square ($\chi 2$) scores indicate that there are no differences in the medians (by calculating the ranks in the data distribution) between the 3 groups, for all lower and upper body strength tests, so the null hypothesis cannot be rejected, for the entire set of applied tests (Sig.> 0.05). Neither BMI group statistically dominates any other group in the tests of muscle strength.

Table 2. The results of the non-parametric Kruskall-Wallis test in the 3 levels of BMI for the investigated groups / muscle power of the lower body (underweight=11, normal weight=53, overweight=13)

Test	Group	Mean Rank	Chi-Square	df	Asymp. Sig.
Vertical Jump Test/VJT	a. underweight	42.05			
	b. normal weight	41.05	3.761	2	0.153
	c. overweight	28.08			
Standing Long Jump Test/SLJ	a. underweight	38.86			
	b. normal weight	41.60	3.584	2	0.167
	c. overweight	28.50			
3-Hop Test	a. underweight	36.50			
	b. normal weight	41.96	3.646	2	0.162
	c. overweight	29.04			
The multiple 5 bounds test/MB5	a. underweight	45.18			
	b. normal weight	40.50	4.423	2	0.110
	c. overweight	27.65			
30s lateral double leg hop test	a. underweight	37.09			
	b. normal weight	40.78	1.250	2	0.535
	c. overweight	33.35			
Speed Test 10m	a. underweight	35.64			
	b. normal weight	38.38	1.044	2	0.593
	c. overweight	44.38			
30s Continuous vertical jumps	a. underweight	39.91			
	b. normal weight	39.91	0.625	2	0.731
	c. overweight	34.54			

Table 3. The results of the Kruskall-Wallis non-parametric test at the 3 BMI steps for the investigated groups / the muscle power of the upper body (underweight=11, normal weight=53, overweight=13)

Test	Group	Mean Rank	Chi-Square	df	Asymp. Sig.
Overhand ball throw	a. underweight	36.27			
	b. normal weight	40.47	0.748	2	0.688
	c. overweight	35.31			
Shot put -track and field	a. underweight	29.23			
	b. normal weight	39.51	3.123	2	0.210
	c. overweight	45.19			
Overhead Medicine Ball Throw-forward	a. underweight	26.73			
	b. normal weight	42.46	4.942	2	0.085
	c. overweight	35.27			
Overhead Medicine Ball Throw-backward	a. underweight	29.91			
	b. normal weight	40.91	2.201	2	0.333
	c. overweight	38.92			
Medicine ball chest throw	a. underweight	33.77			
	b. normal weight	40.12	0.735	2	0.693
	c. overweight	38.85			
30s Plyometric Push-Ups/clap push ups	a. underweight	40.45			
	b. normal weight	40.15	1.218	2	0.544
	c. overweight	33.08			

The comparison of the results between the performances of the underweight and normal weight groups (tables 4 and 5) does not indicate significant differences for the lower body power assessment tests. All Z values for the Mann Whitney U test correspond to P>0.05 thresholds. The situation is similar for the upper body power tests, the only exception being reported for the Overhead Medicine Ball Throw-forward, with the superiority of the normal weight group (Z=-2.091, P=0.037).

Table 4. Nonparametric Mann Whitney U test results between underweight and normal weight for lower body muscle power (underweight=11, normal weight=53)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Vertical Jump Test	a. underweight	33.36	367.00	282.000	-0.169	0.866
	b. normal weight	32.32	1713.00			
Standing Long Jump Test/	a. underweight	30.95	340.50	274.500	-0.303	0.762
	b. normal weight	32.82	1739.50			
3-Hop Test	a. underweight	28.73	316.00	250.000	-0.659	0.460
	b. normal weight	33.28	1764.00			
The multiple 5 bounds test	a. underweight	35.86	394.50	254.500	-0.659	0.510
	b. normal weight	31.80	1685.50			
30s lateral double leg hop test	a. underweight	29.64	326.00	260.000	-0.561	0.575
	b. normal weight	33.09	1754.00			
Speed Test 10m	a. underweight	30.86	339.50	273.500	-0.321	0.749
	b. normal weight	32.84	1740.50			
30s Continuous vertical jumps	a. underweight	32.50	357.50	291.500	0.000	1.000
	b. normal weight	32.50	1722.50			

