

Effectiveness of ballistic exercises for increasing upper body explosive power in physical education lessons for university students

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Abstract

Background and Study Aim Explosive power is an important element of fitness levels, with fast muscle contractions being required in most physical activities. Study implements and verifies the effects of ballistic exercises with medicine balls of various weights on upper body explosive strength for non-sporting university students.

Material and Methods The study involved 184 male and 143 female undergraduate students, all 21 years old. These students had no medical contraindications to participating in the activities required by the physical education program. The development of upper body explosive strength was conducted using ballistic exercises, specifically various types of medicine ball throws, over one academic year. The evaluation comprised six tests: Overhand Ball Throw, Overhead Medicine Ball Throw-forward, Overhead Medicine Ball Throw-backward, Medicine Ball Chest Throw, Shot Put - Track and Field, and 30 s Plyometric Push-Ups. These tests were scheduled at three different times during the academic year: October, December, and May.

Results The results of the Analysis of Variance (ANOVA) with repeated measurements indicate F values associated with statistically significant thresholds ($p < 0.05$). In contrast, partial eta squared (η^2_p) values demonstrate a stronger effect of ballistic exercise application for the male group. Significant improvements in results were observed for both genders from one test to another. The differences were notably larger between the test conducted before the winter holiday (December) and the test at the end of the second semester (May) compared to those between the test at the beginning of the academic year (October) and the one before the winter holiday (December). This pattern indicates a clear improvement in muscle strength in the second semester (January-May). The only test where high percentages of men, and especially women, encountered problems was the 30-second Plyometric Push-Ups. In the final tests, 10% of males and 40% of females scored zero.

Conclusions Ballistic exercises based on various medicine ball throws prove to be an attractive and effective solution to improve upper body muscle strength for non-sporting university students. The application of these exercises can significantly enhance physical education programs by providing clear benefits in terms of strength development. This is particularly evident in environments aimed at general student populations rather than athletes. Furthermore, while the exercises are broadly beneficial, they may require modifications to address the challenges some students face.

Keywords: university students, throws, medicine balls, muscle strength, acceleration, physical education.

Introduction

The importance of developing upper body strength in educational settings is increasingly recognized due to its significant impact on the overall physical health and performance of students. Ballistic exercises, which are dynamic and involve rapid movements, have been identified as particularly effective for this purpose. The term ‘ballistic’ originates from the Greek word ‘*ballein*’, which means ‘to throw’. Ballistic exercises for the upper body typically involve throwing and swinging various objects. These activities not only enhance muscular power but also contribute to the improvement of motor skills and coordination.

Ballistic performance is assessed by several tests (bench throw, medicine ball throws, ability to jump) [1, 2, 3]. Ballistic training involves the recruitment of fast motor fibers, intra- and intermuscular coordination, provides improved strength and contraction velocity, and improves neural factors. The neuromuscular system has different adaptations to ballistic training, compared to the classical version, where movements are slowed or blocked. The ballistic variant aims to maximize acceleration in the concentric contraction phase for the movements on the involved segments [4, 5, 6]. Ballistic exercises maximize the stretch-shortening cycle that characterizes plyometric training, increasing the acceleration of throwing movements of various objects. Their application (for 6 weeks) to

pubertal badminton players improved the quality of badminton overhead simple stroke [7]. For power-based trained athletes (PTA) better values of muscle power are identified for the ballistic bench-throw (BBT) variant compared to athletes using hypertrophy training programmes [8].

Muscular strength and muscle power (explosive force) are influenced by a complex of factors: quality of the periodization process, type of applied training, simultaneous recruitment of motor units, muscle section surface/area, etc. For basketball players, body composition values as well as training and competition experience influence muscle power and speed performance for the upper limbs [9]. Maintaining optimal muscle temperature is important to avoid decreased muscle power and acceleration ability [10]. Anthropometric dimensions (total arm length, upper-arm length, forearm length and upper-arm girth) influence upper-body muscle strength. Research on rugby players (approximately 24 years old) has shown that players with longer upper limbs, greater girths, greater maximal strength and power outputs generate maximal power by using a lower percentage of load, relative to 1RM/one repetition maximum [11]. At the level of Japanese Female Wrestlers differences in upper limb muscle strength are identified between national level and world-class wrestlers. Pull power and Power Endurance have better values for world-class wrestlers [12]. Other solutions to improve muscle performance for the upper and lower body are alternatives to the classical method (resistance training/RT). The redistribution set structure/RR (8 sets x 5 reps x 51 rest between sets) applied on untrained youth is equally effective for muscle hypertrophy, maximal strength and endurance performance. However, no progress is obtained in upper body muscle strength, according to [13].

