The journal represents original scientific researches of scientists from the East-European region.
The Journal welcomes articles on different aspects of physical education, sports and health of students which cover scientific researches in the related fields, such as biomechanics, kinesiology, medicine, psychology, sociology, technologies of sports equipment, research in training, selection, physical efficiency, as well as health preservation and other interdisciplinary perspectives.

In general, the editors express hope that the journal "Physical Education of Students" contributes to information exchange to combine efforts of the researchers from the East-European region to solve common problems in health promotion of students, development of physical culture and sports in higher educational institutions.

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PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

The effects of Baduanjin exercise on physical fitness and mental health of female college students

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Henan University of Urban Construction, China

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

Abstract

Background and Study Aim In the context of increasing stress and declining health among female college students, there is an urgent need for effective methods to enhance their physical and mental well-being. The aim of this study is to analyze the impact of Baduanjin exercise on the physical fitness and mental health of female college students.

Material and Methods Sixty female college students at University were randomly selected from 150 volunteers to participate in this study. They were equally divided into an experimental group and a control group, with 30 students in each. All 60 participants completed the experiment. The study's protocol was conducted in accordance with ethical standards and was approved by the Institutional Review Board of University. Informed consent was obtained from all individual participants involved in the study. The experimental group received a 16-week intervention of traditional Baduanjin exercise, while the control group engaged in other unfixed sports activities synchronously.

Results After the experiment, the average weight of the experimental group decreased significantly from 52.41±6.35 kg to 50.06±5.46 kg ($P<0.01$). Body mass index, waist circumference, and other indicators also showed significant improvements. The step test index in the experimental group increased from 45.09±4.45 to 50.72±4.46, which was significantly different from the baseline ($P<0.01$). Improvements were noted in vital capacity, grip strength, and sit-up performance, all showing significant differences from baseline measures ($P<0.01$). The standing long jump and 800 m running performances in the experimental group showed significant improvement compared to pre-experiment measurements ($P<0.05$). Additionally, all mental health indicators in the experimental group demonstrated a downward trend, with significant differences in 10 indicators such as somatization, obsessive-compulsive symptoms, interpersonal sensitivity, and depression ($P<0.05$ or $P<0.01$). Moreover, there was a significant inter-group difference in motor skills and physical fitness between the experimental and control groups in the 800 m run (230.78±30.61 vs. 231.32±32.15) and standing long jump (1.81±0.33 vs. 1.78±0.42) after the intervention ($P<0.05$). Furthermore, significant differences were observed in mental excitement and participation in the experimental group before and after the Baduanjin exercise as assessed by Baduanjin's Self-Perception Inventory ($P<0.01$).

Conclusions This study demonstrates that a 16-week program of traditional Baduanjin exercise significantly improves both physical and mental health parameters among female college students. These findings suggest that Baduanjin exercise can be an effective intervention for enhancing physical fitness and alleviating psychological distress in this population. The results underscore the potential of integrating traditional physical activities into health promotion strategies for young adults in educational settings.

Keywords: baduanjin, female college students, physical fitness, mental health

Introduction

Declining physical fitness among female college students poses significant health concerns. This trend has been noted across various key indicators, signaling a broader deterioration in physical health. Such declines have critical implications not only for their physical capabilities but also for their overall well-being. The challenge is compounded by external societal pressures and internal lifestyle choices driven by contemporary beauty standards. Recognizing and addressing these trends is essential for promoting healthier lifestyles and improving the mental and physical health outcomes for these students.

These trends were highlighted in the 2019 national survey conducted by the Ministry of Education in China and six other departments [1]. The results showed that compared with 2014, many physical fitness indicators of college students aged 19 to 22 showed a downward trend. Among them, girls' grip strength, standing long jump, and sitting forward bend all declined to varying degrees, and their 800 m running performance dropped by 9.56 seconds. By 2020, the national college students' failure rate of physical health was as high as 30%.

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Especially for female college students, they not only have to deal with external pressures caused by increasingly fierce social competition and an unstable job market, but also manage the internal pressures from negative outcomes related to lack of exercise and poor lifestyle choices driven by a pursuit of a slim figure [2]. Therefore, it is of paramount importance to explore effective ways to improve the physical fitness of female college students and promote their positive mental development.

Fitness Qigong has become increasingly popular worldwide in recent years. According to reports, over the past five years, Fitness Qigong has established 26 provincial-level associations and 1,211 county-level associations in China. It has trained more than 268,000 Fitness Qigong social sports instructors and 26,000 Fitness Qigong referees, established over 33,000 Fitness Qigong stations, and promoted Fitness Qigong to 63 countries and regions. The number of practitioners, both domestic and international, has exceeded 6.5 million [3]. Fitness Qigong promotes the circulation of qi and blood and cultivates physical and mental harmony through the adjustment of breathing, movements, and thoughts, and is considered a secret to maintaining health and prolonging life [4]. Baduanjin exercise, a common form of Fitness Qigong with a history of more than 800 years in China, is attracting an increasing number of young people, particularly women [5, 6]. This exercise meets their dual needs for health preservation and weight loss [7, 8]. However, Baduanjin courses are seldom offered in universities, and few college students practice Baduanjin exercise. Moreover, there are limited research reports on the effects of Baduanjin on the physical and mental health of female college students. Therefore, further research is needed to explore the impact of Baduanjin on the physical and mental health of female college students.

The widespread adoption of Fitness Qigong and its specific forms like Baduanjin underscores its relevance and potential benefits in promoting health and well-being. Despite its historical significance and growing popularity, particularly among young women, there remains a substantial gap in the academic literature regarding its effects on specific populations such as female college students. Existing studies have primarily focused on general populations or on the elderly, with fewer studies assessing the impact on younger, academically involved individuals. Given the unique stressors faced by this demographic, including academic pressures and social expectations, it is crucial to evaluate how traditional exercises like Baduanjin could contribute to their physical and mental health.

The aim of this study is to analyze the impact of Baduanjin exercise on the physical fitness and mental health of female college students.

Materials and Methods

Participants

Sixty female college students from the 2022 cohort at University were randomly selected as experimental subjects from a pool of 150 volunteers. These participants were selected based on the following criteria:

1. no previous medical history;
2. absence of harmful habits such as drinking and smoking, with regular sleeping and working schedules;
3. physical health standard test score that was rated as good or passed in November 2022;
4. aged between 19-22 years;
5. no abnormal cardiopulmonary function.

The selected participants had an average age of 19±1.3 years, and all 60 completed the experiment, achieving a 100% retention rate. Participants were evenly assigned to either the control group or the experimental group. Prior to the experiment, all subjects were informed about the purpose and significance of the study and consent was obtained from each participant. This research was conducted in full compliance with ethical standards, with all procedures involving human participants approved by the Institutional Review Board of University.

Study Design

The experiment was conducted following the approved procedures of the Sports Committee of Henan University of Urban Construction and was in accordance with the ethical standards of the responsible committee (Grant No: 2021JG047).

All subjects were tested on various experimental indices before the experiment, from September 4-6, 2023, and after the experiment, from December 25-27, 2023.

To ensure accurate results, subjects began a light diet and avoided strenuous exercise while maintaining adequate sleep for 48 hours prior to each testing session. Throughout the duration of the experiment, they were required to maintain healthy living habits, which included avoiding overeating, staying up late, drinking alcohol, and smoking.

Experimental Methods

1) Experimental Teaching Time: The experiment lasted 16 weeks, from September 4 to December 27, 2023, and included normal attendance during the Mid-Autumn Festival and National Day holidays. The experimental group participated in five Baduanjin practice sessions each week, with each session lasting one hour from 19:30 to 20:30, Monday through Friday. Similarly, the control group (referred to as the referring group) also practiced five times per week during the same hours as the experimental group. Their activities consisted of focused physical exercises: basketball practice on Mondays and Wednesdays, badminton on Tuesdays

and Thursdays, and a choice of unrestricted exercise (such as table tennis, volleyball, dance, or other sports) on Fridays. Outside of these scheduled activities, neither the experimental group nor the control group engaged in additional aerobic sports.

2) Experimental Teaching Content: Baduanjin. The session includes a 10-minute warm-up activity, primarily consisting of jogging, limb joint mobility exercises, and muscle and ligament stretching. The main component, Baduanjin exercise, comprises a preparatory posture, eight distinct sections, and a closing posture. The eight sections are as follows:

1. Prop up the sky to tune the Sanjiao.
2. Draw the bow on both sides as if to shoot a vulture.
3. Stretch arms asymmetrically to enhance spleen and stomach function.
4. Look back to treat five strains and seven impairments.
5. Sway the head and buttocks to subdue the heart fire.
6. Touch feet to strengthen kidneys and waist.
7. Clench the fist and open eyes wide to enhance vitality.
8. Rise up on toes and land on heels repeatedly to cure diseases.

In order to enhance the exercise effect, music is played during the sessions to minimize external distractions and optimize the fitness outcomes for the experimental group. Participants were systematically taught Baduanjin during the first three weeks, followed by practice of combination movements over the next 13 weeks.

3) Experimental Testing Indicators: All participants in the experiment are over 18 years old. To enhance the scientific rigor and comparability of the experimental data, the student's height is used only as a basis for the calculation of the Body Mass Index (BMI) and not as a separate consideration indicator. All other indicators are indexed as much as possible, in accordance with the National Student Physical Health Standards (revised in 2014). The final determined physical fitness indicators for the students are as follows:

1. Body shape and cardiopulmonary function, and muscle strength indicators:
   - Body shape indicators include weight, BMI, waist circumference, and waist-hip ratio (WHR) [9].
   - Cardiopulmonary function and muscle strength indicators include step test index, lung capacity BMI, grip strength BMI, and sit-up BMI.
2. Sports skills indicators:
   - Physical fitness indicators include 800 m running and standing long jump.
3. Mental health indicators:
   - These are measured using the Symptom Checklist-90 (SCL-90) and the Self-Perception Inventory (SPI).