Table 5. Results of nonparametric test Mann Whitney U between underweight and normal weight for the muscle power of the upper body (underweight=11, normal weight=53)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Overhand ball throw	a. underweight	29.50	324.50	258.500	-0.588	0.557
	b. normal weight	33.12	1755.50			
Shot put -track and field	a. underweight	26.00	286.00	220.000	-1.272	0.203
	b. normal weight	33.85	1794.00			
Overhead Medicine Ball Throw-forward	a. underweight	21.82	240.00	174.000	-2.091	0.037
	b. normal weight	34.72	1840.00			
Overhead Medicine Ball Throw-backward	a. underweight	25.18	277.00	211.000	-1.433	0.152
	b. normal weight	34.02	1803.00			
Medicine ball chest throw	a. underweight	28.27	311.00	245.000	-0.828	0.408
	b. normal weight	33.38	1769.00			
30s Plyometric Push-Ups/clap push ups	a. underweight	32.59	358.50	290.500	-0.019	0.985
	b. normal weight	32.48	1721.50			

The analysis of the non-parametric differences between the results of the underweight and overweight groups (tables 7 and 8) also indicates non-significant differences for the lower body muscular power evaluation tests (all Z values are associated with P>0.05 thresholds). At the level of the upper body, only one significant difference is found, in favor of the overweight group, at Shot put (Z=-2.086, p=0.035). For the rest of the tests, all values of Z correspond to insignificant thresholds.

Table 6. Results of the non-parametric Mann Whitney U test between underweight and overweight for lower body muscle power (underweight=11, overweight=13)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Vertical Jump Test	a. underweight	14.68	161.50	47.500	-1.393	0.164
	b. overweight	10.65	138.50			
Standing Long Jump Test/	a. underweight	13.91	153.00	56.000	-0.899	0.369
	b. overweight	11.31	147.00			
3-Hop Test	a. underweight	13.77	151.50	57.500	-0.812	0.417
	b. overweight	11.42	148.50			
The multiple 5 bounds test	a. underweight	15.32	168.50	40.500	-1.797	0.072
	b. overweight	10.12	131.50			
30s lateral double leg hop test	a. underweight	13.45	148.00	61.000	-0.610	0.542
	b. overweight	11.69	152.00			
Speed Test 10m	a. underweight	10.77	118.50	52.500	-1.102	0.270
	b. overweight	13.96	181.50			
30s Continuous vertical jumps	a. underweight	13.41	147.50	61.500	-0.582	0.560
	b. overweight	11.73	152.50			

Table 7. Results of the non-parametric Mann Whitney U test between underweight and overweight for upper body muscle power (underweight=11, overweight=13)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Overhand ball throw	a. underweight	12.77	140.50	68.500	-0.174	0.862
	b. overweight	12.27	159.50			
Shot put -track and field	a. underweight	9.23	101.50	35.500	-2.086	0.035
	b. overweight	15.27	198.50			
Overhead Medicine Ball Throw-forward	a. underweight	10.91	120.00	54.000	-1.014	0.311
	b. overweight	13.85	180.00			
Overhead Medicine Ball Throw-backward	a. underweight	10.73	118.00	52.000	-1.130	0.259
	b. overweight	14.00	182.00			
Medicine ball chest throw	a. underweight	11.50	126.50	60.500	-0.637	0.524
	b. overweight	13.35	173.50			
30s Plyometric Push-Ups/clap push ups	a. underweight	13.86	152.50	56.500	-0.934	0.350
	b. overweight	11.35	147.50			

Insignificant performance differences are found between the normal weight and overweight groups for all 13 muscle power tests (tables 8 and 9). All Z values correspond to P>0.05 thresholds for this pair. Even though graphs 1 and 2 indicate the superiority of normal weight over overweight for lower and upper body muscle power tests, comparison by non-parametric tests shows only non-significant Z-scores.