The importance of muscle strength in conditioning sports performance is mentioned in numerous studies. Explosive power is crucial in supporting agility and sprint performance [14, 15, 16]. Explosive arm muscle strength significantly influences the skill of jump serve for volleyball players, but also self-confidence [17]. For martial arts practitioners (wrestling, judo, sambo) hand grip strength plays a decisive role in achieving performance [18]. For Japanese female university students (approximately 21 years old) with sports specialisation (track and field or volleyball) the development of isokinetic muscle strength of the trunk has positive effects on trunk stabilization and jump value [19]. Other studies explore and demonstrate the reliability of the Seated Medicine Ball Throw as a test of upper body muscle strength [20]. The type of exercises placed between sets for upper body muscle strength development has varying acute effects, depending on their typology. Variants of plyometrics for agonist muscle groups

and stretching for agonist muscles are effective in increasing strength until the fourth set, where decreases in performance are then observed [21].

The proposed methodology for improving muscle strength and power is diverse. Verification of the effectiveness of High-intensity power training (HIPT) vs. classical/traditional resistance training (TRT) on young subjects (approximately 22 years old) indicates the usefulness of both methods. However, HIPT application has faster effects on lower and upper limb explosive strength and increases in mean anaerobic power [22]. The combination of resistance training with time restricted eating for already trained young men (approximately 24 years old) provides beneficial effects on explosive movements in the upper body, but not in the lower body, according to [23]. The implementation of cluster set configuration (3 weeks x 2 workouts/week) in the training of athletic university students is more effective than the traditional training variant. Adaptations related to muscular strength and speed are optimized, according to [24]. For stronger athletes, the application of explosive strength optimization methods is indicated, for weaker athletes developing strength is indicated first, as a subsequent basis for muscular strength training [25]. Strength-power periodization (SPP) is important in order to scientifically plan strength development in distinct phases/stages: muscle hypertrophy phase, muscle strength and power phase (where neural adaptations are targeted). The use of loads above 80% of 1RM is recommended for advanced performance athletes, with positive effects on medicine ball throwing. Lower loads (30% of 1RM) are used for the ballistic variant [26]. The inclusion of circuit resistance training and mobility exercises for Indian university students (17 – 24 years old) gives better values of movement velocity and explosive force [27]. For university-aged males (approximately 24 years old), bench press execution at 80% of 1RM by two variants (full range of motion/ROM and self-selected partial ROM) shows no significant differences in ballistic push-up (BPU) execution capacity. Both variants have similar effects on ballistic push-ups, although partial ROM generates lower fatigue [28]. A comparison of the effects of Ballistic Bench Press vs. Non-ballistic Bench Press exercises on Plyometric Push-up Test values (net impulse and take-off velocity) finds no significant differences. A possible explanation for this result is acute muscle fatigue generated by programmed effort [29].

Ballistic push-ups are used as an exercise before testing upper limbs muscle strength for mixed martial arts/MMA fighters. Those with better experience and training levels should use a high load for activation exercises, according to [30]. For rugby players, the superiority of ballistic exercises vs. traditional exercises in terms of mean propulsive velocities (MPVs) is mentioned by [31]. The use

of ballistic training (through ballistic resistance exercises) demonstrated its effectiveness in Egyptian gymnasts. Skill performance for acrobatic structures and physical specific abilities are improved [32]. The application of ballistic and plyometric training (8 weeks) for Indian male university volleyball players (18 – 23 years old) results in improvements in muscle strength and vital capacity values [33]. For elite male athletes, the use of isometric bench press (with 80% of 1RM) and ballistic bench throw (with 40-55% of 1RM) are useful to increase dynamic strength index (DSI). The ballistic version provides improvements in bench-throw peak force [34]. The use of ballistic drills in training Egyptian discus throwers brings improvements in explosive power. Its advantage lies in compensating for the lack of speed, specific to classical strength training with weights. The ballistic version is closer to the specific demands of competitive throwing [35]. A comparison of strength training vs. ballistic-power training for novice throwers (shot put) shows positive effects of both variants. Throwing performance increases similarly in both cases, but power training provides greater increases in ballistic throws. In contrast, muscle thickness hypertrophy is evident only after strength training. The percentage of fast fibres/type 2 decreased after strength training, but not after ballistic strength training [36].

Working hypothesis: We estimate that by using the ballistic method – in physical education lessons at the level of non-sporting university students – we will achieve improvements in field test values for upper body muscle strength.

Purpose of the research: Most of the reviewed research promotes the effectiveness of ballistic training in optimising muscle strength. Our study implements and verifies the effects of ballistic exercise with medicine balls of varying weights on explosive upper body strength.

Materials and Methods

Participants

The study was carried out on students of

“Dunarea de Jos” University of Galati, from the Faculty of Automatic, Computer Science, Electrical Engineering and Electronics and the Faculty of Medicine and Pharmacy (Dental medicine). All students of these specialisations (1st and 2nd year undergraduate) who participated in the physical education lessons were invited to get involved in the research. 371 students responded favourably, of which 327 cases remained for statistical processing. Students who were involved in performance sports or had constant participation in leisure-time physical activities were excluded (25 cases). Data was also excluded for those who did not attend most of the planned training sessions in lessons, or who did not participate in taking all muscle strength tests (19 cases). Values for the age-related groups of females and males and anthropometric characteristics are summarised in Table 1.