The Survey Tool

SCL-90 is adopted to evaluate the mental health of the participants, which was revised by Wang and includes 90 questions covering various symptoms such as somatization, obsessive-compulsive symptoms, interpersonal sensitivity, depression, anxiety, hostility, terror, paranoia, psychosis, and others [10]. The evaluation was conducted via questionnaires before and after the experiment on all 60 participants. Out of 60 questionnaires distributed, 56 were validly returned, resulting in an effective response rate of 93.3%. Each item on the questionnaire is scored on a 5-point scale where 1 indicates no symptoms and 5 corresponds to the most severe symptoms.

Using the SPI, 30 female college students who participated in the Baduanjin exercise were evaluated through a questionnaire before and after the experiment. Out of 30 questionnaires distributed, 28 were validly returned, giving a sample effective rate of 93.3%. Based on expert interviews and the characteristics of this study, three sub-scales including subjective experience, will quality, and behavior habit were compiled. Each scale consists of 4 items, scored from 1 to 5 points.

Statistical Analysis

Data were analyzed using SPSS software. Descriptive statistics summarized demographics and test scores. Independent samples t-tests were used to compare the experimental and control groups, depending on the normality of the data. Changes within groups over time were assessed using repeated measures ANOVA. Statistical significance was set at $p<0.05$. The validity coefficient for each symptom on the SCL-90 ranges from 0.80 to 0.94, and the Cronbach α coefficient for the total scale is 0.93. For the SPI, the validity coefficient for each symptom on the self-rating scale ranges from 0.77 to 0.91, and the Cronbach α coefficient for the total scale is 0.90. Cronbach's α was also calculated to confirm the reliability of the scales used.

Results

Body Shape Measurement Results Before and After experiment

From Figure 1, it can be seen that there is no significant difference between the referring group and the experimental group in various body shape indices before the experiment ($P > 0.05$). As illustrated in Figure 2, both the referring group and the experimental group show significant improvement in all body shape indicators after the experiment. Additionally, as shown in Figure 3, there are significant differences in various body shape indicators between the referring group and the experimental group after the experiment ($P < 0.05$).

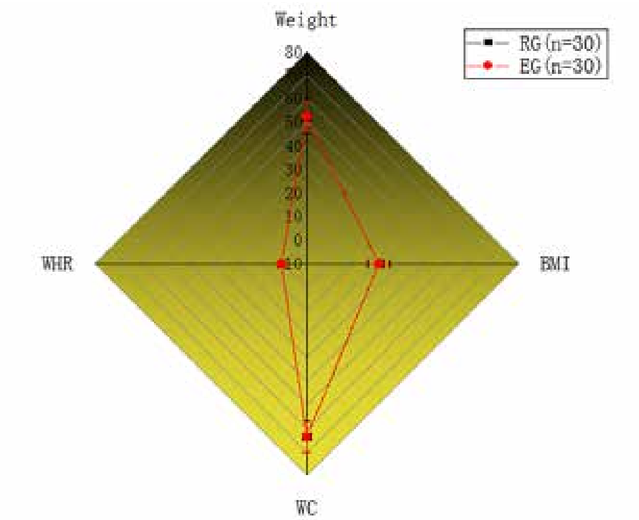

Figure 1. Comparison of body shape index test results between two groups of female college students before the experiment.

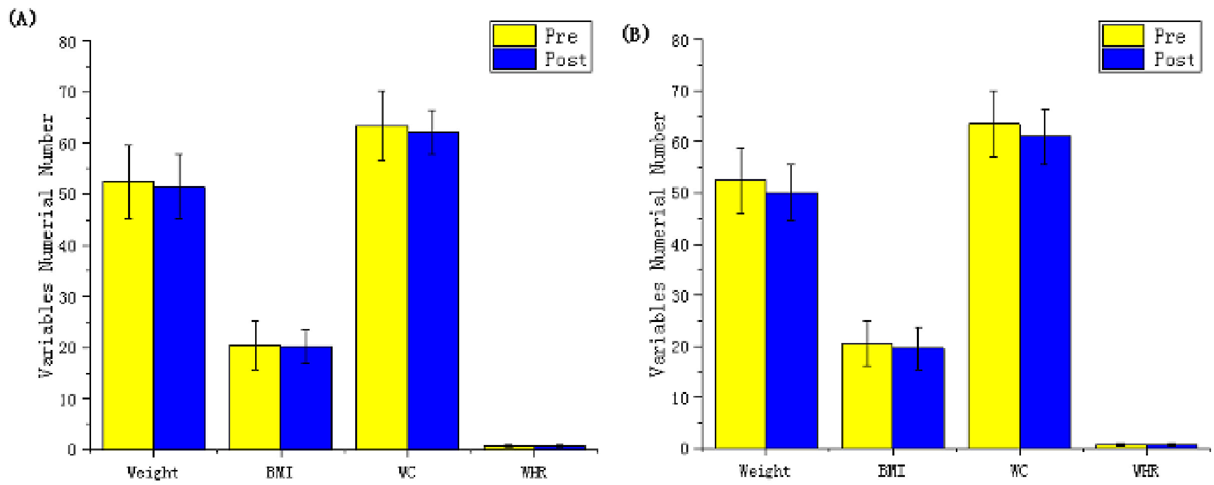

Figure 2. Comparison of body shape index test results in referring group of female college students before and after the experiment. (A) Comparison of body shape index test results in experimental group of female college students before and after the experiment. (B) BMI=body mass index, WC=waist circumference, WHR=waist-hip ratio.

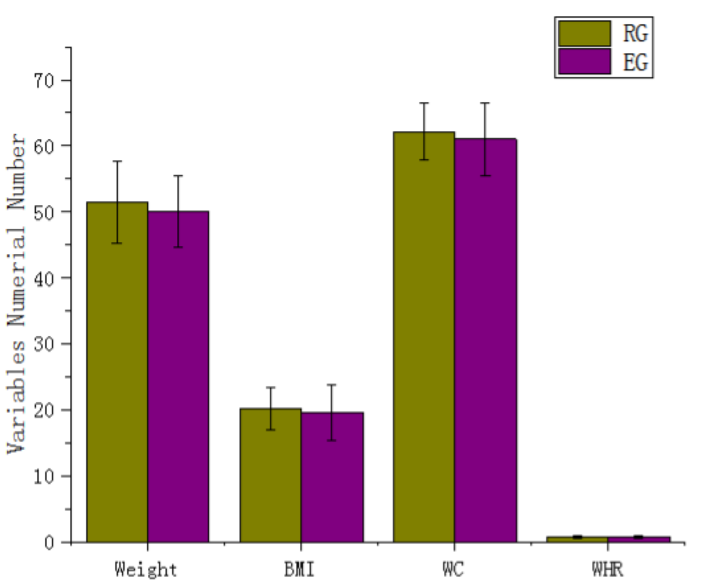

Figure 3. Comparison of body shape index test results between the two groups after the experiment. BMI=body mass index, WC=waist circumference, WHR=waist-hip ratio.

Test Results of Cardiopulmonary Function and Muscle Strength

From Figure 4, it can be observed that there are no significant differences between the referring group and the experimental group in the indices of step test, vital capacity body mass index, grip strength body mass index, and sit-up body mass index before the experiment ($P > 0.05$). Figure 5 shows that both the referring and experimental groups demonstrate significant improvements in all the indices after the experiment ($P < 0.05$). Figure 6 demonstrates that there are significant differences between the referring group and the experimental group in these indices after the experiment ($P < 0.05$).

Test Results of Motor Skills and Physical Fitness

From Table 1, it can be seen that there are no significant differences between the referring group and the experimental group in the 800 m run and the standing long jump before the experiment ($P > 0.05$). Both the 800 m run and the standing long jump show significant improvements before and after the experiment in the referring group ($P < 0.005$). After 16 weeks of practicing Baduanjin, the experimental group also showed significant improvements in the 800 m run and standing long jump compared to before the experiment ($P < 0.01$). Moreover, there was a significant difference between the two groups after the experiment ($P < 0.05$), with the experimental group exhibiting greater improvements in physical fitness compared to the referring group.

Mental Health Measurement Results

As shown in Table 2, there is no significant difference in the SCL-90 scores between the referring group and the experimental group before the experiment ($P > 0.05$). All 10 indices in both groups show a downward trend after the experiment with significant differences ($P < 0.05$ or $P < 0.01$).

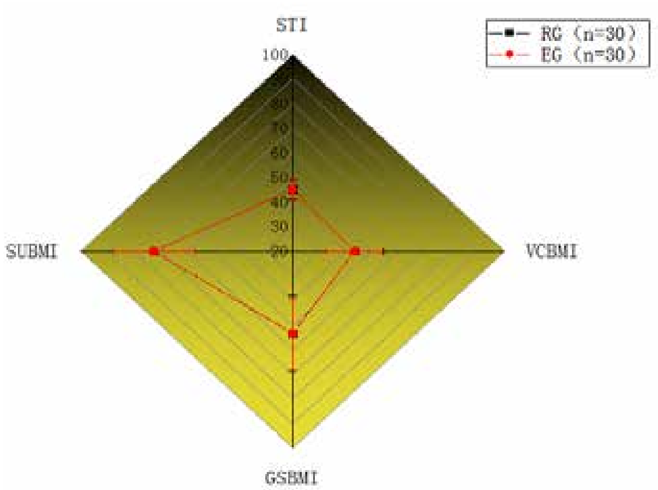

Figure 4. Test results of cardiopulmonary function and muscle strength of the two groups before the experiment. RG = referring group, EG = experimental group, STI=step test index, VCBMI=vital capacity body mass index, GSBMI=grip strength body mass index , SUBMI=sit-up body mass index.