Table 8. Results of the non-parametric Mann Whitney U test between normal weight and overweight for lower body muscle power (normal weight=53, overweight=13)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Vertical Jump Test	a. normal weight	35.73	1893.50	226.500	-1.906	0.057
	b. overweight	24.42	317.50			
Standing Long Jump Test/	a. normal weight	35.78	1896.50	223.500	-1.952	0.051
	b. overweight	24.19	314.50			
3-Hop Test	a. normal weight	35.68	1891.00	229.000	-1.863	0.063
	b. overweight	24.62	320.00			

The multiple 5 bounds test	a. normal weight	35.70	1892.00	228.000	-1.878	0.060
	b. overweight	24.54	319.00			
30s lateral double leg hop test	a. normal weight	34.69	1838.50	281.500	-1.017	0.309
	b. overweight	28.65	372.50			
Speed Test 10m	a. normal weight	32.54	1724.50	293.500	-0.823	0.410
	b. overweight	37.42	486.50			
30s Continuous vertical jumps	a. normal weight	34.41	1823.50	296.500	-0.776	.438
	b. overweight	29.81	387.50			

Table 9. Results of the non-parametric Mann Whitney U test between normal weight and overweight for upper body muscle power (underweight=53, overweight=13)

Test	Group	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig.
Overhand ball throw	a. normal weight	34.35	1820.50	299.500	-0.726	0.468
	b. overweight	30.04	390.50			
Shot put -track and field	a. normal weight	32.66	1731.00	300.000	-0.718	0.473
	b. overweight	36.92	480.00			
Overhead Medicine Ball Throw-forward	a. normal weight	34.75	1841.50	278.500	-1.064	0.287
	b. overweight	28.42	369.50			
Overhead Medicine Ball Throw-backward	a. normal weight	33.89	1796.00	324.000	-0.331	0.741
	b. overweight	31.92	415.00			
Medicine ball chest throw	a. normal weight	33.75	1788.50	331.500	-0.210	0.834
	b. overweight	32.50	422.50			
30s Plyometric Push-Ups/clap push ups	a. normal weight	34.67	1837.50	282.500	-1.058	0.290
	b. overweight	28.73	373.50			

4. Discussion

The results of our groups were compared with other expert references (which included groups of the same age) to identify differences and commonalities related to muscle power values.

High fat mass reduces performance for sedentary Indian female students (21-25 years old), who achieve only 22.05cm in vertical jump/CMJ [62]. At the level of Brazilian amateur boxers of the national team, strong associations between the value of punching impact and the level of muscle strength and strength of the lower limbs are highlighted. The values for CMJ are 27.07cm for women, according to [63]. These results are weaker compared to those of our group, but it must be taken into account that the evaluation by CMJ has a different technique compared to VJT, and the results are slightly lower in the first situation.

Caffeine use by female sports games practitioners (24 years) produces significantly higher knee flexor and extensor values. The group of sportswomen who used caffeine obtained an average value of 40.1cm at CMJ, slightly better compared to the control group (39.7cm), according to [64]. For the elite Spanish handball players (25.74 years old), average values of the vertical jump (CMJ) of 42.6cm are obtained, but the analysis on the playing positions shows obvious differences, also generated by the somatotype variations: center (46.3cm), wing (44.1cm) , back (41.8cm), goalkeeper (41.4cm), pivot (38.3cm) [65]. The combined effect of plyometric training (horizontal, lateral and depth jumps) with training based on weight exercises, on machines for different muscle groups, has positive results on vertical jump performance. Indian volleyball players (21 years old) obtain - after applying this program for 8 weeks x 3 weekly sessions - an increase in VJT/Sargent test values from 35.6cm to 42.4cm [66]. The application of moderate-load and high-load training for young women (20.3 years old), applied for 8 weeks - with alternating lower and upper body efforts - generates increases in VJT (43.1cm vs. 43.8 cm) [67]. All these studies, however, identify superior results in vertical jumps, compared to those obtained by us for the 3 BMI groups.