Research Design

The implementation of the ballistic training programme was conducted during the academic year 2018-2019, from October to May, before the outbreak of the Covid 19 pandemic. The three testing moments were planned at the beginning of the academic year in October (T1), before the winter holiday in December (T2), and at the end of the second semester in May (T3).

The students were informed about the purpose of the study and the tests applied in the Human Performance Research Center, affiliated with the Faculty of Physical Education and Sports of Galati. The deontological rules of conducting research with human subjects were respected, according to [37, 38]. The evaluation included 6 upper body muscle strength tests that are listed in Tables 3-5, details of the technique for performing the medicine ball throwing variants are available at [39].

In the lessons (held weekly) exercises were programmed for upper body muscle strength using the ballistic method, for lower body muscle strength using the plyometric method. In the manuscript only the data for upper body strength is analysed, in another paper the results for lower body strength

Table 1. Statistical indicators for age and somatic parameters in the two investigated groups (184 males and 143 females)

Variables	Gender	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Age (years)	Male	18.50	31.00	21.0707	.14506	1.96775
	Female	18.00	25.00	20.7238	.12101	1.44704
Weight (kg)	Male	50.00	148.00	77.4891	1.32301	17.94618
	Female	39.00	90.00	61.6503	.98867	11.82279
Height (cm)	Male	162.00	193.00	176.8424	.48895	6.63240
	Female	150.00	181.00	164.6154	.50970	6.09511
BMI	Male	16.30	42.75	24.7118	.37847	5.13383
	Female	15.62	36.10	22.7963	.37183	4.44648

Table 2. Exercises summary based on the use of medicine balls for ballistic training

Nr.	Name of the exercise, variants, and description of the execution technique
1.	<i>Chest pull with ball release</i> / From sitting with knees bent and torso leaning forward, medicine ball between palms at knee level, elbows extended. Perform elbow flexion with repeated pulling of the ball toward the chest and releasing it quickly.
2.	<i>Throw preceded by quick steps</i> / From a forward lunge with the knee of the back foot on the ground and the medicine ball placed on the ground next to the ankle of the front foot, 3 – 4 m away from the wall. The subject stands up quickly and takes 2 steps forward, with the ball being thrown into the wall and caught before it falls to the ground, then returns to the starting position and repeats the structure.
3.	<i>Chest press and overhead throw</i> / From standing facing the wall, 1 – 3 m distance, throwing the medicine ball with two hands from the chest, catching the ball and throwing it into the wall with two hands from above the head. Ditto with one-armed throwing, by pushing the ball and twisting the torso (<i>Fire ball</i>). Exercises can also be performed in pairs, with alternating variations of throwing the ball.
4.	<i>Russian bounce</i> / From sitting with knees bent and heels off the ground, twisting the torso right-left, with alternating throwing the ball into the ground on each side.
5.	<i>Tall slam and Tall rotational slam</i> / From standing with the medicine ball held with both palms at chest level, raising the arms vertically and explosively throwing the ball to the ground, recovering, and resuming the action. Idem with standing on tiptoes, twisting the torso and throwing to the ground on the right/left side.
6.	<i>Knees to feet slam</i> / From the knees, with the medicine ball held between the palms at chest level. The subject stands up suddenly and hits/throws the ball vigorously to the floor, catches it and returns to the starting position. Idem with starting from a standing position and executing 2-3 shots, quick steps, followed by throwing the ball to the ground (<i>Jab step slam</i>). Idem from a forward lunge and hitting the ball into the ground with the torso twisting to the same side (<i>Split stance rotational slam</i>). Idem with lifting from a lunge, side step with hitting the ball on the ground, retrieving the ball and returning (<i>Kneeling side jump + slam</i>).
7.	<i>Catch and throw</i> / From standing sideways to the wall at a distance of 2 – 4 m, ball held between the palms, quick side step and throwing the ball into the wall with recovery and return to the original position. Idem with ball received from a partner, with roles reversed after 20 – 30 seconds.
8.	<i>Uppercuts</i> / From standing with knees bent and medicine ball held between palms, uppercuts (twisting the torso to the right, followed suddenly by extending the knees and twisting the torso to the left, with explosive raising of the outstretched arms, without releasing the ball). Idem with the change of execution side.
9.	<i>Seated overhead throw</i> / In pairs, one behind the other, the one in front is sitting far away with a medicine ball between the palms, the other sitting on a high surface/support. The one sitting throws the ball with both palms by extending the elbows vertically (above the head), it is caught by the partner and returned to the one on the ground. After 20 – 30 seconds the roles are reversed. Idem with the <i>supine chest press</i> .
10.	<i>Seated overhead scoop toss</i> / From a sitting position with the medicine ball held between the palms of the hands on the floor, the torso is extended by lifting and throwing the ball overhead backward. Idem with throwing the ball from chest forward into the wall. Idem with throwing the ball from overhead forward. Idem with side twisting the torso and throwing the ball forward into the wall.
11.	<i>Explosive push up</i> / From the top of the feet face down, palms resting sideways on the medicine ball on the ground, ballistic/explosive push-ups with lifting the ball from the floor to the chest and back up.
12.	<i>Fighter sit up</i> / From supine facing the wall, knees slightly bent and heels flat on the floor, 2 – 3 m distance, lift into seated with medicine ball thrown against the chest with both arms. Idem with face-to-face pair passes, distance 2 -5 m.
13.	<i>Monster slam</i> / From standing position with bent knees, medicine ball held between palms at chest level, alternately lifting one knee and explosively throwing the ball perpendicular to the floor, recovering it and repeating the action. Idem with lifting from forward lunge and hitting the ball into the floor (<i>Step up to slam</i>).
14.	<i>Knees to feet scoop toss</i> / From the knees with the ball held with both palms at chest level, lift with crouch pass, then vertical jump with the extension of the arms and throwing the ball vertically.
15.	<i>Overhead throw and hip extension</i> / From forward lunge with ground support of the kneecap and rear tow, raising the arms with the medicine ball between the palms, torso extension with throwing the ball into the wall and lifting the rear tow off the ground. The exercise can also be performed in pairs facing each other, spaced 4 – 6 m apart.
16.	<i>Side to side press</i> / From standing with knees bent, explosive stretching of the arms with the medicine ball held between the palms in different directions: forward, right oblique, left oblique.
17.	<i>Squat overhead throw</i> / From a standing position, with the medicine ball held between the palms of the hands at chest level, perform a semi-bend, then extend the knees, jump vertically, and throw the ball vertically with both arms.