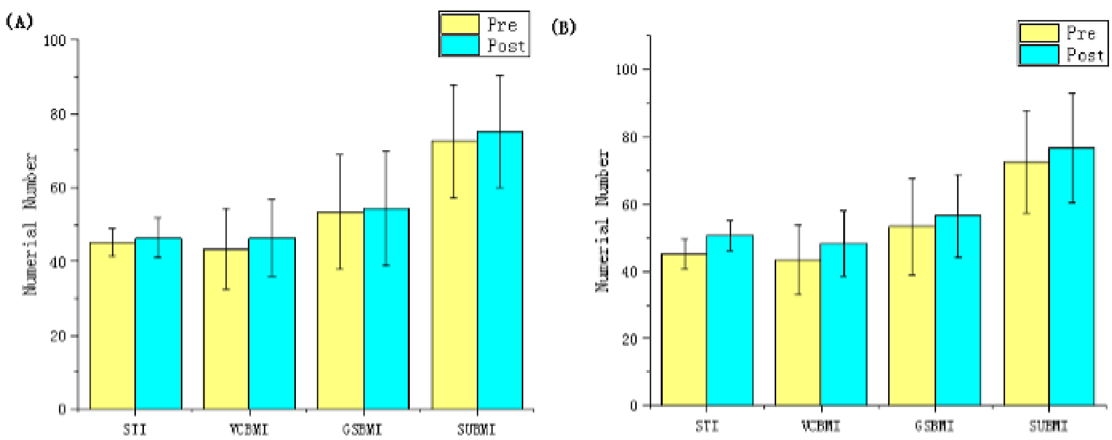

Figure 5. Test results of cardiopulmonary function and muscle strength of the referring group before and after the experiment. (A) Test results of cardiopulmonary function and muscle strength of the experimental group before and after the experiment. (B) RG = referring group, EG = experimental group, STI=step test index, VCBMI=vital capacity body mass index, GSBMI=grip strength body mass index , SUBMI=sit-up body mass index.

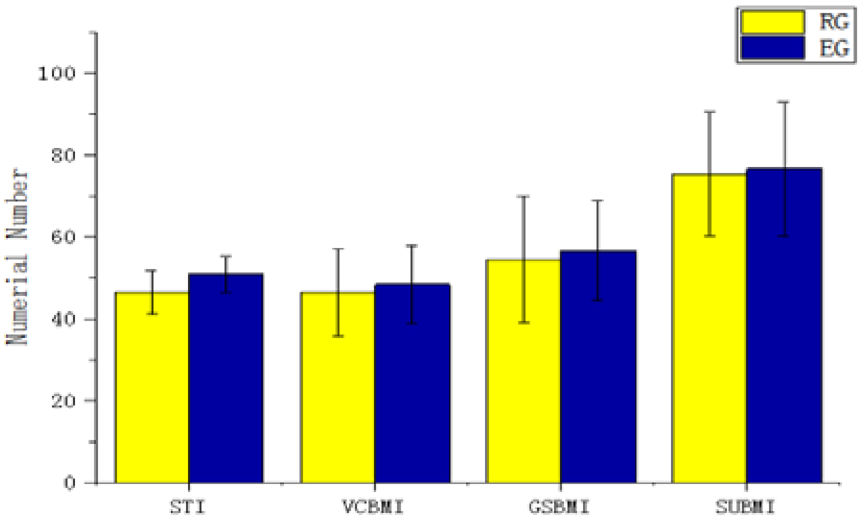

Figure 6. Test results of cardiopulmonary function and muscle strength of the two groups after the experiment. RG = referring group, EG = experimental group, STI=step test index, VCBMI=vital capacity body mass index, GSBMI=grip strength body mass index , SUBMI=sit-up body mass index.

Table 1. Test results of motor skills and physical fitness of two groups of female college students before and after the experiment

Variables	RG (n = 30)		t-value	p-value	EG (n = 30)		t-value	p-value
	Pre	Post			Pre	Post		
800 (m/s)	238.7 ±27.6	231.3± 32.2	6.17	0.01	238.7± 28.8	230.8± 30.6	5.48	0.01
SLJ (m)	1.73± 0.5	1.78 ± 0.4	-2.03	0.04	1.73±0.4	1.81±0.3	-2.54	0.01

Values are expressed as means ± standard deviations. RG - referring group, EG = experimental group, SLJ - standing long jump.

Table 2. Comparison of SCL-90 levels between two groups of female college students before and after the experiment

Group	Statistics before and after experiment	Somatization	OCS	IS	Depression	Anxiety	Hostility	Terror	Paranoia	Psychosis	Others
RG (n=30)	Pre	1.46±0.35	1.57±0.34	1.59±0.30	1.62±0.43	1.58±0.34	1.62±0.38	1.48±0.22	1.61±0.43	1.45±0.39	1.57±0.32
	Post	1.44±0.25	1.56±0.32	1.58±0.31	1.60±0.33	1.59±0.17	1.61±0.34	1.47±0.12	1.63±0.33	1.50±0.35	1.56±0.33
	t- value	0.56	0.11	0.98	1.54	-0.66	5.41	0.70	-1.14	-1.33	1.83
	p-value	0.05	0.06	0.42	0.73	0.82	0.03	0.71	0.91	0.61	0.63
EG (n=30)	Pre	1.46±0.25	1.57±0.44	1.59±0.28	1.62±0.44	1.58±0.44	1.62±0.42	1.48±0.53	1.61±0.52	1.45±0.41	1.57±0.41
	Post	1.42±0.34	1.53±0.42	1.48±0.21	1.41±0.63	1.42±0.47	1.47±0.53	1.42±0.42	1.58±0.38	1.31±0.25	1.50±0.24
	t- value	1.25	1.32	4.58	4.84	5.68	6.62	3.83	2.23	6.62	1.71
	p-value	0.03	0.03	0.01	0.01	<0.01	<0.01	0.01	0.04	<0.01	0.04

Values are expressed as means ± standard deviations. RG - referring group, EG - experimental group, OCS - obsessive-compulsive symptoms, IS=interpersonal sensitivity.

It is evident that the indices of the experimental group are significantly different from those of the referring group after the experiment ($P < 0.05$).

Test Results of Baduanjin Practice Feeling Scale

After 16 weeks of Baduanjin training, the experimental group of female college students (n=30) demonstrated significant improvements in their sense of spiritual arousal (4.27±0.78) and sense of participation (3.86±1.06), compared to their scores before the experiment (2.82±1.39 and 2.90±1.54, respectively). The t-values for these improvements were 7.18 and 8.26, with P values averaging less than 0.01, indicating significant differences. However, their sense of fatigue (2.02±1.59) showed no significant change from the baseline (2.01±1.65), with a t-value of 0.86 and P>0.05.

Discussion

The aim of this study was to analyze the impact of Baduanjin exercise on the physical fitness and mental health of female college students. Our findings indicate that after 16 weeks of regular Baduanjin practice, participants showed significant improvements in both physical and mental health parameters. Physically, there was an enhancement in body shape indices such as BMI, waist circumference, and overall muscle strength. Mentally, participants exhibited reduced symptoms of stress and anxiety, improved emotional regulation, and increased self-esteem, demonstrating the holistic benefits of Baduanjin exercises.

The Effect of Baduanjin exercise on the Body Shape

Our findings are consistent with previous studies that have documented the positive impacts of Baduanjin on body composition. Notably, after 16 weeks of Baduanjin training, there was a significant decrease in all body shape indexes, including weight, BMI, waist circumference, and waist-hip ratio (WHR), among our experimental group. This complements the data from the National Students' Physical Health Standard, suggesting that most college students' body shape indexes typically fall within the middle range, indicative of the general decline in physical quality among this demographic in China [11, 12].

Further comparison with existing literature, such as the study by Zhao and Chen (2017), which also observed similar improvements in BMI and WHR after Baduanjin exercises, validates our results [13]. However, our study extends these findings by showing significant reductions not only in weight and BMI but also in waist circumference and overall girth measurements, which have been less frequently reported [14, 15, 16, 17]. These outcomes suggest that prolonged Baduanjin practice can lead to a fitter, more symmetrical, and better-proportioned physique, going beyond the typical improvements noted in earlier research.

Our results underscore Baduanjin's role in not merely reducing body weight but in enhancing overall physical quality, supporting its integration into fitness programs aimed at improving body shape and health among female college students.

The Effect of Baduanjin Exercise on Cardiopulmonary Function and Muscle Strength

Our study demonstrated significant enhancements in cardiopulmonary function and muscle strength from practicing Baduanjin among female college students. Notably, we observed improvements in blood circulation, oxygen supply, and the functions of the cardiovascular and respiratory systems. This contributed to increased cardiopulmonary endurance, as confirmed by studies on circulatory systems [18]. These benefits are attributed to the integrated movements and controlled breathing that are central to Baduanjin practice, where practitioners are required to synchronize deep inhalations and slow exhalations with physical movements, enhancing both lung capacity and overall oxygen intake [19].

Additionally, the improvement in muscle strength, particularly in upper limb strength and abdominal muscle strength as evidenced by increased grip strength and better sit-up performance, is consistent with known benefits of regular physical exercise [20]. Specific postures like "sway the head and buttocks to subdue the heart fire" and "touch feet to strengthen kidneys and waist" effectively engage core and stabilizing muscles, underlining the comprehensive physical benefits of Baduanjin [21].

Our findings align with the general understanding in physical health research that structured exercise programs like Baduanjin not only improve specific bodily functions but also contribute holistically to physical health [22]. This suggests that continued practice can yield significant and lasting benefits, supporting the inclusion of Baduanjin in fitness regimes aimed at improving the physical health and fitness of young adults.

