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# Improving lower body muscle power indicators for non-athlete university students through plyometric exercise

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**Abstract:** Muscle power (FxV, explosive strength or explosive power) is an element of fitness level that influences the quality and efficiency of movements. Most of the studies that address plyometrics identify the effectiveness of this method at the level of performance athletes with different specializations and muscle power requirements. We considered that we can also study the possibility of using plyometrics in physical education lessons. The research identifies the benefits of implementing plyometric exercises for non-athlete university students on lower body muscle power indicators in curricular physical activities. The group of analyzed students (327 subjects/undergraduate level, of which 143 female and 184 male) participated in physical education lessons during one academic year (1 activity per week). The plyometric exercises used were jumping variants, diversified and adapted in dosage to the motor possibilities of the non-athlete students (on one or both legs, lateral, on ladder rungs or boxes, over hurdles, over cones, vertical and horizontal jumps). Their usefulness and effectiveness were verified by 3 successive tests: at the beginning, middle, and end of the academic year, through a battery of 7 lower body muscle power tests. The statistical calculation identifies significant increases in performance for both genders for all tests applied, both between the initial and final tests (T1-T3) and over the shorter time intervals/T1-T2 and T2-T3 ($p < 0.05$). For males, we found greater progress in the second semester of the year (T2-T3) for 5 of the 7 tests, so their adaptation is better and they respond to plyometric training better in the second part of the academic year. For females better progress in semester 2 (T2-T3) for 3 of the tests, respectively greater differences at the end of semester 1 (T1-T2) for 3 tests, especially for endurance power and 10 m acceleration. The research results confirm the effectiveness of plyometric exercises in increasing muscle power indicators for the studied student groups and are a useful option for improving fitness levels. The attractiveness and diversity of the used exercises ensured good student engagement in the lessons. Although the improvements are statistically significant, the results do not indicate spectacular increases and are still weaker than the values recorded in most other research. This is because the students involved in our study are not at all concerned about engaging in leisure time physical activities, except for curricular physical education activities, sedentarism being a major problem among young people.

**Keywords:** plyometrics, muscle strength, vertical and horizontal jumps, university students, fitness, sedentarism

## 1. Introduction

Plyometrics is based on the stretch-shorten cycle in the musculoskeletal system and is a high-intensity method focused on strong influences on explosive power. Jumps and various throws are the most commonly used plyometric exercises [1]. Extremely effective in increasing muscle strength and neural adaptations, the application of plyometric training to teenagers still generates controversy. Studies based on meta-analyses identify its clear advantages in increasing performance in jumping and sprinting over short distances

(10 – 20 m), but with careful monitoring of the response of young athletes [2]. Other research demonstrates the association between body balance, acceleration, and jumping ability [3].

In school physical education, plyometrics can be adapted and used, according to the motor characteristics and age of the students, the enjoyment dimension being important. Specific plyometric exercises have various positive effects: increases in muscle power, balance, agility, bone strength and speed [4]. The decrease in bone density is evident with increasing age, and body weight control and physical exercise can reduce this process [5]. Another study proposes plyometrics training model for Physical, Health, and Recreation Education students from Indonesia, applied in physical education lessons, as a viable option for improving students' fitness level [6]. Physical activities facilitate the improvement of the quality of life and bone density, the reduction of cases of osteoporosis and osteopenia and the risk of fractures for the lower body [7–9]. Plyometric training can be applied for late-phase rehabilitation (when injured athletes are very close to returning to competitive activity). However, it cannot be applied if there is a lack of strength/foundational strength, but also inflammation, acute or sub-acute sprains, soft tissue limitations, pain, joint instability, according to [10]. Prescription of physical activity as an option for improving public health is strongly conditioned by many factors, the most important being the favorable attitude related to PA/physical activities and the nutritional status of patients [11]. The use of adapted physical activities for the lower body (12 weeks) is useful for improving muscle strength and accelerates the recovery of young Total Knee Arthroplasty patients [12].

The effects of plyometrics are influenced by sport specialization and level of fitness, age, gender, duration, and types of used exercises, surface, movement technique. Although the effects on explosive power are evident in basketball players, there are also opinions that the effectiveness of plyometrics for agility and sprinting is limited [13]. This idea is reinforced by studies on young volleyball players in Iran, where applying plyometrics (6 weeks) significantly improves explosive power and lower limb strength. Results are similar to those obtained using resistance circuit training, but no significant improvements are found in speed and agility [14]. Lack of solid strength training negatively influences results in explosive strength tests. Plyometrics significantly improves the value of horizontal jump performance, but not vertical jump performance, for female volleyball players (22.66 years old) [15]. The explosive force at the lower limb is influenced by the type of stretching applied during warm-up. Positive effects are identified for the dynamic version and the combination of dynamic and static stretching. The singular application of static stretching reduces muscle power performance [16].

Variants of plyometric training improve hamstring and quadriceps muscle performance and are planned and useful in all types of sports activities (field and water sports). Planned sessions are recommended at least twice a week, with increases in muscle strength found for most programs lasting 10 weeks or more. The volume of work differs according to the sport: water sports/300 contacts per session, track and field/80 foot contacts, court sports/50 foot contacts per session. Performance and reduction of muscle soreness are influenced by the type of surface used (grass field, sand, running tracks), according to [17]. Research on university student athletes in Turkey highlights the positive effects of plyometric training on electromyography/EMG in the lower limb muscles (gastrocnemius, vastus lateralis, and vastus lateralis). However, the application of plyometric exercises (6 weeks x 2 sessions per week) has no significant effects on vertical jump values [18]. For young male track athletes, beneficial effects are found by including additional plyometric training (10 weeks x 3 sessions per week). Increases in performance on jumping and acceleration tests are noted, even though cross-sectional muscle volume and maximal strength do not show significant differences [19].

Combining plyometric training with resistance training (8 weeks x 2 sessions x 90 minutes) is a superior solution for preparing young people for puberty. This combination provides significant gains in acceleration capacity and jump/squat jump height for young basketball and football players. Plyometric training is effective for optimizing reactive strength through rapid contractions, and resistance training is preferred for increasing

concentric strength of longer duration [20]. Integrating plyometric exercises into traditional specific training for Indian Kabaddi (traditional Indian team contact sport) practitioners optimizes the fitness level of the players. Increases in explosive power, trunk, and lower limb strength, agility, and flexibility are seen after 12 weeks of training, according to [21]. However, another investigation indicates the superiority of the contrast strength training/CST method vs. the plyometric training/PT variant for adolescent footballers (after 8 weeks of application). Electromyographic activity/EMG for rectus femoris, vastus lateralis and vastus medialis, as well as force-velocity scores, are superior for CST [22]. The effectiveness of plyometrics (Plyo-Box version) applied for 8 weeks for Nigerian student athletes (soccer, basketball, handball, and volleyball players) is supported by [23]. The study shows that jump training provides increases in strength levels for the calf muscle and the hip flexors, and combining plyometrics with traditional methods is recommended.

Integrating plyometric exercises into traditional specific training for Indian Kabaddi (traditional Indian team contact sport) practitioners optimizes the fitness level of the players. Increases in explosive power, trunk, and lower limb strength, agility, and flexibility are seen after 12 weeks of training, according to [21]. Studies on female karate practitioners (18.22 years old) indicate similar effectiveness of Resistance Training and Plyometric training for muscle strength and explosive power, according to [24]. Other investigations indicate the favourable effect of plyometrics (applied to female university volleyball players' leg muscles) to enhance digging skills [25]. The cost of running can be improved by including 3 weekly sessions of strength, explosive, and plyometric training/(SEP) for adult long-distance/ultra-endurance athletes [26]. Lower-body stiffness can be improved by plyometric jumps applied to healthy legs. Training programmes longer than 7 weeks but with lower volumes of jumps per week (< 250) are recommended, according to [27]. Other benefits of plyometric exercises are related to cardiovascular health and reduced risk of disease in Nigerian university student athletes [28]. The improvement of cardiovascular parameters (Nigerian university student athletes) as an effect of plyometric exercises for the upper and lower body is mentioned by [29]. Various physical activities also favorably influence parameters associated with body composition, according to [30,31].

The main effects of plyometric exercises for volleyball players indicate benefits for performance in vertical jumps, horizontal jumps, flexibility, and agility. The use of vertical jumps in training provides superior progress, perhaps as an effect of the similarity to tests assessing explosive leg power [32]. Other research recommends plyometric training (including depth jumps) even for training pubertally athletic children oriented towards track and field. Positive effects on explosive strength increase performance in sprinting, jumping, and throwing after 17 weeks x 4 training sessions, according to [33]. Similar investigations confirm the beneficial effect of plyometrics (applied for 9 weeks) for improving lower body and upper body muscle strength and power in batches of adolescent basketball players [34]. The application of plyometric exercises (6 weeks x 4 sessions/week x 90 minutes) for Indian university student-athletes (19-25 years old) provides significant increases in agility performance but for explosive leg strength and speed, only significant improvements. The workouts used a variety of exercises: Box Jump March, Squat Jump, Vertical Depth Jump, Lateral Jump over the cone, Split Jump/lounges, and Lateral Jump (Single leg version), according to [35]. For young basketball players in Taiwan (22.16 years old), applying plyometrics (8 weeks x 3 sessions per week) increases leg muscle volume and explosive power, with positive results in jumping, sprinting, and agility [36]. Shorter programs (4 weeks) based on jump variations have an effect on explosive power for teenage basketball players in Kosovo, according to [37]. Plyometric workouts bring benefits related to explosive leg power for jumps, acceleration, and change-of-direction ability for basketball players, according to [38]. Using the My Jump 2 app is helpful in evaluating interlimb asymmetry and jump value for young female basketball players, according to [39]. Investigations based on the synthesis of 21 studies (meta-analysis) investigating the effect of plyometric exercises for untrained people (1263 cases). Most research shows significant benefits related to muscular strength, flexibility, BMI and cardiorespiratory fitness. However, the results are debatable as these investigations planned an average of 2-

3 sessions/week [40]. University students majoring in physical education use the plyometric method in independent training programs (daily routine), with positive effects for resistance and good physical performance. However, the coordination of training by professional coaches is necessary, for the scientific adaptation of training to the demands of national and international competitions [41]. The role of physical exercises for optimizing the level of fitness and health is highlighted by [42].

For female footballers (23.69 years old) the application of strength training and plyometric training improves the speed parameters of the ball. Positive effects on the angular velocity of the hip and angular velocity of the knee joint are also found, according to [43]. The benefits of applying plyometrics in training are also highlighted for university student footballers in Malaysia (18.6 years old). Progress is observed in relation to leg muscle strength and possible transfer on ball striking speed after 6 weeks [44]. The use of a submaximal plyometric resistance training method (8 weeks) for Chinese university students – specializing in dance – has significant effects on explosive leg power [45]. Research on Iranian university students has confirmed the benefits of using plyometric exercise (8 weeks x 3 sessions) for speed, agility, and anaerobic power performance [46]. The inclusion of plyometric exercises as a complementary variant of athletic training in young Italian athletes ensures increased performance in vertical jumping and sprinting [20]. The role of plyometric training on sprinting speed capacity for young females is examined by [47]. Implementation of a plyometric exercise programme (12 weeks) for adolescents in North Macedonia provides improvements in explosive power, repetitive force, and segmental velocity values [48].