Table 2 (continued).

Nr.	Name of the exercise, variants, and description of the execution technique
18.	<i>Kneeling lateral jump and shotput</i> / From forward lunge, side jump with return to starting position, quick twist of the torso with medicine ball thrown into the wall. Idem with a succession of 2 -3 successive side steps before throwing.
19.	<i>Hipe drive and press</i> / From standing facing the wall, 2 – 4 m distance, semi-bending followed by extending the legs and throwing the ball into the wall on the lifting phase.
20.	<i>Kneeling overhead throw</i> / From the knees with the medicine ball held with both palms at pelvis level, distance 2 – 3 m from the wall, extend the torse with raising the arms and throwing the ball into the wall. Idem with throwing the ball forward from the chest. Idem with pair throws facing each other from the same position, distance between partners is variable. Idem with twisting the torso right-left and throwing the ball into the ground.
21.	<i>Alternating step bass and toss</i> / From standing with the back to the wall (2 – 4 m away), turn 180 degrees and throw the ball into the wall with both arms from the hip. Idem with passes between partners, arranged in pairs back to back, with the side on which the throw is made changing right/left.
22.	<i>Side step and toss</i> / From standing facing the wall, distance 2 m, throwing the medicine ball from the hip with both arms, catching it and rethrowing. Change throwing side after each execution.
23.	<i>Split stance side toss</i> / From a forward lunge with the body parallel to the wall, distance about 1.5 – 2 m, throwing the medicine ball into the wall by twisting the torse and keeping the position of the legs. Perform 20 – 30 second throws from the hip on the right side, then change the position by turning 180 degrees and perform the throws on the left side as well.
24.	<i>Trunk jump to slam</i> / From standing with the medicine ball held at chest level, jump with lifting the knees, landing and throwing the ball quickly to the ground.

Table 3. Results of sphericity test and parametric ANOVA test with repeated measures by gender (upper body explosive force)

Test	Lot	Maucly's Test of Sphericity		Correction factor	df	Error df	F	Sig.	Partial eta squared (η^2_p)
		Sig.	ϵ						
Overhand ball throw (OBT)	M	0.000	0.549	Greenhouse-Geisser	1.098	200.925	14.809	0.000	0.075
	F	0.000	0.860	Huynh-Feldt	1.721	244.374	60.741	0.000	0.300
Overhead Medicine Ball Throw-forward 3kg	M	0.000	0.578	Greenhouse-Geisser	1.155	211.447	995.900	0.000	0.845
	F	0.000	0.552	Greenhouse-Geisser	1.103	156.665	342.305	0.000	0.707
Overhead Medicine Ball Throw-backward 3kg	M	0.000	0.596	Greenhouse-Geisser	1.191	218.013	764.332	0.000	0.807
	F	0.000	0.521	Greenhouse-Geisser	1.041	147.886	68.021	0.000	0.324
Medicine ball chest throw 3kg	M	0.000	0.621	Greenhouse-Geisser	1.243	227.428	862.012	0.000	0.825
	F	0.000	0.514	Greenhouse-Geisser	1.028	146.005	81.310	0.000	0.364
Shot put - track and field	M	0.000	0.650	Greenhouse-Geisser	1.301	238.045	1166.154	0.000	0.864
	F	0.000	0.638	Greenhouse-Geisser	1.276	181.145	360.083	0.000	0.717
30s Plyometric Push-Ups/clap push ups	M	0.000	0.733	Greenhouse-Geisser	1.466	268.270	324.494	0.000	0.639
	F	0.000	0.755	Huynh-Feldt	1.493	210.338	76.493	0.000	0.350