The use of basketball structures/themes in physical education lessons (15 weeks) for Vietnamese female university students (20.06 years old) generates an increase in performance in tests of agility, sprinting, endurance and explosive strength of the lower limbs. The women in the basketball group, however, obtain a result of 169.97cm at SLJ, superior and insignificant to that of the control group (169.75cm), according to [68]. These results are superior to our overweight group, but inferior to the other 2 tested groups.

Poor results in the horizontal jumps are recorded for Taiwanese female university students, 149.66 cm, with negative correlations between BMI scores and explosive leg strength at the SLJ being reported [69]. Activities in physical education lessons for university students in Saudi Arabia (both genders) improve fitness levels. Average performances of 163.9 cm for soccer and volleyball players and 166 cm for badminton players are recorded at SLJ [70]. The gender and level of physical activity influence lower limb strength values for Italian adolescents (16 years old), for girls an average of 162.4cm at SLJ was reported [71]. Varied strength and endurance training (HIIT, Turbo and Full-body) applied for 6 weeks to non-sporting Polish university students (24.09 years old) contributes to the improvement of body composition and physical fitness indicators. An initial average result of 160.45cm is obtained at SLJ, and at the end we obtain 170.73cm [72]. According to (Zileli & Söyler, 2018), average values of VJT of 31cm are identified for junior girls from the Turkish national boxing team (15.85 years). Our study obtained values superior to these analyzed data, for most of the investigated groups, but it must be taken into account that a series of researches were carried out on younger girls (juniors).

The efficiency of plyometrics in increasing strength performance is highlighted for university female soccer players in Turkey (18.3 years). With just 8 weeks of additional training, significantly higher final scores are achieved for dominant triple leg jumps (560cm) and standing long jump (192.3cm) [73]. Bilateral application of Kinesiotape (KT) at the level of the quadriceps muscle (with a tension of 75%), for university students in Saudi Arabia (19-21 years) shows an improvement in results for SLJ, from 180.04 to 184.52cm [74]. These studies obtained superior leg muscle power values compared to our research.

Involvement in physical activities based on Traditional Exercise Baduanjin (12 weeks x 5 days per week x 1 hour/day) in Chinese medical students (18-25 years, mostly female) has beneficial effects on physical and psychological levels. For the SLJ, a final average performance of 179cm is obtained [75]. This value is close to that obtained by our normal weight group. Other studies in American university student athletes (sprinters and jumpers) and non-athletes (20 years) identify the strong association between maximal strength values and SLJ performance. For SLJ, athletic women 228 cm and non-athletic women 161 cm [76]. The values of the groups of athletes are definitely higher than those obtained by our groups, and those of non-athletes are lower.

Implementation of a program based on Baduanjin exercise for Chinese medical university students (12 weeks x 4 days x 1 hour) provides beneficial effects on fitness level parameters. For SLJ women get extreme values between 126cm and 207cm [77].

Investigations of Japanese university students indicate differences between genders and levels of physical activity engagement for explosive strength tests. Female athletes achieve values for VJT 50.5cm and SLJ 201.6cm, better results compared to non-athletes (37.7 cm and 157 cm). [78]. Our groups have poorer scores compared to these values for VJT and SLJ, only the non-athlete group in the mentioned study having poorer values for SLJ.