Improving lower body explosive strength values is also possible in other ways. The use of an exercise resistance programme with increased intensity for male Serbian university students (20 years old) allows significant increases in velocity and peak power [49]. Plyometric training (unloaded or light-loaded) is recommended for developing explosive leg power during short phases. However, for longer training phases (annual), complex training is recommended, according to [50]. Other studies evaluate the effectiveness of combining high loads with low loads (within the same resistance training exercises). This variant (called complex training/CT) has superior results for short distance sprints/20 m and the 1-RM squat. For jumping and 10 m sprinting, similar results are obtained from other methods [51]. Combined training (plyometric and vibration), applied to Iranian university student athletes, ensures faster recovery and facilitates overcompensation [52]. For Indonesian wrestling athletes, the types of plyometric exercises recommended differ according to the level of strength development of the leg muscles. Side-to-side box shuffle training is more useful for athletes with low levels of strength, and box jump is more effective for those with high levels of leg strength, according to [53]. Improving leg muscle strength for karate practitioners (14-15 years old) can be based on the inclusion of half squat exercises and plyometric exercises side sprint jump [54]. Knee tuck jump based workouts are more effective for explosive power than those using box jump, for Indonesian male volleyball students [55]. Applying hurdle-box jump plyometric exercise is more effective for explosive strength, muscle hypertrophy, and leg strength, compared to barrier hops exercises, for adolescent athletes [56].

The purpose of our research is to determine the influence and effectiveness of the use of plyometric exercises on lower body muscle power for non-athlete university students.

Working hypothesis: We estimate that we will see significant improvemnts in performance on the muscle power battery of tests as an effect of plyometric training.

## 2. Materials and Methods

### *2.1. Participants*

The research involved 327 students (undergraduate level) with various specializations (Medicine and Computer Science/Automatics) from "Dunarea de Jos" University of Galati. Performance sports students, those who did not participate in at least 85% of the training sessions, and those who were constantly involved in other active leisure activities

were eliminated from the study and the statistical calculation so that these additional activities did not influence the results obtained. All students who did not have medical contraindications for engaging in physical exercise were involved in the research. 143 females (age = 20.72 years, weight = 61.65 kg, height = 164.61 cm, BMI = 22.79 kg/m$^2$) and 184 males (age = 21.07 years, weight = 77.48 kg, height = 176.84 cm, BMI = 24.71 kg/m$^2$) remained in the study. All participants were trained on the aim of the research and the requirements of personal data/protection/Declaration of Helsinki were respected [57,58]. The application of plyometric exercise programs and testing of students took place in the Human Performance Research Centre of the Faculty of Physical Education and Sports.

*2.2 Research Design*.

The investigation of both plyometric structure implementations was carried out over an academic year (28 weeks with one activity per week), with initial/T1 tests scheduled in October, intermediate tests in December/T2, and final tests in May/T3. Ballistic exercises to increase upper body explosive power indicators were also included in the lessons, but results from these specific tests will be published in another scientific paper. The planned plyometric exercises were diversified and used alternately to avoid limitations and keep the body constantly exposed to new training stimuli. The heterogeneous level of physical training of the participants required a variable number of sets and repetitions/lower and upper limits so that the dosage of effort could be individualized and the speed of execution of the jumps did not decrease due to fatigue, so we did not apply a standardized dosage for all students. Variants of plyometric jumps (on one or both legs, sideways, on ladder rungs or boxes, over hurdles, over cones, vertical, and horizontal jumps) were frequently used. We avoided deep jumps from high objects, as well as plyometrics with external load, in order not to put undue pressure on the Musculo-articular system and thus avoid injuries. Most of the exercises selected and applied have a simple execution technique, to be as accessible as possible to the participants. We preferred the use of plyometric and accessible structures, based on known jumping techniques and easy for the participants to execute (20-30 minutes/lesson). The work surface for the jumps was variable (grass/football field, clay/running track, concrete/hard stairs/steps). Table 1 summarises the main motor structures and their variants proposed to be used in the lesson, with information on the technical implementation details provided by [59].

**Table 1.** Synthesis and description of plyometric structures and exercises proposed for the programme applied in physical education lessons

| Nr. | Name of the exercise, derivatives, and description of the execution technique | Dosage | Rest |
|---|---|---|---|
| 1. | *Box jump* / From standing facing the box or in front of steps/stairs of varying height (15-30 cm), knees are bent (Squat) at 45 degrees, arms facing backward. Jumps are performed on steps or boxes, landing on both feet. *1 Leg landing* / Ditto with take-off on both legs and landing on one leg, successively or alternately (left-right). | 2-4 sets x 8-12 repetitions | 2-3 minutes |
| 2. | *Box jump W turn* / Jumping from standing sideways to the box or stair step/stadium, rotating the body 90 degrees, and landing on both feet. *Lateral box jump* / Ditto, with side hop on the step or box, without body rotation. It is recommended to change or alternate the sides on which the left-right split is done. *Lateral 1 leg landing* / Ditto, with side jump, body rotation, and landing on one leg. | 2-3 sets x 6-10 repetitions | 2-3 minutes |
| 3. | *Broad jump* / From squat position, long jump with take-off and landing on both feet. Execution can be linked. / *Reactive broad jump* (3-6 successive jumps), or separate, with a return to starting position and then resumed action. *Squat jump w – pause* / Ditto with vertical jumps and landing in the starting position, holding the squat position for 2-3 seconds before another jump. *Tuck jump* / Ditto with repeated vertical jumps and lifting the knees to abdomen level. | 2 sets x 8-10 repetitions | 1-2 minutes |

| | | | |
|---|---|---|---|
| 4. | *Seated jump* / From sitting on a ladder rung or box, quickly lifting the heels off the ground and arm straight up, with a vertical jump and return to sitting. *Seated 1 leg jump* / Ditto with the vertical take-off on one foot and landing on both feet, executions can be successive or alternate (left-right foot). *Seated box jump* / From sitting on a low height box or ladder rung, jumping up, and landing on a higher height surface/box placed forward. *Seated 1 leg box jump* / Ditto with single leg release and box landing. | 2-4 sets x 8-12 repetitions | 2 minutes |
| 5. | *Lunge jump* / From forward lunge, vertical release on both legs and return to starting position. Ditto with the change of leg placed forward. *Alternating jumping lunge* / Ditto with changing/alternating the front support leg after each jump. *Plyo split squat* / From standing on one leg, forward lunge on the other leg, push vigorously on the front leg and return to the starting position (successive executions on the right, then on the left). | 3-4 sets x 10-20 repetitions | 2-3 minutes |
| 6. | *Heidens* / From standing off on one leg, side jump with landing on the other leg, the movement of the arms amplifies the lift off the ground. Executions are alternating. Ditto with side jumps over different objects of varying heights (cones, heads, fences, etc.).<br>*Pogo jump* / From a slightly spread stance, short, springy hops with a break on the forefoot/sole. *1 Leg pogo jump* / Ditto with a successive release on one leg, the next series the contact leg is changed. | 2-4 sets x 8-20 repetitions | 2 minutes |
| 7. | *Kneeling to 1 leg jump* / From the kneeling position, vigorous lifting with transition to squatting on one leg, push and jump forward, then return and resume on the same or opposite leg (alternating). Ditto with jumping over an obstacle/cone. *Kneeling to broad jump* / Ditto with crouching stand pass on both legs, then long jump with airing on both legs, return and resume action, or repeat jumps if space allows. Ditto with jumping over an obstacle/cone or fence. | 2 sets x 5-10 repetitions | 2 minutes |
| 8. | *Plyo step up* / From standing with one leg raised and resting on the ladder rung or a box, explosive thrust into the leg on the rung and lifting the body onto the rung or box, with a change of leg position/movement is performed alternately on the right/left leg.<br>*Depth jump* / From standing on a ladder rung, deep jumps with landing on both feet. *1 Leg Depth jump* / Ditto with landing on one leg, successively or alternately (left-right). / *Depth jump + Squat jump and Depth jump + Broad jump* / Ditto with vertical jump and horizontal jump after touching the ground. | 2-3 sets x 15-25 repetitions | 2-3 minutes |
| 9 | *Depth jump to box jump* / From standing on the rung of the ladder or low box, deep jump, landing and another jump on a higher box. *Depth jump to box jump 1 leg landing* / Same as above, but the vertical jump and landing on the high box is done on one leg. Ditto with successive jumps on both legs or one leg over different obstacles with varying distances between them. | 2 sets x 8-10 repetitions | 2 minutes |
| 10. | *Skier jump* / From sitting, successive horizontal bilateral zig-zag jumps, arms rise vertically to amplify the movements. *Lateral squat jump* / Ditto with successive bilateral right-left side jumps, with emphasis on jump length. *Two foot lateral hops* / Ditto with short side jumps, insisting on the frequency of execution, the arms no longer amplify the movement. *One foot lateral hops* / Ditto with short side jumps on one leg, after each set the ground contact leg is changed. | 2-4 sets x 10-30 repetitions | 2-3 minutes |
| 11. | *Sprinter jump* / From a forward lunge or squat, lifting and executing 3-5 quick steps, then vertical jump on one leg. *Lateral hurdle hop in place* / From standing sideways to a fence (height 20-30 cm), alternate bilateral jumps over the hurdle, arms amplify the movement. *1 Leg lateral hurdle hop in place* / Ditto with side release on one leg, the next series the contact leg is changed. *1 Leg lateral hurdle hop -w pause* / Same as the previous exercise, but after each landing, there is a moment of balance on the contact leg. | 2-4 sets x 10-25 repetitions | 2-3 minutes |
| 12. | *Front to back hurdle hop* / Bilateral jumps over a fence with a return, knees are bent, arms amplify the movement. *1 Leg front to back hurdle hop* / Ditto with jumping and landing on one leg, after each set the contact leg is changed. *Multiple hurdle hop* / Successive bilateral forward jumps over several hurdles placed at equal distances from each other. The route is covered by the same jumps on the return. *Lateral hurdle hop* / Same as the previous exercise, but the successive jumps are | 2-4 sets x 15-30 repetitions | 2-3 minutes |

| | | | |
|---|---|---|---|
| | sideways, back and forth. *1 Leg Lateral hurdle hop* / Successive one leg side jumps over several hurdles, changing contact leg on return. | | |

Assessment of lower body muscle strength involved 7 tests as described:

**1.** *Vertical Jump Test/VJT (Sargent Jump test):* The subject is placed in a standing position lateral facing the wall with one arm raised and perfectly extended. Mark with chalk the maximum height he can reach, without rising on the toes of his feet, then he performs a jump (countermovement jump) with vertical leap on both legs and marking the wall with the fingers at the point of maximum amplitude. The difference between the two signs indicates vertical jump height. https://www.topendsports.com/testing/tests/vertjump.htm

**2.** *Standing Long Jump Test/SLJ (Standing Broad Jump):* The subject is placed with the toes behind a line drawn on the ground, feet parallel and slightly apart. A forward jump is executed with simultaneous release from both legs, with the help provided by the energetic swing of the arms. Measure the distance from the line to the heel placed furthest back. https://www.topendsports.com/testing/tests/longjump.htm