Table 4. Comparison of pair results according to the differences between the means of the three assessments in the upper body explosive strength tests (Male/N=184)

Test	Mean	Std. deviation	Std. error	T1-T2	Sig. ^b	T1-T3	Sig. ^b	T2-T3	Sig. ^b
Overhand ball throw T1	34.736	7.752	0.572						
Overhand ball throw T2	34.791	7.772	0.573	-0.055	0.956	-0.237*	0.000	-0.183*	0.004
Overhand ball throw T3	34.973	7.709	0.568						
Overhead Medicine Ball Throw forward T1	791.923	118.145	8.710						
Overhead Medicine Ball Throw forward T2	794.135	118.226	8.716	-2.212*	0.000	-5.022*	0.000	-2.810*	0.000
Overhead Medicine Ball Throw forward T3	796.945	118.206	8.714						
Overhead Medicine Ball Throw backward T1	1027.891	180.695	13.321						
Overhead Medicine Ball Throw backward T2	1030.668	180.754	13.325	-2.777*	0.000	-5.804*	0.000	-3.027*	0.000
Overhead Medicine Ball Throw backward T3	1033.695	181.035	13.346						
Medicine ball chest throw T1	768.293	91.309	6.731						
Medicine ball chest throw T2	770.701	91.339	6.734	-2.408*	0.000	-5.272*	0.000	-2.864*	0.000
Medicine ball chest throw T3	773.565	91.240	6.726						
Shot put - track and field T1	622.141	91.589	6.752						
Shot put - track and field T2	624.212	91.721	6.762	-2.071*	0.000	-4.815*	0.000	-2.745*	0.000
Shot put - track and field T3	626.956	91.794	6.767						
30s Plyometric Push-Ups/clap push-ups T1	9.587	6.705	0.494						
30s Plyometric Push-Ups/clap push-ups T2	10.092	6.805	0.502	-0.505*	0.000	-1.228*	0.000	-0.723*	0.000
30s Plyometric Push-Ups/clap push-ups T3	10.815	7.014	0.517						

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

will be presented. Ballistic exercises with medicine balls of varying weights (1 – 3 kg) were programmed in each lesson, with alternation/change after a few cycles of lessons to avoid habituation/adaptation with the stimulus and limiting progress. On average, we used 3 – 4 different exercises/lesson, planned in 2-3 sets x 10-20-25 repetitions, with longer breaks between sets (30 – 45 seconds), than those mentioned in the literature (which gives dosing variants for performance athletes). Lighter balls were used for females and the number of repetitions was individualised so that the speed of execution of the movements was not reduced as an effect of fatigue occurrence. Table 1 shows the exercise variations most often programmed in the lessons, with additional information on execution technique provided by [40, 41].

Statistical Analysis

Anthropometric data and students' results from the explosive force tests were transferred and statistically processed with SPSS software (IBM

Vers.24 Chicago, IL, USA). Normality tests applied indicated the possibility of using the parametric ANOVA technique with repeated measures, separately by gender. Sphericity conditions were not met for any test, as a result, Huynh-Feldt ($\epsilon > 0.75$) and Greenhouse-Geisser ($\epsilon < 0.75$) correction factors were used. F-values were calculated, highlighting statistically significant thresholds and Partial eta squared (an indicator of size effect). Bonferroni correction factor was used for the differences between the mean values for the 3 pairs of data. Confidence intervals were set at 5% ($p < 0.05$) [42, 43, 44].

Results

The data obtained by applying ANOVA with repeated measures (Table 3) indicate statistically significant F values ($p < 0.05$) for all 6 tests, so the proposed ballistic exercise programme is effective. However, the η^2_p values are obviously higher for males, indicating that the influence

Table 5. Comparison of pair results according to the differences between the means of the three assessments in the upper train explosive strength tests (Female/N=143)