The Effect of Baduanjin Exercise on Sports Skills and Physical Fitness

Baduanjin exercises include a variety of movements that target different aspects of physical health according to traditional Chinese medicine. Key exercises include:

- "Draw the bow on both sides as if to shoot a vulture," enhancing upper body strength and promoting blood circulation [23].
- "Stretch arms asymmetrically to enhance spleen and stomach function," aiding gastrointestinal function and organ traction [24].
- "Look back to treat five strains and seven impairments," improving neck muscle functionality, body balance, and brain fatigue relief [25].
- "Sway the head and buttocks to subdue the heart fire" and "Touch feet to strengthen kidneys and waist," which relax the mind and strengthen body tissues, particularly supporting kidney and adrenal gland function [26, 27].
- "Clench the fist and open eyes wide to enhance vitality," which benefits eye muscles and helps prevent myopia [28].
- "Rise up on toes and land on heels repeatedly to cure diseases," stimulating internal organs and promoting energy flow [29].

These exercises are supported by five hand types and four step types–such as natural palm, full eight-character palm, horse stance, and lunge–that encourage comprehensive body movement and health adjustment [30].

After 16 weeks of practice, female college students in the experimental group showed significant improvements in the sitting forward bend, 800m run, and standing long jump, indicating enhanced endurance, flexibility, and strength. These findings corroborate the intended benefits of Baduanjin, demonstrating its effectiveness in improving both specific sports skills and overall physical fitness.

Baduanjin's Influence on Mental Health

In modern society, college students face numerous mental pressures, including academic demands, interpersonal relationships, and employment concerns, which can lead to increased anxiety, depression, and stress [31]. The rising incidence of mental health issues among college students is a growing concern [32].

Baduanjin, a traditional fitness regimen, has been shown not only to promote physical health but also to enhance mental well-being in this demographic [33]. The mental health benefits are multifaceted:

1. *Concentration:* Baduanjin requires focused concentration on specific movements and breathing rhythms, helping students disconnect from external distractions and reduce mental stress and anxiety [34].
2. *Relaxation:* The regimen promotes physical and mental relaxation through precise movements and controlled breathing, aligning body posture and respiration to alleviate tension and enhance mental health [35].
3. *Self-confidence and Self-esteem:* Regular practice of Baduanjin improves physical flexibility and strength, which often translates into enhanced self-confidence and self-esteem. Maintaining proper posture during exercises also improves self-presentation [36].
4. *Emotional Management:* Baduanjin enhances emotional regulation by fostering self-control through disciplined breathing and movements. This ability to manage emotions helps students maintain composure under stress, a crucial skill in university settings [37].

These aspects of Baduanjin not only corroborate findings from other studies on traditional exercises but also demonstrate its unique applicability and efficacy in improving the mental health of college students, making it a valuable component of student wellness programs.

The experimental data from this study conclusively demonstrate the positive impact of Baduanjin on the mental health of female college students. After 16 weeks of Baduanjin training, significant improvements were observed in all measured mental health indicators, with notable enhancements in ten specific areas, including somatization, obsessive-compulsive symptoms, interpersonal sensitivity, and depression, all showing P-values less than 0.05 or 0.01. The training also significantly boosted the spirits and sense of participation among the participants, enhancing their mental outlook and contributing to increased vitality and engagement in both their personal lives and academic endeavors. Furthermore, Baduanjin has been shown to improve self-control, further supporting overall well-being.

These findings suggest that Baduanjin could be effectively integrated into mental health interventions for college students, potentially offsetting some of the psychological challenges they face today. Future research could explore the long-term impacts of regular Baduanjin practice on mental health, compare its effects across different demographic groups, or evaluate its efficacy as part of a comprehensive wellness program. Such studies would help to establish more definitively the role of traditional exercises like Baduanjin in modern health care and educational settings.

Conclusions

In conclusion, Baduanjin exercise has been shown to effectively decrease body weight, enhance body shape, and improve both cardiopulmonary function and muscle strength in female college students. Additionally, it significantly reduces mental stress and anxiety, while helping students to boost their self-confidence and manage their emotions more effectively. Given these benefits, Baduanjin proves to be a practical and effective fitness approach for female college students, offering extensive physical and psychological health advantages.

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PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Personality traits and sporting level of athletes

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

Abstract

Background and Study Aim Personality traits significantly influence athletic performance and the development of athletes. However, these traits vary at different levels of sport. This knowledge gap makes it difficult to effectively tailor training and support programs. Thus, the purpose of this article is to identify differences in the expression of personality traits among professional athletes, competitive athletes, and amateur athletes.

Material and Methods The respondents (N=83) were sport seniors from Poland, aged 23 years, studying at the Wroclaw University of Health and Sport Sciences. They were classified into three groups: 1) n=23 professional athletes; 2) n=30 competitive athletes; and 3) n=30 amateur athletes. The Big Five model was used, and the NEO-FFI personality questionnaire was administered. Analyses were performed using IBM SPSS Statistics 27.0, with a statistical significance level set at $\alpha = 0.05$.

Results Differences in neuroticism intensity among athletes from different sport levels were noted. Professional athletes showed the lowest level of neuroticism. However, no differences were observed in the intensity of individual personality traits among athletes by gender. Furthermore, correlations were noted between sport level and athletes' personality traits: neuroticism (strong and negative), extraversion (weak and positive), and conscientiousness (weak and positive).

Conclusions Findings underscore the importance of considering personality traits when developing tailored training and support programs for athletes. The absence of gender differences in personality traits suggests that such programs can be designed without gender-specific adjustments. The identified correlations between sport level and personality traits provide valuable insights for coaches and sport psychologists to better understand and support athletes' psychological profiles.

Keywords: sports psychology, Big Five, professional athletes, competitive athletes, amateur athletes

Introduction

Athletic performance and development are profoundly influenced by personality traits, yet these traits exhibit significant variability across different levels of sport. This variability presents a challenge in tailoring effective training and support programs for athletes. Understanding these differences is crucial for optimizing performance and psychological well-being. Additionally, the cultural context in which sports are perceived by different societies adds another layer of complexity to how personality traits manifest in athletes.

A contemporary cultural issue is the perception of sport by different societies. In this context, various studies indicate possible directions for addressing this issue. In a global perspective, the term qualified sport is known [1]. This means participating in a sporting competition organised by a particular sporting discipline organisation or a body acting on its behalf. In Poland, in physical culture sciences, there is a division into three levels: professional sport, competitive sport, and amateur sport [2].

Professional sport means training and competing in sport as if providing work or services for remuneration [3]. Whether or not there is a formal employment contract between the professional athlete and a certain sports organization is irrelevant here. The remuneration exceeds the costs of training and participating in sporting competitions and constitutes a significant part of the athlete's income [4]. Additionally, there are professional athletes who participate in sports competitions while being employed by uniformed services, such as the army, police, border guards, and firefighters. Such athletes receive the salary of a uniformed employee, but their primary job is to represent the country at international sports competitions [5]. Competitive sport, on the other hand, is undertaken voluntarily through competition for maximum sporting performance. The essence here is performance, achieving something more through competition [6]. Competitive athletes work in the economic sector for their livelihood. They do not have financial contracts with clubs and are not on the payroll. In Poland, the standard is that a competitive athlete works from morning until noon and only trains in the afternoon [7]. In contrast, amateur sport is a voluntary competition undertaken for active leisure and entertainment. What is important here is that the amateur athlete has the ambition to break personal records, but they do not subordinate their

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life to sport. Sporting activity is merely an addition to their life [8].

This cultural problem concerns the organizational division of sport into professional (for profit) and amateur (for pleasure) [9]. In this sense, professional athletes and competitive athletes compete in professional sports organizations, while amateur athletes compete in amateur sports organizations. However, there are also sports, such as triathlon and long-distance running, in which professional, competitive, and amateur athletes participate in the same competition. Moreover, in less developed countries, there have been instances where the core of the national team for a particular World Championships or Olympic Games is made up of both professional athletes and amateurs.

The problem described above may influence the personalities of athletes [10]. Professional, competitive, and amateur athletes, like other people, shape their personalities through experiences, interpersonal contacts, social roles, and repeated situations [11, 12, 13]. Therefore, one may assume that athletes from different sport levels will not differ in the intensity of personality traits. However, one could also assume the opposite: that athletes from different sport levels differ in the intensity of personality traits because they have different lifestyles. This issue remains relevant in physical culture sciences, particularly in the areas of sport psychology and sport theory [14, 15, 16].

Previous results in this area have referred to the relationship between personality and sports performance. The distribution of the neuroticism trait has been shown to be important in taking up sports activities. Lower levels of neuroticism are associated with better sports performance [17]. More successful athletes tend to show higher emotional stability than less successful athletes [18]. A significant relationship between neuroticism and sports performance is also found among disabled athletes [19]. This trait is the most frequently evaluated in studies on sport and exercise psychology [20]. At the same time, it is the most common mediator of associations with stress coping styles [21]. However, analyses of global studies show that, in addition to neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness are also positively correlated with sports performance [22]. Moreover, greater sports experience translates into a more pronounced personality, including lower neuroticism [23]. Therefore, it is reasonable to verify the relationship between personality traits and sporting level. This will either solidify previous results or demonstrate new regularities. In view of the above, the aim of this article was to acknowledge the differences and relationships among professional athletes, competitive athletes, and amateur athletes in the intensity of personality traits.

Materials and Methods

Participants

Eighty-three sport seniors from Poland aged 23 took part in the study. They all held a bachelor's degree and had ten years of experience in sporting competition. The respondents were master's students of sport at the Wroclaw University of Health and Sport Sciences. Among them were 23 professional athletes (including 10 females and 13 males who hold a master class in sport), 30 competitive athletes (including 15 females and 15 males who hold a master or first sports class), and 30 amateur athletes (including 17 females and 13 males). These homogeneities determined the division of the respondents into three groups: professional athletes (n=23), competitive athletes (n=30), and amateur athletes (n=30). Each group included athletes from combat sports (judo, kickboxing, wrestling), individual sports (athletics, modern dance, bodybuilding, fitness, swimming), and team sports (football, handball, basketball, volleyball). Satisfactory numbers of variables by sport were not achieved, so this study is limited to a case study of professional athletes, competitive athletes, and amateur athletes from the Wroclaw University of Health and Sport Sciences. The surveyed professional and competitive athletes had Polish and international successes in leading sports organizations in their respective sports. Similarly, the amateur athletes had Polish and international success in amateur sports organizations. Their behavior was within the norm, and they did not show any disorders.