**3.** *3-Hop Test (3 double leg jumps):* Perform 3 linked/consecutive jumps, similar to the Standing Long Jump technique, with the feet apart in the frontal plane. No standing between jumps is allowed. The value of the distance traveled is recorded. https://www.topendsports.com/testing/tests/hop.htm

**4.** *The multiple 5 bounds test/MB5/*(5 forward jumps with alternative left and right leg contacts): From standing position, perform 5 forward jumps (jump steps) with alternating right-left foot contact, without stopping between steps. The total distance traveled is measured. https://journals.lww.com/nsca-jscr/Fulltext/2015/08000/Effects_of_In_Season_Short_term_Plyometric.8.aspx , https://www.youtube.com/watch?v=PucBxLDCVIk , https://www.youtube.com/watch?v=4UrdQMdgDYw

**5.** *30s lateral double leg hop test (30-Second Endurance Jump)* (jumping over the rope or fence obstacle raised at the height of the knees): The rope is held by two colleagues, at the height of the knees of each performer. Lateral jumps over the rope are performed for 30 seconds, recording the number of repetitions. Executions where there is contact between the rope and the feet are not counted. https://www.topendsports.com/testing/tests/endurance-jump-30sec.htm

6. *Speed Test 10m (Sprint test 10m):* Subjects start from standing with one foot back from the starting line and run the distance as fast as possible without slowing down at the finish line. A good warm-up before the test is indicated. https://www.topendsports.com/testing/results/sprint-tests.htm

7**.** *30s Continuous vertical jumps / Modified Bosco Repeat Vertical Jump Test 30 s with toughing a sign or an object:* From squatting with knees bent at 90 degrees, successive vertical jumps are made and return to squatting with palms on the ground, touching an object/suspended ball, at a height reduced by 1/3 from the maximum jump height value previously measured in the Vertical Jump Test /VJT. If the mark or object is not touched, those jumps are not counted. https://www.topendsports.com/testing/tests/bosco-repetitive-jump.htm , https://www.youtube.com/shorts/j0xQBdN6c9M

*2.3 Statistical Analysis.* S.PSS/Statistical Package

SPSS software (IBM Vers.24 Chicago, IL, USA) was used to transfer the recorded data during the tests and the statistical processing of the obtained results. The Kolmogorov Smirnov normality test was used, and its result allowed the application of the parametric statistical procedures ANOVA with repeated measurements, for each gender. Greenhouse-Geisser ($\varepsilon < 0.75$) and Huynh-Feldt ($\varepsilon > 0.75$) correction factors were used to identify F-values and degrees of freedom since the sphericity conditions were not met for the used test battery. Partial eta squared/size effect was calculated, and the Bonferroni correction factor was used to analyse the significance of differences between the pairs of obtained data. Confidence intervals were set in the software at 95% ($p < 0.05$) [60–62].

**3. Results**

Table 2 summarises the main data from the parametric ANOVA with repeated measures at the level of each applied test, with a separated presentation by gender. We note that F values are associated with statistically significant progress ($p < 0.05$), for the whole applied battery of tests. The size effect values ($\eta^2_p$) indicate a very strong influence of plyometric exercise for most tests. Thus, for females in the Standing Long Jump Test, 74.2% of the variance of the result is explained by the independent variable/exercise programme applied, and for the 30 s Lateral double leg hop test, 62.5% of the variance is explained by the independent variable applied. A strong influence of plyometric exercises is also reported for males: 72.5% of the variance for the Vertical Jump Test, 72% of the variance for the 30 s Lateral double leg hop test, and 71.9% for the Speed Test (10 m). The lowest size effect values are found for both genders for the multiple 5 bounds test: for males 18.8% of the variance and for females 31.3% of the variance are explained by the used plyometric exercise structures.

Table 2. Maucly's Test of Sphericity and repeated ANOVA test measure values for lower body muscle power (gender differentiated)

| Test | Lot | Maucly's Test of Sphericity | | Correction factor | df | Error df | F | Sig. | Partial eta squared ($\eta^2_p$) |
|---|---|---|---|---|---|---|---|---|---|
| | | Sig. | ε | | | | | | |
| Vertical Jump Test/VJT | M | 0.000 | 0.834 | Huynh-Feldt | 1.668 | 305.301 | 482.809 | 0.000 | 0.725 |
| | F | 0.000 | 0.604 | Greenhouse-Geisser | 1.209 | 171.659 | 165.701 | 0.000 | 0.539 |
| Standing Long Jump Test/SLJ | M | 0.000 | 0.696 | Greenhouse-Geisser | 1.392 | 254.645 | 363.068 | 0.000 | 0.665 |
| | F | 0.000 | 0.722 | Greenhouse-Geisser | 1.443 | 204.966 | 408.535 | 0.000 | 0.742 |
| 3-Hop Test | M | 0.000 | 0.579 | Greenhouse-Geisser | 1.158 | 212.004 | 168.152 | 0.000 | 0.479 |
| | F | 0.000 | 0.625 | Greenhouse-Geisser | 1.250 | 177.551 | 152.271 | 0.000 | 0.517 |
| The multiple 5 bounds test/MB5 | M | 0.000 | 0.516 | Greenhouse-Geisser | 1.032 | 188.873 | 42.457 | 0.000 | 0.188 |
| | F | 0.000 | 0.582 | Greenhouse-Geisser | 1.164 | 165.340 | 64.783 | 0.000 | 0.313 |
| 30s Lateral double leg hop test | M | 0.000 | 0.762 | Huynh-Feldt | 1.523 | 278.734 | 470.405 | 0.000 | 0.720 |
| | F | 0.000 | 0.722 | Greenhouse-Geisser | 1.444 | 205.012 | 265.787 | 0.000 | 0.652 |
| 30s Continuous vertical jumps | M | 0.000 | 0.937 | Huynh-Feldt | 1.873 | 342.843 | 214.120 | 0.000 | 0.539 |
| | F | 0.000 | 0.690 | Greenhouse-Geisser | 1.379 | 195.877 | 197.642 | 0.000 | 0.582 |
| Speed Test (10m) | M | 0.000 | 0.627 | Greenhouse-Geisser | 1.254 | 229.525 | 468.608 | 0.000 | 0.719 |
| | F | 0.000 | 0.715 | Greenhouse-Geisser | 1.430 | 203.040 | 97.517 | 0.000 | 0.407 |

Table 3 shows the mean values of the results of the group of male students at each of the three points of the assessment. We found that there is progress from one stage to the next and this is in all cases statistically significant ($p < 0.05$), which confirms the effectiveness of the proposed plyometric exercise programme. For the Vertical Jump Test, Standing Long Jump Test, 3-Hop Test, 30 s Lateral double leg hop test, and 30 s Continuous vertical jumps, we identified higher performance increases in the 2nd semester (T2-T3) compared to those in the first semester (T1-T2). This indicates that the adaptive response to the proposed plyometric exercises was better in the second part of the academic year. The only exception is the multiple 5 bounds test and Speed Test (10 m), where the differences/progress at the semester 1 level are greater than those in semester 2. Even if the differences between the initial and final tests (T1-T3) are not spectacular, the fact that they still show statistically significant progress is a supporting argument for the viability of the different jumping variants in increasing lower body explosive power values.

**Table 3.** Comparison of values and lower body muscle power tests by data pair, according to differences between the means of the three assessments (Male/N=184)

| Test | Mean | Std. deviation | Std. error | T1-T2 | Sig.[b] | T1-T3 | Sig.[b] | T2-T3 | Sig.[b] |
|---|---|---|---|---|---|---|---|---|---|
| Vertical Jump Test/VJT T1 | 32.622 | 7.953 | 0.586 | -0.408* | 0.000 | -1.019* | 0.000 | -0.611* | 0.000 |
| Vertical Jump Test/VJT T2 | 33.029 | 7.955 | 0.587 | | | | | | |
| Vertical Jump Test/VJT T3 | 33.641 | 7.962 | 0.587 | | | | | | |
| Standing Long Jump Test/SLJ T1 | 192.750 | 30.464 | 2.246 | -0.660* | 0.000 | -1.554* | 0.000 | -0.894* | 0.000 |
| Standing Long Jump Test/SLJ T2 | 193.410 | 30.391 | 2.241 | | | | | | |
| Standing Long Jump Test/SLJ T3 | 194.304 | 30.366 | 2.239 | | | | | | |
| 3-Hop Test T1 | 578.956 | 84.025 | 6.194 | -1.261* | 0.000 | -2.772* | 0.000 | -1.511* | 0.000 |
| 3-Hop Test T2 | 580.217 | 84.078 | 6.198 | | | | | | |
| 3-Hop Test T3 | 581.728 | 84.030 | 6.195 | | | | | | |
| The multiple 5 bounds test/MB5 T1 | 976.706 | 117.388 | 8.654 | -2.500* | 0.000 | -4.196* | 0.000 | -1.696* | 0.007 |
| The multiple 5 bounds test/MB5 T2 | 979.206 | 117.317 | 8.649 | | | | | | |
| The multiple 5 bounds test/MB5 T3 | 980.902 | 117.719 | 8.678 | | | | | | |
| 30s Lateral double leg hop test T1 | 21.320 | 9.452 | 0.697 | -0.538* | 0.000 | -1.364* | 0.000 | -0.826* | 0.000 |
| 30s Lateral double leg hop test T2 | 21.858 | 9.461 | 0.698 | | | | | | |
| 30s Lateral double leg hop test T3 | 22.684 | 9.448 | 0.697 | | | | | | |
| 30s Continuous vertical jumps T1 | 12.940 | 3.472 | 0.256 | -0.310* | 0.000 | -0.853* | 0.000 | -0.543* | 0.000 |
| 30s Continuous vertical jumps T2 | 13.250 | 3.464 | 0.255 | | | | | | |
| 30s Continuous vertical jumps T3 | 13.793 | 3.481 | 0.257 | | | | | | |
| Speed Test (10m) T1 | 2.083 | 0.168 | 0.012 | 0.014* | 0.000 | 0.027* | 0.000 | 0.012* | 0.000 |
| Speed Test (10m) T2 | 2.069 | 0.168 | 0.012 | | | | | | |
| Speed Test (10m) T3 | 2.056 | 0.167 | 0.012 | | | | | | |

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 4 summarizes the mean scores on the 3 tests and the differences between them for the group of females. As in the case of males, we report progress from one assessment to the next and significant differences between the pairs of resulting data ($p < 0.05$), so the usefulness of plyometric training is also found for the group of females. However, we