Test	Mean	Std. deviation	Std. error	T1-T2	Sig. ^b	T1-T3	Sig. ^b	T2-T3	Sig. ^b
Overhand ball throw T1	19.481	4.234	0.354						
Overhand ball throw T2	19.555	4.268	0.357	-0.075*	0.002	-0.265*	0.000	-0.191*	0.000
Overhand ball throw T3	19.746	4.256	0.356						
Overhead Medicine Ball Throw forward T1	500.258	80.984	6.772						
Overhead Medicine Ball Throw forward T2	503.055	80.985	6.774	-2.797*	0.000	-6.972*	0.000	-4.175*	0.000
Overhead Medicine Ball Throw forward T3	507.230	81.220	6.792						
Overhead Medicine Ball Throw backward T1	570.244	116.120	9.710						
Overhead Medicine Ball Throw backward T2	572.755	116.586	9.749	-2.510*	0.000	-6.035*	0.000	-3.524*	0.000
Overhead Medicine Ball Throw backward T3	576.279	116.913	9.777						
Medicine ball chest throw T1	469.972	83.079	6.947						
Medicine ball chest throw T2	473.175	83.136	6.952	-3.203*	0.000	-7.881*	0.000	-4.678*	0.000
Medicine ball chest throw T3	477.853	83.153	6.954						
Shot put - track and field T1	460.860	77.819	6.508						
Shot put - track and field T2	462.335	77.848	6.510	-1.476*	0.000	-3.566*	0.000	-2.091*	0.000
Shot put - track and field T3	464.426	78.104	6.531						
30s Plyometric Push-Ups/clap push-ups T1	1.398	2.643	0.221						
30s Plyometric Push-Ups/clap push-ups T2	1.727	2.883	0.241	-0.329*	0.000	-0.678*	0.000	-0.350*	0.000
30s Plyometric Push-Ups/clap push-ups T3	2.077	3.213	0.269						

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

of the implemented programme explains higher percentages of the variance in the applied tests compared to the female values. For example, for a medicine ball chest throw 3 kg, in males, 82.5% of the variance of the result in this test is explained by the proposed programme, while in women only 36.4% of the variance is influenced by the independent variable. The worst side effect values are found for overhand ball throw (OBT), with 30% of the variance in men and only 7.5% of the variance in women explained by the application of ballistic exercises.

The differences identified between the pairs of results for the 3 successive measurements in males are summarized in Table 4. With the exception of the Overhand ball throw test, where for the pair (T1-T2) we found a non-significant difference ($p > .05$), for the other pairs of data only statistically significant differences are identified ($p < .05$). We observed for all tests greater progress (better differences between means) for semester 2 (T2-T3) compared to the first semester (T1-T2). This indicates that

the accumulations were lower in the first stage and the adaptation to the used exercises had smaller effects on upper body muscle strength values. An interesting aspect should be reported for the 30 s Plyometric Push-Ups, where there are however a few cases that cannot perform this test (null/0 plyometrics push-up result). Males with 0 push-ups: T1 = 24 cases/13.04%, T2 = 20 cases/10.86%, T3 = 18 cases/ 9.78%. Even if the number of students who can perform at least one push-up increases from one stage to the next, this result is an indicator of the low fitness level for some of the students.

The results of the females group for the three measurements are shown in Table 5. In contrast to males, all differences between pairs of data are statistically significant ($p < .05$). We observe the same situation of obtaining larger differences between T2-T3 compared to T1-T2 as for the male group. However, for the 30 seconds Plyometric Push-up test, we report a much higher number of cases where the result is null, even if there is significant progress from one stage to the next. This

test is the only one that indicates the impossibility of obtaining a positive result for a high percentage of females. Zero plyometric push-ups obtained at T1 - 72 females/50.34%, at T2 - 62 females/43.35%, and T3 - 58 cases/40.55%.

The statistical comparison of the differences between genders in the applied tests has not been made, with figure 1 representing the mean values of the two groups in the final tests. The superiority of the males group is clear, a fact confirmed by all similar research that has studied muscle strength values at the upper body level.

Discussion

The results achieved should be viewed with reserve, unlike the sports training we had only one activity per week, with goals oriented towards explosive strength. Studies on the application of training programmes on non-sporting university students are very few, with most research channelled into explorations at the level of performance sport. For this reason, a comparison of results is irrelevant, as the athletes' results are clearly superior.

Research on health university students (23 - 25 years old) distinguishes gender differences in ballistic arm movements. Males score higher than females for throwing velocity and maximum moments of forces at the muscle level [45]. And for the batches we investigated, males have superior values in all applied tests.

The use of weightlifting training for competitive handball players (approximately 21 years old) for 8 weeks x 2 sessions/week facilitated improvements related to throwing velocity, muscle hypertrophy, and maximal upper limb strength. In the 3 kg medicine ball overhead throw test significant progress was achieved, from 18.5 m initially, to 26 m [46]. Muscle strength training is a good alternative to classical karate training (Kumite training) for increasing execution speed indexes and explosive movements. The explosive upper body performance of overhead medicine ball throwing is improved by a 6 week programme [47]. The values obtained by our batches are obviously weaker for the 3 kg medicine ball overhead throw test.