Research Design

The Big Five model was used, which is nowadays regarded as the most reliable and tested theory of personality traits. This model considers five dimensions as the theoretical construct of personality, each of which has an opposite pole. These dimensions are: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness [24]. Together, they provide a comprehensive description of the human personality. The intensity of these dimensions is measured on a scale from 1 to 10 sten. The Big Five dimensions exist in real life and are relevant to an individual's adaptation to the environment. They are invariant, universal, and have a high degree of heritability [25]. The NEO-FFI personality questionnaire, which has applications in both theoretical and applied sport psychology, was chosen as the tool. The NEO-FFI is a shortened version of the NEO-PI-R used in clinical research.

Therefore, the NEO-FFI provides only the most important information within the five main factors—neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness—

without their components. The NEO-FFI consists of 60 self-report statements. The truthfulness of these statements in relation to the self is assessed by the respondent on a five-point scale. Each dimension consists of 12 statements. The NEO-FFI has specific norms that relate to gender and age in the ranges of 15-19 years, 20-29 years, 30-39 years, 40-49 years, and 50-80 years [26]. Due to the age of the subjects, the NEO-FFI norms for ages 20-29 were adopted. The internal consistency of the measurement scales was verified. The following Cronbach's alpha reliability coefficients were obtained: 0.88 (neuroticism), 0.78 (extraversion), 0.59 (openness to experience), 0.63 (agreeableness), and 0.85 (conscientiousness). The coefficients for neuroticism and conscientiousness are highly satisfactory.

The study was conducted in January 2023 at the Wroclaw University of Health and Sport Sciences. The athletes were queried during a sport psychology class, in a room isolated from noise and well-lit. The inclusion criteria for the athletes were a voluntary and written willingness to participate in the study and a documented record of achievement at the relevant sporting level. All respondents also gave their consent for the results obtained to be used, with full anonymity, for scientific research purposes by the Wroclaw University of Health and Sport Sciences. Prior to completing the NEO-FFI, the subjects were given instructions on how to complete the questionnaire. The athletes completed the NEO-FFI within 60 minutes. Each respondent was individually briefed on their results, followed by a discussion. After these activities, the data were coded and prepared for analysis. The entire procedure was carried out in accordance with the Declaration of Helsinki. The research received approval from the Senate Committee for Research Ethics at the Wroclaw University of Health and Sport Sciences, number 20/2019.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 27.0 software. The program conducted analysis of basic descriptive statistics, one-way analysis of variance, tests of differences for independent samples, and Spearman rank correlations. The level of statistical significance in the analyses was set at $\alpha = 0.05$. A sensitivity analysis of the statistical test was also performed to determine the minimum power of the effect (sensitivity analysis for computing required effect size). With a test sample size of N = 83, a significance level of $\alpha = 0.05$, and a statistical power of the test corresponding to 95%, it was possible to detect an effect size of $\eta^2 = 0.14$ (Cohen's f = 0.40).

Results

In the first step of the analysis, basic descriptive statistics were performed along with a normality test of the distribution. The analyses used results converted into stens according to the applicable norms (Table 1).

Within the analysis carried out, it was observed that the distribution of the variables follows a normal distribution. The exception is the distribution of agreeableness (p = 0.037), but by analyzing the low skewness value (Sk. < 1), it can be concluded that the distribution of this variable does not deviate significantly from the normal distribution. Therefore, it is reasonable to use parametric tests. In the next step of the analysis, the intensity of individual personality traits was compared between the sport levels of professional (n = 23), competitive (n = 30), and amateur (n = 30) athletes.

The compared groups are equal, $\chi^2(2) = 1.18$, $p = 0.554$. An equal gender distribution was also observed in the compared groups, $\chi^2(2) = 0.91$, $p = 0.634$. A one-way ANOVA was performed as part of the analysis. The dependent variable was individual personality traits, while the independent variable was the level of the athletes. The analysis showed that there were differences between athletes of different sport levels in the severity of neuroticism, $F(2,82) = 36.04$, $p < 0.001$. The observed effect size is large, $\eta^2 = 0.474$ (Table 2). Post-hoc analysis (Table 3) showed that professional athletes significantly differed in neuroticism intensity (M = 10.70) from competitive athletes (M = 21.00) and from amateurs (M = 22.23). In addition, competitive athletes also have lower levels of neuroticism than amateurs.

In the next step, the intensity of individual personality traits was compared by the gender of

Table 1. Basic descriptive statistics including normality of distribution test.

Dependent variable	M	Mdn	SD	Sk.	Kurt.	Min.	Max.	W	p
Neuroticism	20.40	20.00	9.59	0.24	0.20	0.00	46.00	0.98	0.353
Extraversion	31.22	31.00	7.02	-0.09	-0.26	14.00	48.00	0.99	0.664
Openness	26.39	26.00	5.70	0.39	-0.58	15.00	39.00	0.97	0.037
Agreeableness	30.20	30.00	5.34	-0.17	-0.79	19.00	40.00	0.97	0.079
Conscientiousness	32.57	33.00	7.81	-0.06	-0.55	13.00	48.00	0.98	0.342

M - mean; Mdn - median; SD - standard deviation; Sk - skewness; Kurt - kurtosis; Min - the lowest value of the set; Max - the highest value of the set; W - Shapiro-Wilk test; p - significance level.

Table 2. Comparison of amateur, competitive and professional athletes in terms of individual personality traits.

Dependent variable	Professionals (n = 23)		Competitive (n = 30)		Amateurs (n = 30)		F(2, 82)	p	η^2
	M	SD	M	SD	M	SD			
Neuroticism	10.70	6.27	21.00	5.00	22.23	9.06	36.04	<0.001	0.474
Extraversion	33.61	5.38	31.53	7.63	29.07	7.07	2.90	0.061	0.068
Openness	26.13	5.72	26.90	5.35	26.07	6.16	0.19	0.829	0.005
Agreeableness	30.78	4.85	29.83	6.17	30.13	4.95	0.21	0.815	0.005
Conscientiousness	35.52	7.81	32.00	7.68	30.87	7.87	2.53	0.086	0.059

M– mean; SD– standard deviation; F - ANOVA test statistics; p - significance level; η^2 - eta square.

Table 3. Multiple comparisons of the level of intensity of individual personality traits among athletes from different sport levels.

Level	Neuroticism	Extraversion	Openness	Agreeableness	Conscientiousness
Professionals - Competitive	10.30[b]	-2.07	0.77	-0.95	-3.52
Professionals - Amateurs	16.54[b]	-4.54	-0.64	-0.65	-4.65
Competitive - Amateurs	6.23[b]	-2.47	-0.83	0.30	-1.13

b - significant difference between groups (p<.001) adjusted by the Bonferroni method.

Table 4. Comparison of standardised scores of severity of personality traits by gender of respondents

Variables	Female (N = 42)		Male (N = 41)		t	p	d
	M	SD	M	SD			
Neuroticism	4.79	2.32	4.63	2.35	-0.29	0.768	-0.065
Extraversion	6.48	2.31	6.76	1.94	0.60	0.553	0.131
Openness	4.60	1.87	4.80	1.82	0.52	0.607	0.113
Agreeableness	5.76	2.21	6.41	2.00	1.41	0.162	0.310
Conscientiousness	6.76	2.30	6.71	2.16	-0.11	0.911	-0.025

M - mean; SD - standard deviation; t - Student's t-test; p - significance level; d - average deviation.

the subjects. For this purpose, the standardized results for women (n = 42) and men (n = 41) were compared using the Student's t-test for independent samples. No difference in the intensity of individual personality traits was observed between men and women (Table 4).

In the last step of the analysis, the existence of a relationship between sport level and the intensity of the athletes' personality traits was verified. The analysis showed a strong (rho > 0.6) and negative correlation between sport level and neuroticism, rho(82) = -0.65, p < 0.001. A weak (rho < 0.3) and positive correlation was also observed between sport level and extraversion, rho(82) = 0.26, p = 0.018, and between sport level and conscientiousness, rho(82) = 0.22, p = 0.043 (Table 5).

Discussion

The results of the study provide new insights in the areas of sport psychology and sport theory. One difference in the intensity of personality traits was detected in the studied population of Polish athletes: professional, competitive, and amateur. The hypothesis was verified, and the studied groups differed significantly, but only in the intensity of neuroticism. Professional athletes

Table 5. Correlations between sporting level and personality traits of athletes

Variable		Level	1.	2.	3.	4.
1. neuroticism	Spearman's *rho*	**-0.654****				
	relevance	**<0.001**				
2. extraversion	Spearman's *rho*	**0.259***	**-0.386****			
	relevance	**0.018**	**<0.001**			
3. openness	Spearman's *rho*	0.030	-0.13	**0.261***		
	relevance	0.800	0.258	**0.017**		
4. agreeableness	Spearman's *rho*	0.050	-0.08	0.02	0.030	
	relevance	0.682	0.490	0.862	0.765	
5. conscientiousness	Spearman's *rho*	**0.223***	**-0.271***	0.160	0.140	0.040
	relevance	**0.043**	**0.013**	0.159	0.220	0.725

Note: * - $p < 0.05$; ** - $p < 0.001$

showed a lower intensity of neuroticism compared to competitive athletes and amateurs. Competitive athletes also showed lower neuroticism intensity compared to amateur athletes. Furthermore, the strong and negative correlation between sport level and neuroticism confirmed these significant differences. In contrast, the weak and positive correlations between sport level and extraversion, and between sport level and conscientiousness, do not contribute significantly, as no significant differences were observed in the intensity of these traits in the study population. This means that higher levels of sports performance are associated with lower neuroticism. That is, professional athletes, compared to competitive and amateur athletes, are more emotionally stable and better able to cope with difficult life situations. They are also more satisfied with themselves and have a greater sense of security. Stressful situations are unlikely to make them nervous or throw them off balance. They are more calm, balanced, and relaxed. The same description applies to the relationship between competitive athletes and amateur athletes. It is also important to note that the studied population does not differ in the intensity of personality traits by gender. Therefore, a low intensity of neuroticism may also occur in women's sports and be one of the conditions necessary for an athlete to reach a higher sporting level.