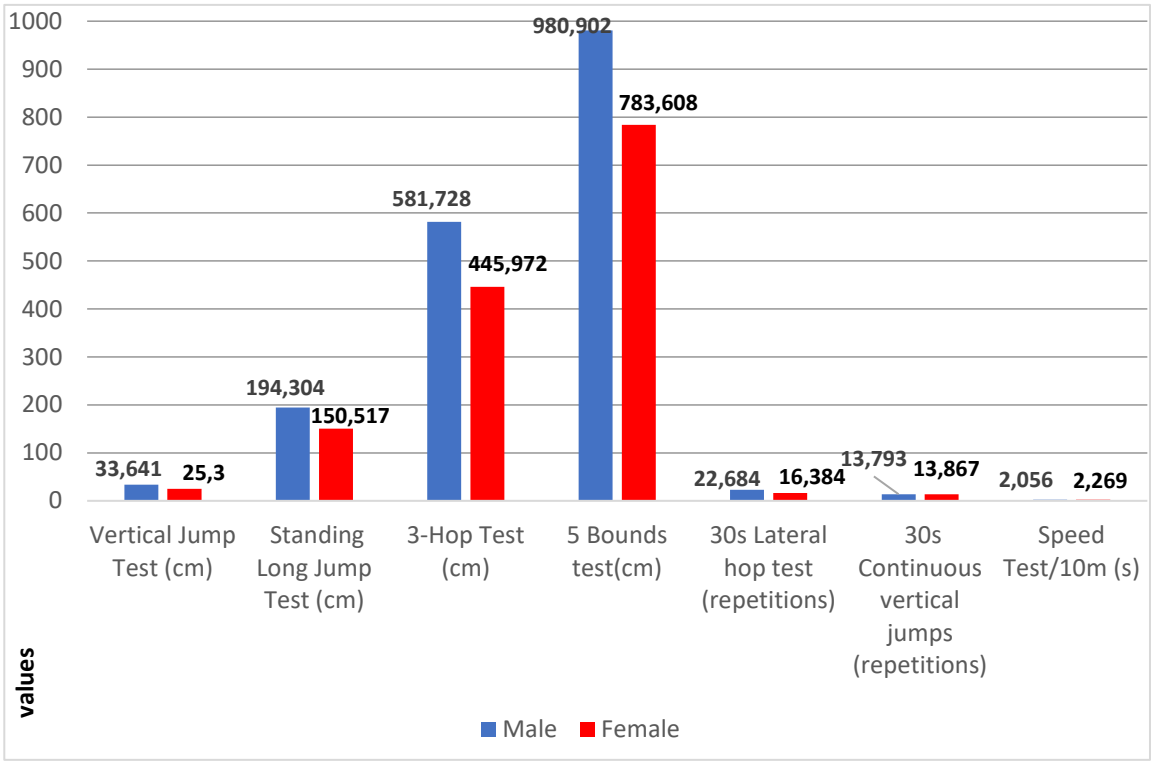
noted greater progress in the first semester (T1-T2) compared to semester 2 (T2-T3) for the Vertical Jump Test, Standing Long Jump Test, and 3-Hop Test, the multiple 5-bounds test. Except for the last test, the situation is exactly the opposite compared to the males' results, where progress was higher in semester 2, so the female group adapted and responded faster to the plyometric exercises in the first semester for these tests. Only for the 30 s Lateral double leg hop test, 30 s Continuous vertical jumps, and Speed Test (10 m) we identified better progress in the females in semester 2/(T2-T3).

**Table 4.** Comparison of lower body muscle power test values by data pair according to differences between the means of the three assessments (Female/N=143)

| Test | Mean | Std. deviation | Std. error | T1-T2 | Sig.[b] | T1-T3 | Sig.[b] | T2-T3 | Sig.[b] |
|---|---|---|---|---|---|---|---|---|---|
| Vertical Jump Test/VJT T1 | 23.913 | 5.012 | 0.419 | -0.838* | 0.000 | -1.387* | 0.000 | -0.549* | 0.000 |
| Vertical Jump Test/VJT T2 | 24.751 | 5.148 | 0.431 | | | | | | |
| Vertical Jump Test/VJT T3 | 25.300 | 5.226 | 0.437 | | | | | | |
| Standing Long Jump Test/SLJ T1 | 148.028 | 20.987 | 1.755 | -1.476* | 0.000 | -2.490* | 0.000 | -1.014* | 0.000 |
| Standing Long Jump Test/SLJ T2 | 149.503 | 21.231 | 1.775 | | | | | | |
| Standing Long Jump Test/SLJ T3 | 150.517 | 21.358 | 1.786 | | | | | | |
| 3-Hop Test T1 | 441.629 | 60.675 | 5.074 | -2.322* | 0.000 | -4.343* | 0.000 | -2.021* | 0.000 |
| 3-Hop Test T2 | 443.951 | 61.137 | 5.113 | | | | | | |
| 3-Hop Test T3 | 445.972 | 60.898 | 5.093 | | | | | | |
| The multiple 5 bounds test/MB5 T1 | 776.958 | 96.981 | 8.110 | -3.965* | 0.000 | -6.650* | 0.000 | -2.685* | 0.007 |
| The multiple 5 bounds test/MB5 T2 | 780.923 | 97.288 | 8.136 | | | | | | |
| The multiple 5 bounds test/MB5 T3 | 783.608 | 97.592 | 8.161 | | | | | | |
| 30s Lateral double leg hop test T1 | 15.230 | 5.848 | 0.489 | -0.413* | 0.000 | -1.154* | 0.000 | -0.741* | 0.000 |
| 30s Lateral double leg hop test T2 | 15.643 | 5.896 | 0.493 | | | | | | |
| 30s Lateral double leg hop test T3 | 16.384 | 5.931 | 0.496 | | | | | | |
| 30s Continuous vertical jumps T1 | 12.902 | 3.785 | 0.317 | -0.322* | 0.000 | -0.965* | 0.000 | -0.643* | 0.000 |
| 30s Continuous vertical jumps T2 | 13.223 | 3.778 | 0.316 | | | | | | |
| 30s Continuous vertical jumps T3 | 13.867 | 3.857 | 0.323 | | | | | | |
| Speed Test (10m) T1 | 2.308 | 0.148 | 0.012 | 0.019* | 0.000 | 0.039* | 0.000 | 0.020* | 0.000 |
| Speed Test (10m) T2 | 2.289 | 0.149 | 0.013 | | | | | | |
| Speed Test (10m) T3 | 2.269 | 0.151 | 0.013 | | | | | | |

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

Graphic 1 shows the mean values of the final tests for all 6 assessment samples compared by gender. Statistical analysis of the significance of the differences recorded for each pair of data was not carried out, as the superiority of males was evident in most of the applied tests. All the consulted scientific sources confirm this for comparisons between genders of the same age and level of training or sports specialization. The only test where we found a similarity of performance for both genders is the 30 s Continuous vertical jumps, which assesses muscular strength in endurance mode.




Graphic 1: Mean values in final muscle power tests (gender comparison)

**4. Discussion**

By comparing the results obtained with similar studies for similar age groups in which plyometric exercises were implemented, in most cases we identified weaker values of our student groups, the main explanation being that the reviewed research focused on investigations at the level of different sports categories, with few studies focused on non-athlete subjects.

The Neuro-Myo-Arthro-Kinetic System (NMAK) is strongly required during jumping, the quality and health of the articular elements conditioning the possibility of executing the movements [63]. Even if there are studies that support the contraindications of applying plyometrics for children, using exercises correctly and progressively with the supervision of trainers/teachers reduces the risk of injuries. These exercises based on plyometrics with low intensity, ensure obvious progress for the value of running speed and jumps [64]. The level of physical maturity of our students did not generate such interpretations, but to eliminate the risk of injuries, overweight and obese students had more accessible dosages regarding the applied exercises (reduced number of series and repetitions, lower height of obstacles/hurdles).

Investigations on adolescent males in North Macedonia confirm the effectiveness of plyometric exercises (12 weeks x 3 workouts/1 hour) for increasing muscle strength. The plyometrics-trained group achieves very good values in the final tests: 266.53cm in SLJ/SBJ, 621.54 cm in 3-Hop Test, and 49.94 cm in VJT [65]. All the values of our male group are below these performances.

For adolescent males in Kosovo, plyometrics (12 weeks x 3-4 sessions) results in increases in explosive power and acceleration capacity. Results of 2.10 s for 10 m speed, 199 cm for SLJ, and 594.10 cm for 3-Hop Test are obtained in the final tests [66]. Our male group has slightly weaker scores in the SLJ and 3-Hop Test, but better in the 10 m speed (2.05 s).

Implementing plyometrics for Chinese aerobic gymnasts ensures increases in jumping performance, but also a reduction in short-distance acceleration performance. The experimental group obtains for SLJ 219.33 cm, 1.67 s for 10 m sprint, according to [67]. The

use of acceleration and jumping based exercises (12 weeks) for adolescents in North Macedonia provides muscle strength gains. Very good results are achieved in VJT (49.9 cm) and SLJ (266.5 cm), according to [68]. Plyometric exercises (scheduled in 10 successive sessions) improve the results of explosive leg strength for Algerian university student athletes (18-20 years old). These workouts increase SLJ/Standing long jump performance from 216 cm to 234 cm and are useful in optimizing long jump test results [69]. Again, the values presented are obviously better than those obtained by our students.

Optimizations of maximal power output and rebound time for male Polish university students of the Faculty of Physical Education (20.3 years old) are observed after applying plyometric exercises for 6 weeks. The values are better for vertical jump in depth jump variant, compared to counter movement jumps. For the five bounds test, a final value of 1302 cm is obtained [70]. The final assessment values for our group in the five bounds test in only 980.90 cm, obviously lower.

Many studies indicate the possibility of successful implementation of plyometric exercises in physical education lessons, for students of different age categories. The application of plyometrics is also advantageous for 7-9 years old students (12 weeks x 2 sessions x 20 min/session). Progress is noted for health-related physical fitness and gross motor coordination [71]. A research on prepubertal boys demonstrated the favorable effects of plyometric exercises (10-week program x 60-100 jumps/session). Increases in vertical jump values and speed are found over short distances, but not for the 10m distance [72].The pubertal period is characterized by advances in muscle strength levels for both sexes, with better male values [73]. Other studies on children with low motor competence (5-14 years) identify the effectiveness of plyometric exercises for improving the ability to run and jump, as well as for increasing kicking distance, agility and balance. These effects are ensured by programs of 8-10 weeks x 2 sessions x at least 50-60 jumps a session. However, no significant progress was determined for the level of strength [74]. The implementation of plyometric exercises in physical education lessons for schoolchildren generates favorable conditions for increasing fitness indicators. Progress related to kicking, jumping and running, but also an optimization of the results in the lessons, are noted [75]. And other similar research identifies the favorable effect of plyometric exercises (20 minutes in each physical education lesson) for schoolchildren in Saudi Arabia (muscle strength, balance and flexibility), according to [76]. Even if the subjects investigated in the research analyzed belong to lower age categories compared to our group, the positive results obtained by using plyometric exercises confirm the possibility of applying this method to groups that are not part of the category of performance athletes.