A programme applied to handball players (approximately 20 years old) for 12 weeks x 2 sessions/week yields improvements in throwing, maximal strength, peak power and acceleration capacity [48]. Evaluation of upper body explosive strength for athletic throwers (approximately 20 years/college level) can be done by several tests/variants: push up jump, one repetition maximum of the bench press/ BP - 1RM or medicine ball throw/ MBT. Of these variants, a strong and significant association was evidenced between athletic performance and medicine ball throw, so this test is very useful in physical fitness evaluation. Results on the other two tests are strongly influenced by body mass or do not identify the shrinkage rate of

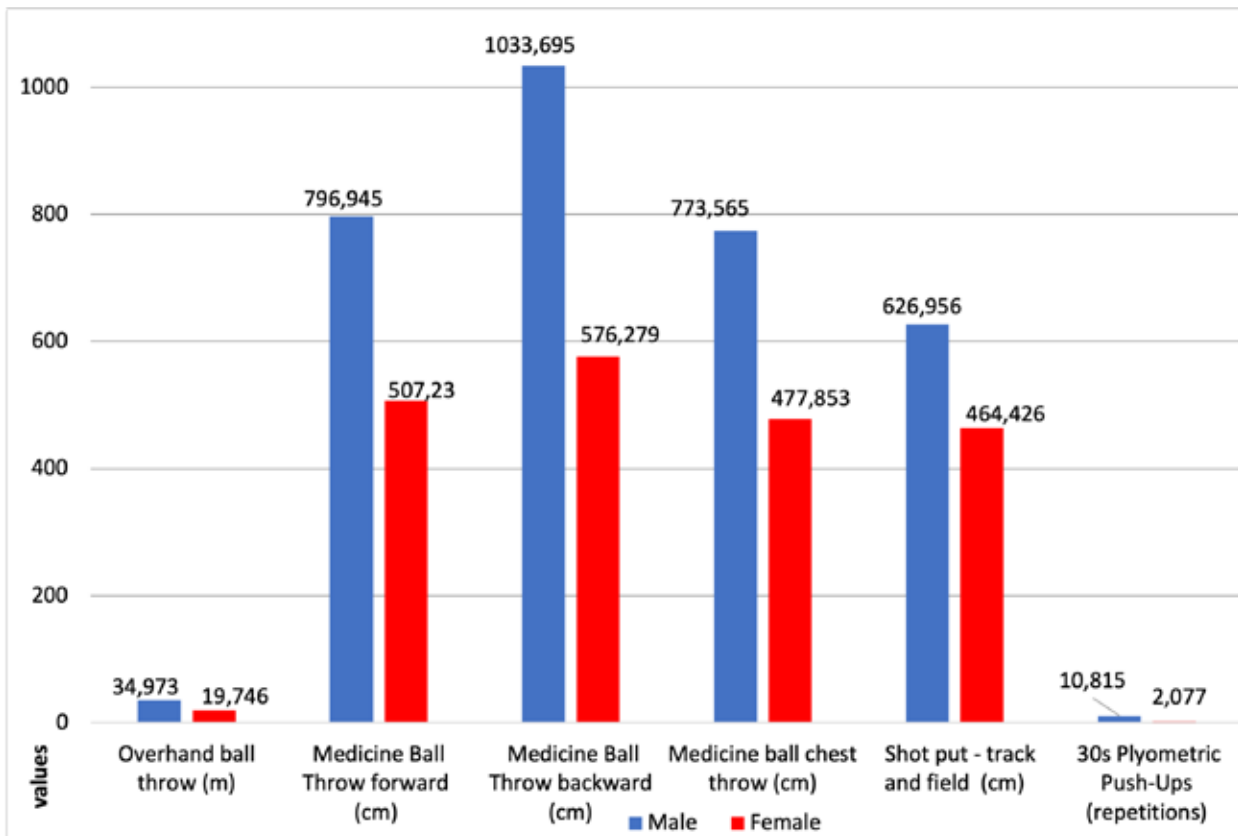


Figure 1. Mean values of final test results, comparatively presented by gender

the muscle required for the execution of the throws, according to [49]. Our batches obtained a significant improvement in performance for the 3 variants of medicine ball throw. Reporting results on body mass and BMI indicators could not be presented in this study due to the high volume of data.

Using Post-activation Potentiation/PAP for Bosnian university student athletes (21 years old) provides an increase in upper body muscle strength for medicine ball throwing. The best performance is achieved at 3x3 – 90% of 1RM, with a recovery time of 7 minutes [50]. Implementing Lower Body Postactivation Exercises provides an improvement in results for the Shot Put test. Significant differences are found after using plyometric push-ups and isometric push-ups for undergraduate physical education students (18 – 23 years old) with one year experience in track and field throws. We obtain 855 cm for females and 1110 cm for males after the application of the plyometric push-up variant, according to [51]. The results of our groups are obviously worse for shot put, but they have from the start an obvious deficit of experience, muscle mass development and strength.

Using the ballistic bench press is a useful option for optimising strength and power, as well as assessing upper body speed [52, 53]. Unfortunately, our students could not benefit from these exercise variants due to lack of access to the gym.