For female athletes from USA X (22.67 years old), involved only in team sport games, average scores of 43.44cm are obtained for the VJT, 1.98s for the 10m acceleration test and 179cm for the SL, [79]. Developing lower body muscle strength is an important component in the training of USA Lacrosse (18 years old) players. Average performances of 39.3 cm at CMJ and 1.9s at 10m sprint were identified, strong correlations were also reported between these 2 tests [80]. The performance analysis of the 10m acceleration test (for adolescent Taekwondo practitioners) identifies close values between genders: 1.79s for females and 1.76s for males [81]. The use of short-duration sprint exercises as a substitute for classical training in Norwegian teenage soccer girls improved performance in the 10m Speed test from 1.99s to 1.91s [82]. Research on female soccer players from Chile indicates negative, strong and significant associations between vertical jump performance and short sprint (10 and 30m) and moderate 180^0 direction changes. For junior (16.4 years) and senior (26.4 years), in the 10 m sprint both categories get the same result (2.0s), according to [83]. We obtained weaker values for acceleration over 10m compared to the results of these studies.

Research on university athletes mostly involved in team sport games/TSG identifies that performance in vertical jump tests is a predictor of agility performance only for women, and short distance speed performance for both genders. In the 10m sprint women obtain an average value of 2.17s [84]. This is one case where all of our groups have outperformed.

Studies on Italian high school girls (16.2 years) - in relation to fitness level assessment - indicate 521.9cm in Standing Overhead Medicine Ball Throw 2kg/forwards [85]. However, the different weight of the medicine ball does not allow an objective comparison with the values of our groups.

The use of plyometrics in the training of female volleyball players from Kosovo (high level, 21.6 years old) optimizes explosive leg and arm strength performance compared to Skill-Based Conditioning. Average results of 205.3cm in SLJ, 48.5cm in CMJ and 760cm in medicine ball throw (MBT) are obtained [86]. The inclusion of medicine ball training (for 12 weeks) in the training program of young female handball players (16.9 years) ensures a significant increase in upper body muscle strength. When throwing the medicine ball (3kg), all performances are improved for all execution variants (797cm for medicine ball chest throw, respectively 698cm for Overhead Medicine Ball Throw/forwards) [87]. The results of these studies are superior to the performance recorded by our research.

5. Conclusions

The comparison of the average values between the results of the 3 tested groups confirms the superiority of normal-weight and underweight women for the muscle power of the lower body, and the overweight group has the worst performance in the jumping tests. For the tests of upper body muscle power, better values of normal and overweight are identified, especially for throwing medicine balls and shot put, with the underweight group having the lowest scores in these tests. However, the analysis of the significance of the differences between the 3 groups (by non-parametric methods) indicates only two significant differences, where the values of Z are associated with $P<0.05$: Overhead Medicine Ball Throw-forward (with the superiority of the normal weight over the underweight) and Shot put - track and field (with the superiority of the normal weight over the underweight). We can state that curricular and sports physical activities reduce the gaps between performances for the 3 groups (according to BMI levels). However, the results must be viewed with caution, due to the small groups of underweight and overweight students, but also because the female students tested are involved in different sports activities, which have a specific influence on the muscle power values.

Author Contributions: "Conceptualization, G.D.M.; methodology, G.D.M.; software, G.D.M.; validation, G.D.M.; formal analysis, G.D.M..; investigation, G.D.M.; resources, G.D.M.; data curation, G.D.M.; writing—original draft preparation, G.D.M.; writing—review and editing, G.D.M..; visualization, G.D.M.; supervision, G.D.M.; project administration, G.D.M.; funding acquisition, G.D.M. The author have read and agreed to the published version of the manuscript."

Funding: "This research received no external funding"

Institutional Review Board Statement: "The study was conducted according to the guidelines of the Declaration of Helsinki, and ap-proved by the Institutional Review Board (or Ethics Committee) of "Dunarea de Jos" University of Galati.".

Informed Consent Statement: All investigated students agreed to participate in the study.

Acknowledgments: The author of this work thanks the students of the Faculty of Physical Education and Sports from Galati, for their involvement in the research carried out.

Conflicts of Interest: "The author declares no conflict of interest."

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