Improved results are obtained on non-athlete university students from Pakistan (21.37 years old) engaged in high, moderate, and low intensity plyometric training. Speed, muscular endurance, and explosive leg power are significantly higher for the high intensity variant. This group obtains a final SLJ value of 232 cm, significantly better than the low intensity group with 226 cm [77]. Aquatic Plyometric Training is a variant that provides increased values for adolescent Indian athletes for explosive leg strength and speed. For the standing long jump at the final test, a significantly increased result is obtained/239 cm [78]. Implementing Plyometric-Resistance Training/PRT and Plyometric-Sprint Training/PST for male university students (18-22 years old / Saudi Arabia) generates performance increases for leg muscle strength, agility, and acceleration/deceleration capacity. However, values are better for PST in agility and standing long jump (6 week programme x 2 sessions/week x 40 min/session). At SLJ/standing long jump a value of 207.49 cm is obtained for PST, compared to 202.79 cm for PRT [79]. Research on Indonesian male students verified the usefulness of *knee tuck jump and plyometric front cone hops* exercises in explosive lower body strength increases. Improvements are shown, with the standing long jump achieving a final value of 208 cm [80]. Variants of plyometrics and resistance training were tested on Indonesian adolescents (16-18 years old). The plyometric knee tuck jump exercises provided 206.57 cm at the final test for the standing long jump, while the squat jump exercises only 198.22 cm. The best final average value is obtained for the classic squat exercise (resistance training method), 211.33 cm. Resistance squat exercise and plyometric knee tuck jump are also more effective for improving acceleration over short distances

[81]. All these studies show superior performance in the standing long jump compared to our male group, which has a final average of only 194.30 cm.

Research on Slovak university students with different specialisations has identified obesity problems and low levels of motor fitness. However, for vertical jumps, satisfactory values are obtained (34.48 cm in the countermovement jump test and 30.74 cm in the squat jump test) [82]. These values are slightly weaker than those obtained by us in the vertical jump, but the technique used in the test is different.

Favorable effects regarding the level of fitness, muscle toning and health improvement are found through the implementation of Kangoo jumps programs (a variant that involves demands on muscle power through repetitive actions), according to [83]. Plyometrics is also applicable for Schoolchildren of Both Sexes, regardless of the type of surface used for jumping (firm/hard vs. sand). Increases in physical fitness performances are observed after applying 4 weeks x 2 plyometric training sessions for SLJ, VJ, agility, maximal aerobic velocity and balance [84]. In our research we used different surfaces for the execution of jumps, so that the demands on the muscles and joints are diversified and this aspect ensures a good adaptation to various exercises.

The combination of competition exercise training and plyometric training (12 weeks) is more effective for optimizing explosive strength endurance in Indian university volleyball players [85]. High intensity plyometric training (6 weeks) is more effective than low intensity plyometric training for Polish university volleyball players. The jumping performance for attack and block is significantly increased. In the Arm swing vertical jump test, a final average value of 52.8 cm is obtained [86]. For male Ethiopian university athletes (21.77 years old), PT/Plyometric training is more effective than RT/Resistance training in terms of gains in muscle strength, agility, and speed tests. For the VJT/vertical jump test, initial values of 42.16 cm, and final values of 47.09 cm are obtained after 8 weeks x 8 sessions/week of plyometric training, according to [87]. The use of jumping-based exercises generates remarkable increases in detent for male Indonesian medical university students. Initial values of 35.93 cm, intermediate 49.21 cm, and final of 54.21 cm are obtained for VJT, according to [88]. However, there are also studies reporting no significant effects after plyometrics in elite Czech basketball players (6 weeks pre-season training) for explosive leg strength, except for an agility test. However, the values for Vertical Jump/Counter Movement Jump Free Arms are very good: 49.42 cm in the final test [89]. For Algerian university student athletes (21.82 years old), applying plyometric training (6 weeks x 2 sessions) improves leg explosive power values. For the Vertical jump test/VJT an average performance of 47.84 cm is obtained at the final test [90]. Our male group obtained only 33.64 cm in the final Vertical jump test, which is obviously lower than the mentioned studies.

Combining dynamic stretching with plyometric exercises allows a superior increase in vertical jump values for female volleyball players (19.2 years old). After 8 weeks a result of 51.23 cm for VJT is obtained for the experimental group and only 42.36 cm for the control group (in this case only a conservation of results is reported) [91]. These values are obviously much better than those of the females we studied.

The use of exercise from sports and modern dance combined with trunk and leg strength exercises for female university students in Serbia (19-24 years old) provides increases in coordination and explosive strength. After applying this training (10 weeks x 3 sessions x 90 minutes) results of 23.65 cm in the squat jump test and 25.47 cm in the CMJ test are obtained [92]. The results are similar to our VJT results, but the comparison should be viewed with caution, as the vertical jump evaluation technique is different.

Plyometrics is more effective than Squat Training in increasing lower body muscle strength and flexibility for physically inactive/untrained Indian female university students (19.23 years old). After applying 4 weeks x 2 sessions, a result of 24.22 cm is obtained in VJT [93]. This is the only study where, by comparison, the results of our female group are better (25.30 cm at the VJT).

Plyometric training is more useful, compared to skill-based conditioning, in terms of explosive performance in sprinting, throwing, and jumping for elite female volleyball players in Kosovo (21.8 years old). For the vertical jump/countermovement jump, a final

value of 48.5 cm and for SBJ/SLJ 205.3 cm is obtained [94]. For university volleyball players (20.9 years old), applying plyometric training for 8 weeks (5-7 sets/exercise x 8-12 reps with 3 min. break between sets) provides increases in lower limbs power and vertical jump. For the standing long jump, a final value of 189.46 cm is obtained [95]. The SLJ values for our female group are obviously lower (only 150.51 cm).

Implementation of plyometric training for 20-21-year-old university students (Physical Education and Sports School) in Turkey (8 weeks x 2 sessions/week) generated improvements in muscle strength, agility and flexibility values. For SLJ, a final value of 236 cm is obtained [96]. The use of plyometric exercises (10 weeks x 2 sessions) in young Turkish female handball players (school team, 14.57 years) generates improvements in SLJ (178.38 cm at final testing), anaerobic power and flexibility. However, no significant progress was found for speed, agility and vertical jump (28.78 cm in the final test), according to [97]. And in these cases, our group of men and women obtain results inferior to the studies analyzed for SLJ.

The use of upper and lower limb plyometric training (10 weeks x 2 sessions weekly) for young female handball players generates increases in explosive strength tests. For the 10 m acceleration, a final result of 2.05 s is obtained and for the multiple 5 bounds test/five jump test, 930 cm [98]. These values are better than those obtained by our group of students (2.26 s for the 10 m Speed Test and 783.6 cm for the multiple 5 bounds test).

And other research on university students supports the effectiveness of plyometric training (12 weeks x 2 sessions x 45 minutes) for improving fitness levels. Performance increases are observed for agility, speed, explosive power, and muscular endurance [99]. Plyometric exercises applied to male Indian university student athletes (18-21 years old) provide an increase in vertical jump performance [100]. Favourable results for short-distance acceleration and explosive leg power are obtained using vertical and horizontal jumping (8 weeks x 2 sessions) in Spanish adolescent basketball players [101]. Even though we only had one weekly training session and our results were not spectacular, plyometric exercises proved their viability as well.

An investigation on young Moroccans indicates the need to avoid sedentary behaviour in children and adolescents. Physical activity participation deficits negatively influence lower limb explosive movement performance and anaerobic strength [102]. The effects of plyometrics are influenced by the training surface, but also by the training volume. Higher volumes provide higher explosive power gains than lower ones. However, jumps performed on hard training surfaces (and requiring fast stretch-shortening cycle) allow important increases in explosive force even for moderate training volumes [103]. We used jumps on different surface variations (grass, running track, concrete/hard stairs/steps), which involved adapting the muscular system to these particularities.

Using unipodal combined training for Chinese university students is more effective than the two-legged combined training variants for lower-body explosive power, according to [104]. A comparison of the effectiveness of unilateral vs. bilateral plyometric training on Greek university student athletes (both genders) was studied by [105]. Unilateral plyometric training is more effective for single and double-leg jumping performance progress, as well as for the rate of force development. In our study, we used both jumping variants (bilateral and unilateral jumping), with the height of the objects adjusted according to individual possibilities.

Comparative analysis of 3 variants of plyometrics (rebound jumping, horizontal jumping, and depth jumping) on leg muscle strength was applied to non-athlete/untrained Nigerian students (18-27 years old). After 12 weeks x 3 training sessions/week, all variants provide increases in muscle strength, but the most effective are depth jumping and rebound jumping [106]. We cautiously used the depth jumping variant, with a decrease in fall height, to prevent injuries and high joint pressures, especially for overweight and obese students.

The use of plyometrics as a variant of the recovery program for the return of injured athletes imposes certain limits, due to the high intensity of the jumps. Effort progression, execution surface and reduction of relapse risk are important. Other aspects that must be analyzed are the mobility of the joints, the appropriate level of muscle strength, a good

knowledge and execution of the tennis structures, the capacity of the injured tissue to bear the load [107]. The use of plyometrics in the recovery process requires an adaptation of the volume, intensity and frequency of the planned jumps [108]. The application of plyometric exercises in the recovery process after trauma is conditioned by a detailed analysis of health problems, motor experience and previous injuries. In this way possible intensities that are too high are avoided and the individualization of recovery is ensured [109]. In the functional recovery of ACLR/anterior cruciate ligament reconstruction, the application of plyometrics must be associated with the relative intensity of the effort, to ensure a reduced risk of injury and a good burst of motion. The progressive and controlled increase in effort is important for the success of neuro-muscular reconditioning, the quality of the execution technique influencing this aspect and the loading of the joints [110]. Investigations on elite athletes with anterior cruciate ligament rupture (ACL) have highlighted the beneficial effect of combining plyometric exercises with eccentric exercises. Their application after rehabilitation from surgery (14 weeks) within a planning of 6 weeks x 2 sessions/week ensured favorable effects related to functional performance and stability. [111]. Other research finds similar effects by applying low-intensity plyometrics vs. plyometrics with high intensity, for patients during rehabilitation after anterior cruciate ligament reconstruction. For both groups, positive effects in knee function and facilitation of return to sports activities were found. [112]. Even if it is primarily used to optimize the muscular power of healthy athletes, plyometric training also offers possibilities for recovery after many lower limb injuries. Comparison of the effectiveness of plyometric exercises vs. resistance exercises (6-week training) for athletes with acute lateral ankle sprain (applied 3 weeks after the acute injury) show better ankle functional performance values after plyometric application. [113]. An adapted variant of plyometric exercises (aqua plyometric training program) ensures beneficial effects related to neuromuscular performance, without generating increases in vertical stiffness [114]. These studies also identify the possibility of applying plyometrics in the recovery process after trauma in the lower body joints.

## 5. Conclusions

The research results confirm the effectiveness of plyometric exercises in increasing muscle power indicators for the studied groups of university students and are a useful option for improving fitness levels. The attractiveness and diversity of the exercises used ensured good student engagement in the lessons, being a solution to counteract sedentarism. The fact that the students were able to perform the proposed plyometric exercises without reporting muscle or joint pain, confirms the possibility of applying these structures in physical education lessons. However, the poor fitness level and poor basic training for muscle strength could be another argument for more limited progress. Although the improvements are statistically significant, the results do not indicate spectacular increases and are still weaker than the values recorded in most other research. This is because the students involved in our study are not at all concerned about engaging in leisure time physical activities, except for curricular physical education activities, sedentarism being a major problem among young people. Another major difference is that the research to which we have reported the results are studies of short duration, but with a higher frequency of work/sports training sessions (4-12 weeks x 2-3 sessions), whereas we had only one session per week allocated in the physical education lesson. *Future research directions* will identify the possibility of adapting plyometric training for athletes with joint and muscle injuries.