The above indicates that the distribution of the trait of neuroticism remains important in undertaking sports activities. The lowest intensity of this trait among professional athletes shows that these individuals have managed their negative emotional states through constant training and competition, as their sports environment functions as a working environment [27, 28]. In contrast, the higher intensity of neuroticism among competitive athletes relates to their different functioning. For these individuals, the sports environment is not a working environment. On one hand, there is a tendency to maximize athletic performance through training and competing [29, 30], and on the other hand, there is a burden of responsibilities and work problems, often linked to finding funding to compete [31]. In contrast, the slightly higher intensity of neuroticism among amateur athletes emphasizes the impact of physical activity on individuals who occasionally engage in sport competition [32] and highlights the differences between those who participate in sport competition systematically [33, 34]. Accordingly, the positive aspects of sport are favored, including the dissemination of educational values such as the idea of Olympism and the principles of fair play [35, 36], which shape the personality of athletes [37].

An earlier study on the relationship between personality and sports performance also indicated the relevance of neuroticism levels [17, 18, 19, 20, 21, 22, 22]. Moreover, gaining sports experience also translates into competitive proficiency and lower neuroticism [23]. In contrast, the results further solidified the importance of a low level of neuroticism and provided a new argument. The level of neuroticism among athletes can both enhance and undermine athletic competition. Professional athletes experience negative emotional states to a lesser extent, while competitive athletes experience them somewhat more. This translates into their athletic performance [38], abstracting from physiology, of course [39]. A lower level of neuroticism makes it possible to interpret the start situation positively. This is because negative emotional reactions are not perceived as debilitating, but as a positive state [40]. In contrast, athletes with higher levels of neuroticism are more likely to experience negative consequences of emotional states in sports competition [41]. Therefore, it should be noted that these emotional states can become habitual and ingrained in the athlete [42]. In addition, this may explain why athletes may be more prone to depression compared to the general population, as they are constantly burdened by the physical and psychological demands placed on them by the sports environment [43]. This is compounded by extra-sport problems and, in the case of professional and competitive athletes, the added pressure of results [44]. Publicly judged performance, perceived acceptance in the sports community, risk-taking behavior, and eating disorders can increase the risk of developing common psychiatric disorders in athletes [45]. This is why the mental preparation of athletes for competition plays such an important role. It is crucial for the education of each athlete that, without exception, there is a mental coach or sports psychologist present in the coaching staff. A mental coach brings out an athlete's hidden potential by educating them in the use of psychological skills. A sports psychologist, on the other hand, has the competencies of a mental coach but can also provide comprehensive psychological support. Therefore, the promotion of this knowledge is beneficial for the overall health of athletes and for the effective management of sports training by coaches.

It is recommended to introduce psychological programs into the mental preparation of athletes aimed at the formation and maintenance of a healthy personality. A correctly managed process of personality improvement is extremely important, as it allows for the development and correction of disturbed traits. This, in turn, enhances the functioning of the athlete and their ability to maximize their sporting performance.

The present study is limited to a case study of Polish athletes aged 23 years, who were competitors in the following sports: judo, kickboxing, wrestling, athletics, modern dance, bodybuilding, fitness, swimming, football, handball, basketball, and volleyball from different sport levels. These athletes were master's students in sport at the Wroclaw University of Health and Sport Sciences. The small size of the sample for each sport discipline did not allow for the verification of differences between the intensity of personality traits and sport level in specific sports, but only refers to general differences between professional, competitive, and amateur athletes. Therefore, the results must be related to a specific place, time, and population. The lack of this knowledge makes it impossible to verify the metacognitive question: what personality traits did the subjects have before they started sporting activities, and did these traits influence their choice of a specific sport?

In view of the relevance of the issue of personality in sport psychology and sport theory, this subject matter should be continued. Research work should be carried out on as large a scale as possible, taking into account nationality, gender, and age, across all contemporary sports. In this sense, the results obtained may serve as a pilot for larger-scale studies.

Conclusions

The study highlights the importance of considering personality traits in sport psychology and sport theory. It is evident that the level of neuroticism significantly influences athletic performance, with lower levels being characteristic of professional athletes, contributing to better emotional stability and stress management. This underscores the need for integrating psychological programs into the training of athletes aimed at developing and maintaining healthy personality traits. Furthermore, the findings suggest that future research should be conducted on a larger scale, considering variables such as nationality, gender, and age across various sports. These results can serve as a pilot for more extensive studies, enhancing our understanding of the role of personality in athletic success.

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PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Impact of arm technique and elastic force on vertical jump performance in physical education students: a convergent validation study

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

Abstract

Background and Study Aim Vertical jump performance is crucial for athletes in many sports. However, the optimal techniques for maximizing jump height and efficiency for both students and professional soccer players require more effective solutions. This study aimed to investigate the influence of various vertical jump techniques, focusing on arm swing and elastic force utilization, and to evaluate the extent of the impact that each modification has on biomechanical characteristics and performance outcomes.

Material and Methods Ten first-grade Sport Science students and ten professional soccer players from F.C. Malisevo participated in the study. The participants performed a series of jumps, including the Countermovement Jump (CMJ), Squat Jump (SJ), and Abalakov jump (ABL), while being recorded on an iPhone 13 Pro at 240 frames per second. Data analysis was conducted using the My Jump 3 app and SPSS 26 software. Descriptive statistics and one-way ANOVA were employed for comparative analysis. The Independent Samples T-test was used to compare differences in jump performance between the groups.

Results Significant differences in jump performance and force production were observed between SP and PES, with professional athletes demonstrating superior neuromuscular capabilities and better utilization of elastic energy. However, within each group, no significant differences were found between the different jump techniques, suggesting that arm swing and elastic force contribute similarly to overall jump height. Arm swing contributed 11.0% to jump performance in PES and 12.0% in SP, while the influence of elastic force stored in tendons during the eccentric phase was 7.0% in PES and 6.0% in SP.

Conclusions Specialized training significantly enhances jump performance, as evidenced by differences in CMJ, SJ, and ABL between SP and PES. Arm swing and elastic force utilization play crucial roles in vertical jumping, with professional athletes potentially leveraging arm mechanics more effectively. The study validates the reliability of the My Jump 3 app for measuring jump performance across diverse athletic backgrounds.

Keywords: Abalakov, countermovement jump, squat jump, arms swing, proficiency, athletes, data validation

Introduction

Vertical jumping is a multi-joint movement that necessitates intricate motor coordination and is recognized as a cornerstone skill in movement proficiency [1]. Vertical jump tests are integral in sports as they serve as reliable indicators of lower body power, a crucial attribute for various athletic activities. Sports performance professionals frequently employ vertical jump height as a substitute for directly assessing power [2]. Coaches and athletic trainers can utilize assessments of vertical jumping ability to enhance performance and identify talent among athletes.

One common method to evaluate lower body mechanical capabilities is the Countermovement Jump (CMJ). The CMJ stands out as a widely adopted testing method for evaluating lower body mechanical capabilities. Its applications extend to monitoring sports performance, inter-limb asymmetries, neuromuscular fatigue, and the effectiveness of different training programs [3]. The CMJ is distinguished by the presence of an initial countermovement (CM) prior to the toe-off phase [4].

In contrast, the Squat Jump (SJ) entails maintaining a flexed, semi-squat position briefly before initiating the upward or concentric phase of the jump [5]. The SJ test primarily measures the capacity to generate explosive force, whereas the CMJ assesses the ability to express reactive elastic force [6]. Another variant is the Abalakov jump, named in honor of Vitaly Abalakov, who first described it in 1938. The Abalakov jump mirrors the mechanics of a CMJ, with the additional incorporation of an arm swing [7].

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However, while the CMJ has been extensively studied and utilized, the role of arm swing technique in influencing jump performance and the utilization of elastic force stored in tendons remains a topic of growing interest and investigation. The incorporation of arm swing during vertical jumping has been recognized as a critical factor influencing jump height and efficiency [8]. Understanding the mechanics and impact of arm swing, in conjunction with lower body mechanics, is crucial for a comprehensive analysis of vertical jumping performance.

Besides this, as physical education students are not trained in jumping techniques, their arm swing and the speed of the eccentric contraction phase may not accurately reflect the percentage effect of the arm swing technique and elastic force stored in tendons during jumping. Therefore, data validation with professional athletes is crucial.

In the context of vertical jumping, understanding elastic force, also known as elastic energy, is crucial for optimizing performance and elucidating the mechanics underlying athletic proficiency. Elastic force refers to the energy stored within tendons, ligaments, and muscle fibers during the initial countermovement phase of jumps like the CMJ [9]. As an individual descends into the countermovement, these structures undergo stretching, accumulating potential energy. Upon transition to the upward phase of the jump, this stored energy is rapidly released, contributing to the propulsion and elevation of the body. This phenomenon, akin to a spring-like mechanism, enhances jump height and efficiency by augmenting the force generated by muscular contractions [10]. Understanding the dynamics of elastic force utilization is essential for coaches, athletic trainers, and sports scientists seeking to enhance athlete performance and prevent injuries.

This study aimed to investigate the influence of various vertical jump techniques, focusing on arm swing and elastic force utilization, and to evaluate the extent of the impact that each modification has on biomechanical characteristics and performance outcomes.