The application of ballistic training using a special arm and shoulder strength device (2 sessions/week x 8 weeks) is effective for Tunisian handball players (approximately 18 years old). Performance is increased from a number of parameters: peak velocity, peak power, peak force, muscle volume, and ball throwing velocity for jump throw and standing throw [54]. The implementation of the Ballistic Six exercise program (12 weeks) for young female volleyball players provides an improvement in upper body muscle strength. Performance on push-ups and overhead medicine ball throwing tests is increased, according to [55]. The application of ballistic resistance training over a period of 6 weeks for young Egyptian female swimmers (approximately 21 years old) resulted in optimized start times and muscle strength compared to traditional training [56]. Muscle strength training and throw-based ballistic training (5 exercises x 3 sets) applied for 8 weeks are equally effective in terms of progress in multiple directions. Improvements in strength, explosive power, muscle endurance and agility have been found for male table tennis players/elite level [57]. We used alternating 3 – 4 exercises x 2 – 3 sets x 10 – 20 reps with 30 – 45 seconds break between sets in lessons due to the low fitness level of the students.

Research on young men (18 – 35 years old) has shown that ballistic push-up exercise (BPU) is a tool with a good level of reliability for assessing upper

body muscle strength and power. Ballistic push-up execution generates maximal power outputs in the absence of external load, compared to load at 10 and 20% of body mass [58, 59]. Other sources indicate that Explosive Push-ups exercises are optimal variants for increasing upper body muscle power. At the same time, push-ups are also valid field tests for strength assessment, the execution positions (standard vs. kneeling position) allowing the adjustment of the mass supported by the arms and flight phase [60]. Even if progress is noted for plyometric push-ups, our final results for the female group indicate the existence of cases where performance on this test is still 0.

The use of training based on ballistic exercises (8 weeks x 3 sessions per week) has better results on the explosive strength of Indian volleyball players (18 – 25 years old). Significant increases in performance are found for Seated medicine ball throw [61]. Implementation of the Ballistic Six exercise programme (12 weeks) for young female volleyball players provides an improvement in upper body muscle strength. Performance on push-up and overhead medicine ball throwing tests are increased according to [55]. Inclusion of a Ballistic Six exercise programme for Indian badminton players (18 – 25 years old) results in improved outcomes related to muscle strength and shoulder strength. Seated medicine ball throw test (SMBT) results are increased by reducing the deceleration phase. For each exercise, 3 sets x 10 – 20 repetitions are performed with 30 seconds of rest between sets [62, 63]. The use of 6 ballistic exercises (7 weeks) for the upper body on a group of female tennis players has superior effects compared to classical methods. Grip Strength performance is optimized for dominant hand and Medicine ball throw (3 kg) [64]. Even though our 3 tests with the medicine ball did not involve the one-armed throw, some of these throws were included in the training programme.

Other research refutes the beneficial short-term effect (4 weeks x 2 sessions/week) of ballistic and upper body strength training for increasing throwing speed in inexperienced handball players. Neither high/strength oriented loads nor lower/light loads, specific to ballistic efforts, allow for progress in movement velocity [65]. In our case, the period of application of the ballistic exercise programme was much longer, so there were conditions and adaptations for accumulations in terms of muscle power.

For untrained individuals, young men and beginners in sports activities, the classical/Strength training vs. Ballistic Power method was tested. Both versions (applied for 10 weeks) have similar effects in terms of maximum muscle power, sprint, movement velocity and jump height. Acceleration and movement velocity were better for those trained in the Ballistic Power method. In contrast,

Strength Training – based on the execution of sport-like movements – generates higher values of muscle thickness and increased maximal neural activation. For those untrained or with a poor level of strength development, ballistic training is not recommended in the first phase until a solid foundation of strength is obtained [66]. We could not compare the two training options in our batches, but it is clear that there is a lack of a good foundation of strength training, which is why progress is not spectacular even if significant.

Comparative analysis of two different ballistic exercise programmes (with medical balls of various weights and ballistic tapes) is performed on Iraqi athletes specialising in the long jump. The application of exercises with ballistic tapes is more effective, with higher values of velocity and explosive arm strength found in medicine ball throwing tests [67]. This new variant analysed/ballistic taped may be a future research direction for our batches as well.

Conclusions

Ballistic exercises based on varied medicine ball throws are an attractive and effective solution

to improve upper body muscle strength for non-sporting university students. Even if the improvements are statistically significant, they do not reflect values that indicate very large differences from the baseline. This can be explained by the obvious initial deficiencies in the development of hypertrophy and muscle strength in students without constant preoccupation with active leisure or sports physical activities. Furthermore, these results may also be influenced by the low frequency of use of throwing-based exercises in our sample (only one activity per week). The ballistic variant still improves the results related to explosive upper body strength, but in the future, the effects generated by the use and combination of other methods aimed at optimizing muscle strength should be studied.

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Conflict of interest

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

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