*Study limitations*: The large number of applied tests and independent variables defined at the group level generated a high volume of data, which could not be fully published in this manuscript. The results obtained from the upper body muscle strength tests, i.e. the performance differences between the 4 BMI categories (underweight, normal weight, overweight, and obese) will be published in other scientific papers as a complement to the current study.

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## References

1. Goodwin, J.E.; Jeffreys, I. Plyometric Training: Theory and Practice. In Strength and Conditioning for Sports Performance; Routledge, 2016; p. 37 ISBN 978-0-203-85228-6.
2. Chen, L.; Zhang, Z.; Huang, Z.; Yang, Q.; Gao, C.; Ji, H.; Sun, J.; Li, D. Meta-Analysis of the Effects of Plyometric Training on Lower Limb Explosive Strength in Adolescent Athletes. International Journal of Environmental Research and Public Health 2023, 20, 1849, doi:10.3390/ijerph20031849.
3. Jouira, G.; Alexe, D.I.; Tohănean, D.I.; Alexe, C.I.; Tomozei, R.A.; Sahli, S. The Relationship between Dynamic Balance, Jumping Ability, and Agility with 100 m Sprinting Performance in Athletes with Intellectual Disabilities. Sports 2024, 12, 58, doi:10.3390/sports12020058.
4. Howard-Shaughnessy, C.; Bush, G.; Cherry, S. Six Steps for Implementing Plyometric Training in Elementary Physical Education. Strategies 2013, 26, 10–16, doi:10.1080/08924562.2013.820122.
5. Vizitiu, E.; Costea, A.I.; Silișteanu, S.C. Prevalence of Osteoporosis and Risk Factors in Different Age Categories in Adult Women. Balneo and PRM Research Journal 2023, 14, 627, doi:10.12680/balneo.2023.627.
6. Ricky, Z.; Prananda, G.; Triana, E. Development of Plyometric Exercises in Learning Physical Education. J. Ilm. Pendidik. Jasm 2020, 4, 76–85, doi:10.33369/jk.v4i2.12394.
7. Abdula, I.; Ungureanu, A.E.; Vîlcea, L.C.; Stanciu, L.E.; Azis, O.; Iliescu, M.G. Trabecular Bone Score – the Newest Diag-nostic Tool for Patients with Osteoporosis and Osteopenia from Different Pathologies. Balneo and PRM Research Journal 2023, 14, 625, doi:10.12680/balneo.2023.625.
8. Argeșanu, R.D.; Brîndușe, L.A.; Mogoș, C.I.; Bratu, E.C.; Armean, P.; Cucu, M.A. Improvement of the Quality of Life and the Physical Activity Status in Women with Osteoporosis and Osteopenia Following Physical Activity Intervention Program. Balneo and PRM Research Journal 2023, 14, 634, doi:10.12680/balneo.2023.634.
9. Holubiac, I. Ștefan; Leuciuc, F.V. The Role of the Dual X-Ray Absorptiometry Investigation in the Design of Personalized Training Programs for Women with Postmenopausal Osteopenia / Osteoporosis. Balneo and PRM Research Journal 2023, 14, 598, doi:10.12680/balneo.2023.598.
10. Davies, G.; Riemann, B.L.; Manske, R. Current concepts of plyometric exercise. Int J Sports Phys Ther 2015, 10, 760–786.
11. Argeșanu, R.D.; Mogoș, C.I.; Cucu, M.A.; Bratu, E.C.; Brîndușe, L.A. Factors That Influence the Prescription of Physical Activity: A Cross Sectional Survey. Balneo and PRM Research Journal 2023, 574, doi:10.12680/balneo.2023.574.
12. Vitalis, L.; Feier, A.M.; Russu, O.; Zuh, S.-G.; Szórádi, G.-T.; Pop, T.S. Evaluating a Tailored 12-Week Post-Operative Re-habilitation Program for Younger Patients Following Total Knee Arthroplasty: Addressing a Growing Need. Balneo and PRM Research Journal 2023, 14, 611, doi:10.12680/balneo.2023.611.
13. Aksović, N.; Bjelıca, B.; Milanović, F.; Jovanović, N.; Zelenović, M. Plyometric Training Effects on Explosive Power, Sprint and Direction Change Speed in Basketball: A Review. Turk J Kinesiol 2021, 7, 73–79, doi:10.31459/turkjkin.929325.
14. Ali Niya, N.; Shabani, R.; Ali Ákbari, A. Comparison of the Effects of Plyometric and Resistance Circuit Training on Body Mass Index and Physical Fitness of Male Teenage Student Volleyball Players. Journal of Applied Health Studies in Sport Physiology 2016, 3, 104–114.

15. Maćkała, K.; Synówka, A.; Ćorluka, M.; Vodicar, J. Impact of plyometric training on the power of lower limbs in moderately advanced female volleyball players. Acta kinesiol. 2021, 5–12, doi:10.51371/issn.1840-2976.2021.15.S1.1.
16. Li, F.Y.; Guo, C.G.; Li, H.S.; Xu, H.R.; Sun, P. A Systematic Review and Net Meta-Analysis of the Effects of Different Warm-up Methods on the Acute Effects of Lower Limb Explosive Strength. BMC Sports Sci Med Rehabil 2023, 15, 106, doi:10.1186/s13102-023-00703-6.
17. Booth, M.A.; Orr, R. Effects of Plyometric Training on Sports Performance. Strength & Conditioning Journal 2016, 38, 30, doi:10.1519/SSC.0000000000000183.
18. Sozbir, K. Effects of 6-Week Plyometric Training on Vertical Jump Performance and Muscle Activation of Lower Extremi-ty Muscles. The Sport Journal 2016, 18.
19. Chelly, M.S.; Hermassi, S.; Shephard, R.J. Effects of In-Season Short-Term Plyometric Training Program on Sprint and Jump Performance of Young Male Track Athletes. The Journal of Strength & Conditioning Research 2015, 29, 2128, doi:10.1519/JSC.0000000000000860.
20. Fischetti, F.; Cataldi, S.; Greco, G. A Combined Plyometric and Resistance Training Program Improves Fitness Performance in 12 to 14-Years-Old Boys. Sport Sci Health 2019, 15, 615–621, doi:10.1007/s11332-019-00560-2.
21. Dharod, R.; Shetty, T.; Shete, R.; Mullerpatan, R. Effect of Plyometric Training on Explosive Power, Agility, Balance, and Aerobic Performance of Young Adult Male Kabaddi Players. CRP 2020, 32, 183–192, doi:10.1615/CritRevPhysRehabilMed.2020035312.
22. Hammami, M.; Gaamouri, N.; Shephard, R.J.; Chelly, M.S. Effects of Contrast Strength vs. Plyometric Training on Lower-Limb Explosive Performance, Ability to Change Direction and Neuromuscular Adaptation in Soccer Players. The Journal of Strength & Conditioning Research 2019, 33, 2094, doi:10.1519/JSC.0000000000002425.
23. Akinbiola, O.O.; Yekeen, A.M. Effect of an Eight-Week Plyometric Exercise Training on Athletes' Muscular Strength in Selected Ball Games in Nigeria. Turk J Kinesiol 2022, 8, 9–14, doi:10.31459/turkjkin.1076794.
24. Aminaei, M.; Yazdani, S.; Amirseifadini, M. Effects of Plyometric and Cluster Resistance Training on Explosive Power and Maximum Strength in Karate Players. International Journal of Applied Exercise Physiology 2017, 6, 34–44, doi:10.22631/ijaep.v6i2.142.
25. Uzor, T.N.; Iheanacho, F.U.; Ujuagu, N.A.; Offodile, H.N. Effects of lower body plyometrics training on digging skill of female university vollyball players. Medical and Health Sciences European Journal 2024, 8, 9.
26. Giovanelli, N.; Taboga, P.; Rejc, E.; Lazzer, S. Effects of Strength, Explosive and Plyometric Training on Energy Cost of Running in Ultra-Endurance Athletes. European Journal of Sport Science 2017, 17, 805–813, doi:10.1080/17461391.2017.1305454.
27. Moran, J.; Liew, B.; Ramirez-Campillo, R.; Granacher, U.; Negra, Y.; Chaabene, H. The Effects of Plyometric Jump Train-ing on Lower-Limb Stiffness in Healthy Individuals: A Meta-Analytical Comparison. Journal of Sport and Health Science 2023, 12, 236–245, doi:10.1016/j.jshs.2021.05.005.
28. Nkiru, U.T.; Nonye, U.A. Optimising University Athletes Cardiovascular Health Using Lower and Upper Body Plyometric Training. The International Journal of Science & Technoledge 2020, 8, 64–70, doi:10.24940/theijst/2020/v8/i5/ST2005-030.
29. Uzor, T.N.; Emeahara, G.O. Effects of lower and upper body plyometric training on cardiovascu-lar variables of athletes. Journal of the Nigerian Academy of Education 2020, 15, 91–105.
30. Munteanu, C.; Munteanu, D. Thalassotherapy Today. BALNEO 2019, 10, 440–444, doi:10.12680/balneo.2019.278.
31. Vizitiu, E.; Constantinescu, M. Comparative Study on the Importance of Physical Activity on Body Composition in Adults. Balneo and PRM Research Journal 2022, 13, 530–530.
32. Silva, A.F.; Clemente, F.M.; Lima, R.; Nikolaidis, P.T.; Rosemann, T.; Knechtle, B. The Effect of Plyometric Training in Volleyball Players: A Systematic Review. International Journal of Environmental Research and Public Health 2019, 16, 2960, doi:10.3390/ijerph16162960.
33. Branet, C.; Grigoroiu, C.; Netolitzchi, M.; Wesselly, T. The Effect of Plyometric Training on Lower Body Strength in Pre-adolescent Athletes. BRAIN. Broad Research in Artificial Intelligence and Neuroscience 2021, 11, 13–29, doi:10.18662/brain/11.4Sup1/153.
34. Canlı, U.; Bayru, M. The effect of lower and upper extremity plyometric exercise program on maximal strength and body fat ratio of young basketball players. BSD 2020, 14, 374–390.
35. Baro, D.M.; Sonowal, A. Effect of Selected Plyometric Exercises on Explosive Strength, Speed and Agility. International Journal of Science and Research 2014, 3, 3.