Materials and Methods

Participants

The study comprised ten first-grade Sport Science students, with an average height of 171.3 ± 8.1 centimeters and an average weight of 62.9 ± 6.5 kilograms. This selection criterion aimed to ensure uniformity in physical attributes and training backgrounds, thereby bolstering the study's validity and reliability. Additionally, to enable convergent validation, the study included ten professional soccer players from the F.C. Malisevo team. These players, with an average height of 179.8 ± 1.5 centimeters, an average weight of 75.0 ± 1.8 kilograms, and an average age of 23.7 ± 3.41 years, represent a high-performance standard, being ranked 4th in the AlbiMall Super League of Kosovo and participating in the Conference League in 2024.

My Jump 3 app

The methodology of this study began with the collection of crucial performance parameters using the My Jump 3 application. This data encompassed height, weight, height at 90°, lever length, and leg length, all vital for analyzing jump performance outcomes. Each participant executed a series of jumps, including the Countermovement Jump (CMJ), Squat Jump (SJ), and Abalakov jump, while being recorded on an iPhone 13 Pro at 240 frames per second, capturing high-definition video resolution.

Within the My Jump 3 app, jump recordings were loaded, and specific frames for take-off and landing were manually selected. Clear criteria were established beforehand to ensure accuracy: for take-off, the first frame where both feet were off the ground was chosen, free from motion blur or shoe deformation; for landing, the frame where one foot touched down without a visible gap between the shoe and the ground, and no motion blur, was selected. Utilizing these defined events, the app calculated jump height based on flight time [11].

It is noteworthy that the validity of the My Jump 3 app has been confirmed by numerous studies [12, 13, 14].

Statistical analysis

Following video analysis using the My Jump 3 app, the collected data underwent rigorous testing to ensure a comprehensive analysis of the results. Data collected from My Jump 3 was analyzed using the SPSS 26 package. Normality was assessed using Shapiro-Wilks tests to confirm that the data distribution met statistical assumptions. Descriptive statistics, including percentiles and percentages, were calculated to offer a clear overview of the data distribution and characteristics.

Moreover, One-way ANOVA tests were employed to scrutinize any significant differences between groups or conditions, facilitating a detailed comparison of jump performance across various parameters and conditions. The differences in jumps between Physical Education Students (PES) and Professional Soccer Players (SP) were examined using Independent Samples T-tests. Similarly, Independent Samples T-tests were used to assess percentage differences in arm technique and elastic force between PES and SP for data validation.

Consequently, the absence of statistically significant differences validated the findings as convergent.

Results

Based on the findings presented in Table 1, it is evident that both jumping performance (ABL, CMJ, SJ) and force (N) production are significantly higher in professional soccer players (SP) compared to physical education students (PES), with a p-value < 0.05.

The results presented in Table 2 reveal statistically significant differences (p < 0.05) between ABL and SJ in both physical education students and professional soccer players. However, no statistically significant differences (p > 0.05) were observed between ABL and CMJ, or between CMJ and SJ in either group.

According to the data in Table 3, the impact of arm swing techniques on jumping performance was observed to be 11.0% in physical education students and 12.0% in professional soccer players. However, these discrepancies did not reach statistical significance between the two groups (p > 0.05). In contrast, the influence of elastic force stored in tendons during the eccentric phase on jumping performance was found to be 7.0% in PES and 6.0% in SP. Once again, these distinctions did not exhibit statistical significance (p > 0.05).

Discussion

This study aimed to investigate the impact of various vertical jump techniques, specifically focusing on arm swing and elastic force utilization, and to validate the findings from physical education students by comparing them with professional soccer players. The results demonstrated notable differences in jump performance and force production between the two groups, highlighting key insights into the mechanics of vertical jumping.

The higher jump performance and force production observed in professional soccer players compared to physical education students align with previous research indicating that trained athletes typically exhibit superior neuromuscular capabilities and better utilization of elastic energy stored in tendons and muscles [15]. The significant differences in the CMJ, SJ, and ABL between SP and PES (p < 0.05) underscore the influence of specialized training and physical conditioning in

Table 1. Comparative Analysis of Height and Force Discrepancies Between PES and SP, Including Percentile Distribution

Tests	Groups	Height (cm)		Force (N)		Percentiles		
		x̄± SD	p	x̄± SD	p	25th (cm)	50th (cm)	75th (cm)
ABL	PES	36.87±5.23	.000	1434.8±269.2	.001	31.40	37.85	40.87
	SP	48.7±7.13		2225.0±280.4		44.60	47.40	56.97
CMJ	PES	32.99±5.81	.002	1352.9±268.1	.000	30.15	33.55	37.22
	SP	43.00±5.89		2019.7±213.9		39.52	41.90	47.97
SJ	PES	30.67±5.41	.004	1302.5±256.8	.000	27.27	31.45	34.20
	SP	40.21±6.41		1965.3±216.6		34.47	37.75	45.57

Note: PES - Physical education students, SP - Soccer Players, Significant differences - p<0.05, ABL - Abalakov (free arms countermovement jump), CMJ - Countermovement Jump, SJ - Squat Jump

Table 2. Comparative Analysis of Arm Swing Technique and Lower Extremities Elastic Force Effects on Jump Performance in PES and SP

Tests	Jumps	Groups	x̄ ± SD	F	Sig	Bonferroni (sig.)
Jumps (cm)	ABL	PES	36.99±4.98	4.270	.023	ABL>SJ (.021)
	CMJ		34.50±4.70			
	SJ		30.79±5.74			
	ABL	SP	48.77±7.13	4.509	.020	ABL>SJ (.020)
	CMJ		43.00±5.89			
	SJ		40.99±6.41			
Force (N)	ABL	PES	1469.0±279.4	1.476	.245	-
	CMJ		1466.8±228.8			
	SJ		1300.3±296.1			
	ABL	SP	2225.0±280.4	3.284	.053	-
	CMJ		2019.7±213.9			
	SJ		1965.3±216.6			

Note: PES - Physical education students, SP - Soccer Players, F - variation between sample means, Significant differences - p<0.05, ABL - Abalakov (free arms countermovement jump), CMJ - Countermovement Jump, SJ - Squat Jump, N - Newton

Table 3. Differences in Arm Swing Technique and Elastic Force Between PES and SP During Jump Performance

Groups	Measured features	x̄± SD Height (cm)	Force (N)	Diff%	p
PES	Arms swing technique (ABL vs CMJ diff)	3.88	81.85	11.0	.731
SP		5.77	205.3	12.0	
PES	Elastic force (CMJ vs SJ diff)	2.32	50.40	7.0	.827
SP		2.79	54.4	6.0	

Note: PES - Physical education students, SP - Soccer Players, Significant differences - $p<0.05$, ABL - Abalakov (free arms countermovement jump), CMJ - Countermovement Jump, SJ - Squat Jump, N - Newton

enhancing jump performance [16].

Interestingly, the lack of statistically significant differences between ABL and CMJ, and between CMJ and SJ within both groups ($p > 0.05$), suggests that while the arm swing and elastic force contribute to overall jump height, their relative impact may not differ drastically between these techniques. This finding is particularly relevant for sports performance professionals, as it indicates that focusing on one type of jump technique may suffice for evaluating an athlete's explosive power and reactive strength. However, it is generally better to include multiple jump type assessments. This multifaceted approach can provide a fuller picture of an athlete's capabilities and training needs [17].

Additionally, a larger difference between CMJ and SJ performances is not necessarily better. It may reflect not only the utilization of elastic energy in a small-amplitude CMJ due to a well-developed capability to co-activate muscles and quickly build up muscle stimulation but also a poor capability to reduce the degree of muscle slack and quickly build up stimulation in the SJ [18]. Therefore, analyzing both CMJ and SJ can provide more comprehensive insights into an athlete's explosive power and reactive strength.

The observed 11.0% impact of arm swing on jumping performance in PES and 12.0% in SP highlights the importance of arm mechanics in maximizing jump height [19]. Although the differences between the two groups were not statistically significant ($p > 0.05$), the slightly higher percentage in SP suggests that professional athletes may utilize arm swing more effectively due to better coordination and technique refinement [20].

Similarly, the influence of elastic force stored in tendons during the eccentric phase of the jump was found to be 7.0% in PES and 6.0% in SP, with no significant difference between the groups ($p > 0.05$). This indicates that both trained and untrained individuals benefit from the elastic energy stored during the countermovement phase [21]. It highlights the role of inherent biomechanical properties in jump performance, irrespective of the training level.

These findings support the importance of including both CMJ and SJ in assessments to provide a comprehensive evaluation of an athlete's explosive and reactive strength capabilities. Moreover, the study reinforces the validity of using the My Jump 3 app for accurately measuring jump performance, as indicated by the absence of significant differences in the validation data between PES and SP [12].

It is important to acknowledge that while this study provides valuable insights into vertical jump performance among soccer players and physical education students, the observed findings may vary when testing athletes from different sports. For instance, basketball players may have perfected distinct characteristics such as proficiency in arm swing technique, while track and field athletes may excel in elastic force utilization. Further exploration across a diverse range of sporting backgrounds would offer a more comprehensive understanding of the nuanced influences on jump mechanics and performance [22].

This study provides valuable insights into the mechanics of vertical jumping. It emphasizes the importance of specialized training in enhancing jump performance. Professional soccer players demonstrated superior neuromuscular capabilities and better utilization of elastic energy compared to physical education students. However, the lack of significant differences between the various jump techniques suggests that arm swing and elastic force contribute similarly across different types of jumps. These findings support the inclusion of both CMJ and SJ in assessments to provide a comprehensive evaluation of an athlete's explosive and reactive strength capabilities. Additionally, the study reinforces the validity of using the My Jump 3 app for accurately measuring jump performance. Future research should explore these dynamics across a broader range of sports to further understand the nuanced influences on jump mechanics and performance.