36. Huang, H.; Huang, W.-Y.; Wu, C.-E. The Effect of Plyometric Training on the Speed, Agility, and Explosive Strength Performance in Elite Athletes. Applied Sciences 2023, 13, 3605, doi:10.3390/app13063605.
37. Kryeziu, A.; Begu, B.; Asllani, İ.; Iseni, A. Effects of the 4 Week Plyometric Training Program on Explosive Strength and Agility for Basketball Players. Turk J Kinesiol 2019, 5, 110–116, doi:10.31459/turkjkin.553453.
38. Nikolic, A. Plyometric Basketball Training. Turk J Kinesiol 2018, 4, 101–105, doi:10.31459/turkjkin.468867.
39. Stojiljković, N.; Stanković, D.; Pelemiš, V.; Čokorilo, N.; Olanescu, M.; Peris, M.; Suciu, A.; Plesa, A. Validity and Reliabil-ity of the My Jump 2 App for Detecting Interlimb Asymmetry in Young Female Basketball Players. Front. Sports Act. Liv-ing 2024, 6, doi:10.3389/fspor.2024.1362646.
40. Deng, N.; Soh, K.G.; Abdullah, B.B.; Huang, D.; Xu, F.; Bashir, M.; Zhang, D. Effects of Plyometric Training on Health-Related Physical Fitness in Untrained Participants: A Systematic Review and Meta-Analysis. Sci Rep 2024, 14, 11272, doi:10.1038/s41598-024-61905-7.
41. Eyzaguirre-Maldonado, E.H.; Reynaga-Chavez, R.; Jeri, Y.G.; Huamani, O.G.; Huaman-Romani, Y.-L. Plyometric Train-ing for Physical Education University Students. ijirss 2024, 7, 1163–1173, doi:10.53894/ijirss.v7i3.3146.
42. Vizitiu, E.; Costea, A.-I.; Silişteanu, S.-C.; Constantinescu, M. Study on the Assessment of Cognitive and Functional Status for a Segment of the Population during the Ageing Process. Balneo and PRM Research Journal 2023, 14, 624, doi:10.12680/balneo.2023.624.
43. Golzari, A.; Rahimi, A.; Meli, M.H.N. Comparison of the effect of six weeks of strength and plyome-tric exercises on some of the kinematic parameters of the lower extremities in the impact on the foot of football player's girl of 20 to 25 years old. International Journal of Ecosystems & Ecology Sciences 2018, 8, 367–374.
44. Wee, E.H.; Boon, A.H.; Ler, H.Y. Effects of short-term plyometric training on lower extremity power, strength, endurance and kicking speed in male college soccer players. Malaysian Journal of Sport Science and Recreation (MJSSR) 2023, 19, 95–110, doi:10.24191/mjssr.v19i1.21760.
45. Li, R. Effect of plyometric on the lower limbs of sports dancers. Rev Bras Med Esporte 2022, 29, e2022_0383, doi:10.1590/1517-8692202329012022_0383.
46. Sedaghat, R.; Solhjo, M.H.; Nikseresht, A. The Impact of 8 Weeks of Plyometric Exercises on Anaerobic Power, Speed, and Agility of Male Students. Advances in Environmental Biology 2014, 410–414.
47. Talukdar, K.; McGuigan, M.; Harrison, C. Practical Strategies in Developing Strength and Plyometric Training to Improve Sprinting Speed in Female Student Athletes Within a School Curriculum. Strength & Conditioning Journal 2023, 45, 122, doi:10.1519/SSC.0000000000000713.
48. Iseni, A.; Kryeziu, A. Effect of the 12 week program for developing explosive strengthening in students 'segmental velocity and repetitive force performance. Research in Kinesiology 2021, 49, 10–13.
49. Radenković, O.; Stanković, R.; Bubanj, S.; Kostić, R.; Kahrović, I. The effects of physical exercise with resistance on the explosive strength of students. Facta Universitatis, Series: Physical Education and Sport 2017, 14, 447–454, doi:10.22190/FUPES1603447R.
50. Wang, X.; Lv, C.; Qin, X.; Ji, S.; Dong, D. Effectiveness of Plyometric Training vs. Complex Training on the Explosive Pow-er of Lower Limbs: A Systematic Review. Front. Physiol. 2023, 13, doi:10.3389/fphys.2022.1061110.
51. Bauer, P.; Uebellacker, F.; Mitter, B.; Aigner, A.J.; Hasenoehrl, T.; Ristl, R.; Tschan, H.; Seitz, L.B. Combining Higher-Load and Lower-Load Resistance Training Exercises: A Systematic Review and Meta-Analysis of Findings from Complex Train-ing Studies. Journal of Science and Medicine in Sport 2019, 22, 838–851, doi:10.1016/j.jsams.2019.01.006.
52. Rostamkhany, H.; Nikbakht, H.; Sadeqi, H. Plyometric Training Effect on Lower Limb Biomechanical Parameters. Sleep Hypn 2017, 30, 166–173, doi:10.5350/Sleep.Hypn.2017.19.0149.
53. Sabillah, M.I.; Nasrulloh, T.A.; Yuniana, R. The Effect of Plyometric Exercise and Leg Muscle Strength on the Power Limb of Wrestling Athletes. JPES 2022, 22, 1403–1411, doi:10.7752/jpes.2022.06176.
54. Hadi, R. The difference of training effect of plyometric side jump sprint and half squat to the power of lower extremities. in proceedings of the the 4th international conference on phys-ical education, sport and health (ismina) and workshop: enhancing sport, physical activi-ty, and health promotion for a better quality of life; Sports Science Faculty, Universitas Negeri Sema-rang: Semarang – Central Java, Indonesia, 2017; pp. 331–338.
55. Syafrizar, S.; Rifki, M.S. The Effect of Plyometrics Training and Achievement Motivation Towards Leg Muscle Explosive Power of Volleyball Athletes in Universitas Negeri Padang. In Proceedings of the The 1st Yogyakarta International Seminar on Health, Physical Education, and Sports Science 2017; Faculty

of Sport Sciences Universitas Negeri Yogyakarta: Yogyakarta, October 14 2017; pp. 205–209.
56. Permana, D.A.; Kusnanik, N.W.; Nurhasan; Setijono, H.; Arifin, M.Z.; Purwoto, S.P. Enhancing Strength, Leg Muscle Ex-plosive Power, and Muscle Hypertrophy Using Hurdle-Box Jump Plyometric. Physical Education Theory and Methodology 2022, 22, 113–120, doi:10.17309/tmfv.2022.1.16.
57. Sandu, A.S. Etica si deontologie profesionala; Lumen: Iasi, 2012; ISBN 978-973-166-302-9.
58. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. JAMA 2013, 310, 2191, doi:10.1001/jama.2013.281053.
59. The Best Plyometric Exercises for Vertical Jump, Explosiveness and Athleticism - 85 Variations; 2019;
60. Armstrong, R.A. When to Use the Bonferroni Correction. Ophthalmic and Physiological Optics 2014, 34, 502–508, doi:https://doi.org/10.1111/opo.12131.
61. Opariuc, D.C. Statistica Aplicata in Stiintele Socio-Umane. Analiza Asocierilor Şi a Diferenţelor Statistice; Arhip Art: Sibiu, 2011;
62. Weinfurt, K.P. Repeated Measures Analysis: ANOVA, MANOVA, and HLM. In Reading and understanding MORE multi-variate statistics; American Psychological Association: Washington, DC, US, 2000; pp. 317–361 ISBN 978-1-55798-698-6.
63. Munteanu, C.; Onose, G.; Turnea, M.-A.; Rotariu, M. Cellular and Molecular Homeostatic Microenvironmental Imbalanc-es in Osteoarthritis and Rheumatoid Arthritis. Balneo and PRM Research Journal 2023, 14, 564, doi:10.12680/balneo.2023.564.
64. Zerf, M.; Bengoua, A.; Atoutı, N.; Mokkedes, M.I. What Child Game Improve? The Benefits of Plyometric Training. IntJSCS 2016, 4, 339–346, doi:10.14486/IntJSCS524.
65. Kryeziu, A.R.; Iseni, A.; Teodor, D.F.; Croitoru, H.; Badau, D. Effect of 12 Weeks of the Plyometric Training Program Model on Speed and Explosive Strength Abilities in Adolescents. Applied Sciences 2023, 13, 2776, doi:10.3390/app13052776.
66. Thaqi, A.; Berisha, M.; Hoxha, S. The Effect of Plyometric Training on the Power-Related Factors of Children Aged 16 Years-Old. Progress in Nutrition 2020, 2, 10, doi:10.23751/pn.v22i2-S.10441.
67. Li, L.; Chen, Q. Impact of plyometric training on the lower limb strength of gymnasts. Rev Bras Med Esporte 2023, 29, e2022_0658, doi:10.1590/1517-8692202329012022_0658.
68. Iseni, A.; Abdullai, M. The effect of a 12-week experimental program on the segmental velocity and explosive strength of the lower and upper extremities in adolescents. Journal of Sport and Health 2023, 10, 31–42.
69. Benzidane, H.; Mokrani, D.; Mohamed, K.S.; Houcine, A.; Sadek, Z. Effect of using some plyometric exercises to improve explosive power and digital achievement in the long jump. European Journal of Physical Education and Sport Science 2016, 1, 9, doi:10.46827/ejpe.v1i2.55.
70. Makaruk, H.; Sacewicz, T. Effects of Plyometric Training on Maximal Power Output and Jumping Ability. Human Move-ment 2010, 1, 17–22, doi:10.2478/v10038-010-0007-1.
71. Almeida, M.B. de; Leandro, C.G.; Queiroz, D. da R.; José-da-Silva, M.; Pessôa dos Prazeres, T.M.; Pereira, G.M.; das-Neves, G.S.; Carneiro, R.C.; Figueredo-Alves, A.D.; Nakamura, F.Y.; et al. Plyometric Training Increases Gross Motor Co-ordination and Associated Components of Physical Fitness in Children. European Journal of Sport Science 2021, 21, 1263–1272, doi:10.1080/17461391.2020.1838620.
72. Kotzamanidis, C. Effect of plyometric training on running performance and vertical jumping in prepubertal boys. The Journal of Strength & Conditioning Research 2006, 20, 441.
73. Pavlović, R.; Marko, M.; Eken, Ö.; Radulovic, N.; Badau, D. Gender Differences in Hand Grip Strength of Children in Bos-nia and Herzegovina Aged 11 to 14 Years. A Cross - Sectional Study. Balneo and PRM Research Journal 2023, 14, 606, doi:10.12680/balneo.2023.606.
74. Johnson, B.A.; Salzberg, C.L.; Stevenson, D.A. A Systematic Review: Plyometric Training Programs for Young Children. J Strength Cond Res 2011, 25, 2623–2633, doi:10.1519/JSC.0b013e318204caa0.
75. Sortwell, A.; Newton, M.; Marinho, D.A.; Knijnik, J.; Ramirez-Campillo, R. Potential Role of Plyometric Training in the Development of Motor Performance Skills: A Narrative Review. Kinesiology Review 2021, 11, 158–170, doi:10.1123/kr.2021-0006.
76. Radwan, N.L.; Mahmoud, W.S.; Mohamed, R.A.; Ibrahim, M.M. Effect of Adding Plyometric Training to Physical Educa-tion Sessions on Specific Biomechanical Parameters in Primary School Girls. J Musculoskelet Neuronal Interact 2021, 21, 237–246.
77. Khan, W.; Arif, T.; Muhammad, K.K.; Sohail, S.N.; Kriventsova, I.V. Effects of Varied Packages of Plyometric Training on Selected Motor Ability Components among University Students. Physical Education of Students 2020, 24, 278–285, doi:10.15561/20755279.2020.0504.
78. Ghosh, S.S.; Biswas, R. Effect of Plyometric Training Conducted in Aquatic Medium on Speed and Explosive Strength of the Athletes. International Journal of Kinesiology and Sports Science 2023, 11, 16–26, doi:10.7575/aiac.ijkss.v.11n.1p.16.

79. Almoslim, H. Effect of Combined Plyometric-Sprint and Combined Plyometric-Resistance Training Protocols on Speed, Explosive Power and Change of Direction. Indian Journal of Science and Technology 2016, doi:10.17485/ijst/2016/v9i32/128821.
80. Effendi, S.; Basuki, S.; Shadiqin, A. Effect of Plyometric Training Front Cone Hops and Knee Tuck Jump on Improvement Muscle Explosion Power. In Proceedings of the Advances in Social Science, Education and Humanities Research; Atlantis Press, February 27 2020; Vol. 407, pp. 141–143.
81. Arianda, E.; Rustiadi, T.; Kusuma, D.W.Y. The Effect of Plyometric and Resistance Training on Increasing The Speed And Explosive Power of The Leg Muscles. Journal of Physical Education and Sports 2021, 10, 200–210, doi:10.15294/jpes.v10i2.48415.
82. Pupišová, Z. The level of explosive strength of the lower limbs in the group of the student's. Slovak Journal of Sport Science 2016, 1, 33–38.
83. Russu, O.M.; Pop, T.S.; Feier, A.M.; Iova, A.; Farcaș, D.M.; Burta, O.L.; Borodi, P.-G.; Sebestyen, K. Evaluation of Kangoo Jumps Rebound Exercise Program: A Prospective Study of a General Population. Balneo and PRM Research Journal 2022, 13, 511, doi:10.12680/balneo.2022.511.
84. Marzouki, H.; Dridi, R.; Ouergui, I.; Selmi, O.; Mbarki, R.; Klai, R.; Bouhlel, E.; Weiss, K.; Knechtle, B. Effects of Surface-Type Plyometric Training on Physical Fitness in Schoolchildren of Both Sexes: A Randomized Controlled Intervention. Bi-ology 2022, 11, 1035, doi:10.3390/biology11071035.
85. Rai, V.S.; Yadav, R.K. Comparative Effects of Plyometric Exercises, Competition Exercises and Combination of Plyome-tric and Competition Exercises on Explosive Strength Endurance of Volleyball Players. International Journal of Physical Education, Sports and Yogic Sciences 2012, 1, 1–5.
86. Jastrzbeski, Z.; Wnorowski, K.; Mikolajewski, R.; Jaskulska, E.; Radziminski, L. The Effect of a 6-Week Plyometric Train-ing on Explosive Power in Volleyball Players. Baltic Journal of Health and Physical Activity 2022, 6, doi:10.2478/bjha-2014-0008.
87. Abebe, A.G. Comparison of the effects of plyometric and resistance training on speed, agility and explosive power: the case of gondar university regular sport science students. thesis, bahir dar university, sport academy, department of sport science, 2020.
88. Pandoyo, P.A.S.; Indraswari, D.A.; Marijo, M.; Bakhtiar, Y. The effect of plyometrics training on explosive power of medical students in diponegoro university. Jurnal Kedokteran Diponegoro (Diponegoro Medical Journal) 2020, 9, 213–219, doi:10.14710/dmj.v9i3.27495.
89. Lehnert, M.; Hůlka, K.; Malý, T.; Fohler, J.; Zahálka, F. The Effects of a 6 Week Plyometric Training Programme on Ex-plosive Strength and Agility in Professional Basketball Players. Acta Gymnica 2013, 43, 7–15, doi:10.5507/ag.2013.019.
90. Houcine, B.; Djamel, M.; Ahmed, A. Plyometric Exercises Improves Muscular Power and Digital Achievement in High Jump Among Students. Acta Facultatis Educationis Physicae Universitatis Comenianae 2020, 60, 158–169, doi:10.2478/afepuc-2020-0013.
91. Thattarauthodiyil, U.; Shenoy, K.B.; Mantargi, M.J.S. Study on the Effects of Lower Body Plyometrics and Dynamic Stretching on Vertical Jump in Female Collegiate Volleyball Players. Saudi Journal of Sports Medicine 2019, 19, 51, doi:10.4103/sjsm.sjsm_10_19.
92. Stošić, D.; Uzunović, S.; Pantelić, S.; Veličković, S.; Đurović, M.; Piršl, D. Effects of exercise program on co-ordination and explosive power in university dance students. Facta Universitatis, Series: Physical Education and Sport 2020, 17, 579–589, doi:10.22190/FUPES191016052S.
93. Murugan, S.; Saravanan, P.; Hadia, K.; Agarwal, K.; Tapaniya, M.; Sudani, P. Is Plyometric Exercise Effective than Squat Training in Improving Flexibility and Vertical Jump Height in Untrained Female College Students? International Journal of Health Sciences and Research 2020, 10, 151–156.
94. Gjinovci, B.; Idrizovic, K.; Uljevic, O.; Sekulic, D. Plyometric Training Improves Sprinting, Jumping and Throwing Capaci-ties of High Level Female Volleyball Players Better Than Skill-Based Conditioning. J Sports Sci Med 2017, 16, 527–535.
95. Foqhaa, B.; Brini, S.; Alhaq, I.A.; Nairat, Q.; Abderrahman, A.B. Eight Weeks Plyometric Training Program Effects on Lower Limbs Power and Spike Jump Performances in University Female Volleyball Players. The Swedish Journal of Scien-tific Research 2021, 8, 7.
96. Erdoğan, E.; İnce, A.; Dinçer, Ö.; Sözen, H.; Cevahircioğlu, B.; Arı, E. The Effects of Plyometric Training on Some Motor Skills of Students at Physical Education and Sports School. (PJSS) 2014, 3, 938–940.
97. Karadenizli, Z.I. The Effects of Plyometric Education Trainings on Balance and Some Psychomotor Characteristics of School Handball Team. Universal Journal of Educational Research 2016, 4, 2292–2299, doi:10.13189/ujer.2016.041007.
98. Hammami, M.; Gaamouri, N.; Suzuki, K.; Shephard, R.J.; Chelly, M.S. Effects of Upper and Lower Limb Plyometric Train-ing Program on Components of Physical Performance in Young Female Handball Players. Front. Physiol. 2020, 11, doi:10.3389/fphys.2020.01028.

99. Abdulhameed, A.A. Influence of Plyometric Training Program on Selected Motor Fitness Components Among University Males - ProQuest. International Journal of Applied Exercise Physiology 2020, 9, 46–51.
100. Thakur, J.; Mıshra, M.; Rathore, V. Impact of Plyometric Training and Weight Training on Vertical Jumping Ability. Turk J Sport Exe 2016, 18, 31–37, doi:10.15314/tjse.20098.
101. Uribarri, H.G.; Pardos, E.M.; Guerrero, O.V.; Serrano, A.C.; Skok, O.G.; Roso-Moliner, A.; Lozano, D. Effects of Plyometric Training on Lower Limb Strength and Power in Young Postpubertal High Level Basketball Players. Int J Sport Stud Health 2023, 6, doi:10.5812/intjssh-138646.
102. Boujdi, R.; Rouani, A.; Hassouni, T.; Lamri, D. Physical Activity, Gender and Biological Maturation Influence on Lower- Limb Explosive Anaerobic Power Measured in Sprinting and Jumping among Youth Students: From a Biomechanical Per-spective. International Journal of Chemical and Biochemical Sciences 2023, 24, 527–544.
103. Ramírez-Campillo, R.; Andrade, D.C.; Izquierdo, M. Effects of Plyometric Training Volume and Training Surface on Ex-plosive Strength. The Journal of Strength & Conditioning Research 2013, 27, 2714, doi:10.1519/JSC.0b013e318280c9e9.
104. Wang, D.; Taek, J.Y.; Wang, S. Combined training and explosive strength in basketball players' lower limbs. Rev Bras Med Esporte 2023, 29, e2022_0572, doi:10.1590/1517-8692202329012022_0572.
105. Bogdanis, G.C.; Tsoukos, A.; Kaloheri, O.; Terzis, G.; Veligekas, P.; Brown, L.E. Comparison Between Unilateral and Bilat-eral Plyometric Training on Single- and Double-Leg Jumping Performance and Strength. The Journal of Strength & Conditioning Research 2019, 33, 633, doi:10.1519/JSC.0000000000001962.
106. Abass, A.O. Comparative Effect of Three Modes of Plyometric Training on Leg Muscle Strength of University Male Stu-dents. European Journal of Scientific Research 2009, 31, 577–582.
107. Arias-Vázquez, P.I.; Quezada-González, H.R.; Loeza-Magaña, P.; Castillo-Ávila, R.G.; Hernández-Gil, K. del C.; Poblete-Magaña, J. Jumps and Plyometric Exercises in the Return to Play After Sports Injuries. Clinical Journal of Sport Medicine 2024, 34, 386, doi:10.1097/JSM.0000000000001234.
108. Voight, M.L.; Tippett, S.R. Plyometric Exercise in Rehabilitation. In Rehabilitation Techniques for Sports Medicine and Athletic Training; Routledge, 2020; p. 26 ISBN 978-1-00-352630-8.
109. Parish, M.R. Plyometric Approaches and Their Efficiency in Sports Treatment and Rehabilitation. Primedia eLaunch LLC 2021, 12–20, doi:10.36074/smpsbr:at.ed-1.02.
110. Buckthorpe, M.; Della Villa, F. Recommendations for Plyometric Training after ACL Reconstruction – A Clinical Com-mentary. Int J Sports Phys Ther 16, 879–895, doi:10.26603/001c.23549.
111. Kasmi, S.; Zouhal, H.; Hammami, R.; Clark, C.C.T.; Hackney, A.C.; Hammami, A.; Chtara, M.; Chortane, S.G.; Salah, F.Z.B.; Granacher, U.; et al. The Effects of Eccentric and Plyometric Training Programs and Their Combination on Stability and the Functional Performance in the Post-ACL-Surgical Rehabilitation Period of Elite Female Athletes. Front. Physiol. 2021, 12, doi:10.3389/fphys.2021.688385.
112. Chmielewski, T.L.; George, S.Z.; Tillman, S.M.; Moser, M.W.; Lentz, T.A.; Indelicato, P.A.; Trumble, T.N.; Shuster, J.J.; Cicuttini, F.M.; Leeuwenburgh, C. Low- Versus High-Intensity Plyometric Exercise During Rehabilitation After Anterior Cruciate Ligament Reconstruction. Am J Sports Med 2016, 44, 609–617, doi:10.1177/0363546515620583.
113. Ismail, M.M.; Ibrahim, M.M.; Youssef, E.F.; Shorbagy, K.M.E. Plyometric Training Versus Resistive Exercises After Acute Lateral Ankle Sprain. Foot Ankle Int. 2010, 31, 523–530, doi:10.3113/FAI.2010.0523.
114. Sporri, D.; Ditroilo, M.; Rodriguez, E.C.P.; Johnston, R.J.; Sheehan, W.B.; Watsford, M.L. The Effect of Water-Based Plyometric Training on Vertical Stiffness and Athletic Performance. PLOS ONE 2018, 13, e0208439, doi:10.1371/journal.pone.0208439.