Conclusions

This study underscores the significant role of specialized training in enhancing vertical jump performance, as evidenced by the superior neuromuscular capabilities and efficient utilization of elastic energy in professional soccer players compared to physical education students. Despite the lack of statistically significant differences between various jump techniques, the consistent contribution of arm swing and elastic force across different types of jumps highlights the necessity of including both CMJ and SJ in performance assessments. The validation of the My Jump 3 app as an accurate tool for measuring jump performance further supports its use in diverse athletic contexts. Future research should extend these findings by exploring vertical jump mechanics across a wider range of sports to provide a more comprehensive understanding of the factors influencing jump performance and to refine training programs accordingly.

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PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Self-evaluation of appearance by female medicine students

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Abstract

Background and Study Aim Nowadays western culture promotes appearance-wise the ideal of a slim body. The purpose of the research was to study body composition of female medicine students and compare these results with their self-evaluation on the problem.

Material and Methods Ninety-nine Casimir Pulaski Radom University in Radom females students (22.0±2.1 years old) who studied at a medicine faculty have been involved in the research. The study was conducted in accordance with the basic bioethical norms of the Helsinki Declaration of the World Medical Association on Ethical Principles for Conducting Scientific and Medical Research. Written informed consent was obtained from each study participant. The study was approved in advance by Ethical Committee of the Casimir Pulaski Radom University in Radom. The studies included survey research: The International Physical Activity Questionnaires (IPAQ) - Short Form, The 5-item World Health Organization Well-Being Index (WHO-5), Questionnaire of self-evaluation of appearance, body mass and height. According to the Three Sigma Rule border values, research samples were selected regarding compacted values of corresponding parameters. Pearson correlation has been used with a purpose to study an interaction between anthropometric parameters of subjects. Two pair t-test for arithmetic means was applied to compare mean values of the anthropometric parameters of the subjects. Factor analysis has been used with a purpose to study body building of students. Calculations were done using Data Analysis from MS Excel Offices and computer package Statistica.

Results Shapiro – Wilk method was used to determine normality of distribution of quantity parameters studied in the research ($p>0.4$). Because Gauss distribution was noticed, parametric statistics were applied in mathematics elaboration of anthropometric parameters. According to the Method of Principal components, the Factor analysis has been done. A number of variables were reduced to twenty-three (11 – 33). Three Eigenvalues appeared greater than one (17.4; 3.3; 1.1). Number of factors extracted equals 3. Corresponding part of variation forms 94.7% of the total. The rest of variation (5.3%) presents other factors. The main factor (the first one) forms more than three quarters of variation – 75.7%.

Conclusions Accuracy of estimation of a body height among female subjects was determined as a difference between results of subject's answer and results of measurement. Two groups of subjects have been formed: 58 subjects presented their knowledge of values of body height and 38 subjects – estimated their own hypothetic values.

Keywords: physical fitness, BMI, body composition, physical activity, health.

Introduction

Human body viewed objectively and subjectively as a dynamic and multifaceted construct shaped by biological, social, psychological and cultural factors. Its representation is a reflection of current views and social norms on one hand, and one's own thoughts and emotions on the other. In the collective consciousness of people living in specific times and cultural circles, ideals of the human body are created and become objects of desire. Nowadays western culture promotes appearance-wise the ideal of a slim body [1, 2].

The dynamic development of traditional media (television, radio, newspapers, and magazines) and online media (Facebook, Instagram, Snapchat and Twitter) favors the rapid creation and spread of norms and patterns of behavior, but also, unfortunately, exerts pressure forcing certain, not always beneficial, health behaviors. The ideal of a slim body today occupies a central place in social media and is becoming an attractive and desirable value. Exposing this pattern is an everyday practice and every day it causes cognitive dissonance in a huge group of recipients - dissatisfaction with their body and great determination in striving for slimness, often at the expense of risky health behaviors [3, 4, 5].

Modern media excessively expose people to the ideal of thinness, starting from an early age. They point it as a necessary condition for success in life. This very often causes fears related to the inevitable evaluation by others, mainly based on physical appearance, which may negatively affect the individual's mental balance and satisfactory participation in social life [6, 7].

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Body dissatisfaction and distorted appearance perception are common among university students (especially female students). Over 60% of students have inadequate self-esteem, which does not correspond to reality and causes them to incorrectly perceive their physical image [8, 9].

Studying involves living without the help and supervision from parents. Physical activity decreases and there are problems with regular and healthy eating. Greater autonomy comes with great academic pressure and the need to make independent lifestyle choices. This causes physical and mental health problems, which intensify the disturbed body image [10, 11].

A healthy body image not only impacts students' self-esteem and satisfaction, but also their overall mental health. Poor body image is associated with reduced quality of life and performance and requires appropriate interventions [12, 13].

You need to take care of your good appearance and proper body weight first of all to be healthy. Therefore, awareness of being overweight or underweight is very important not only for maintaining a healthy lifestyle, but also for the prevention of many lifestyle diseases [14].

It is worth noting that students consider those whose BMI values are within the norm to be attractive [15].

Therefore, it is important that during their studies they are equipped with basic, reliable knowledge and practical skills on how to assess their ideal body weight and how to take care of their health. This especially applies to students in the field of medical sciences, who in the future will be specialists responsible for promoting and improving public health. It is worth replacing the idea of a slim body with the idea of a healthy person in the physical and other dimensions: mental, social and spiritual.

Hypothesis. Female university students have a detailed knowledge about their body composition, especially regarding the body mass and body height and are able to self-evaluate these parameters.

The *purpose* of the research was to study body composition of female students and compare these results with their self-evaluation on the problem.

Materials and Methods

Participants

Ninety-nine Casimir Pulaski Radom University in Radom female's university students (22.0±2.1 years old) who studied at a medicine faculty has been involved in the research. The study was conducted in accordance with the basic bioethical norms of the Helsinki Declaration of the World Medical Association on Ethical Principles for Conducting Scientific and Medical Research as amended (2000, amended in 2008), the Universal Declaration on Bioethics and Human Rights (1997), the Council of Europe Convention on Human Rights and Biomedicine (1997) and do not contradict the norms of Ukrainian legislation and meets the requirements of the Law of Ukraine "On Scientific and Scientific Technical Activity" of dated November 26, 2015 No. 848-VIII. Written informed consent was obtained from each study participant. The study was approved in advance by Ethical Committee of the Casimir Pulaski Radom University in Radom.

Research Design

During the organizational meeting, females Casimir Pulaski Radom University in Radom students of the medicine faculty were informed about the aim and course of the study. The studies included survey research (The *International Physical Activity Questionnaires* (IPAQ) - Short Form, The 5-item World Health Organization Well-Being Index (WHO-5), Questionnaire of self-evaluation of appearance, body mass and height). Moreover, the participants were informed that they are free to withdraw from participation in the study at any stage. Next the persons interested were asked to give written informed consent to participate in the research. Then, the principles of preparing for a body composition test were discussed in detail. The participants of the study were informed in advance of the required conditions prior to measurement:

- no alcohol and coffee intake in the previous 24 h,
- no vigorous exercise in the previous 12 h,
- no food or drink intake in the previous 3 h,
- no urination immediately before measurement.

The studies were conducted in April and May 2023 in accordance with the previously agreed schedule with the participants. At the beginning of the study, students completed the above-mentioned questionnaires and provided information about whether they knew their body mass and height. Then, an experienced researcher conducting the study measured body height. Body height was measured upright, barefoot, rounded to 0.1 cm using a portable Harpenden anthropometry (Holtain Ltd, Crosswell, UK). The measurement was taken, with the participant stretching to the maximum height and the head positioned in the Frankfort plane. The body composition study was conducted according to the Tanita MC-980 PLUS MA guidelines. Participants were asked to remove footwear and socks and any metal objects. Measurements were made in underwear, standing in designated places on the platform. According to the Tanita MC-980 PLUS MA guidelines, accurate measurement requires the participants stood upright on the platform with their legs extended, placing their feet so that they touched the front and rear electrodes, ensuring that the weight was evenly distributed on both feet. The person examined held handles in their hands that were taken from the body at an angle of 35–40.

Apparatuses

Anthropometric measurements, body composition and body mass index have been used. Body composition was measured using the electrical bioimpedance method and a calibrated segment analyzer (Tanita MC-980 MA PLUS, Tokyo, Japan) with an accuracy of 0.1 kg/0.1%. Tanita MC 980 MA PLUS has approvals for medical use and meets the NAWI and CLASS III standards and the MDD 93/42/ EEC directive, as well as the CE0122 EU certificate. The analyzer automatically measures body weight and then impedance. The Commuter software (a microprocessor) imbedded in the product uses the measured impedance, the participant's sex, body height, fitness, age, and the weight to determine body fat percentage based on equation formulas. The device gives general values of body composition such as fat mass, fat free mass, muscle mass, skeletal muscle mass, total body water, bone mass, protein mass, basal metabolic rate and their derivatives [16].

The body weight and height of the participants were measured using the standard protocol and equipment that was calibrated before and during the data collection period. Body height was measured upright, barefoot, to the nearest 0.1 cm using a portable Harpenden anthropometer (Holtain Ltd, Crosswell, UK) [17]. The measurement was taken, with the participant stretching to the maximum height and the head positioned in the Frankfort plane [18]. Body mass was assessed with an accuracy of 0.1 kg using a body composition analyzer (Tanita MC-980 MA PLUS). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Survey questionnaires

The *International Physical Activity Questionnaires* (IPAQ) - Short Form. For physical activity rating of the short IPAQ questionnaire approved by the IPAQ Study Group was used (polish version). The questionnaire contained 7 questions pertaining to all kinds of physical activity related to the job, everyday life and leisure and, specifically, to the time spent on vigorous and moderate activities, on walking and sitting [19]. The 5-item World Health Organization Well-Being Index (WHO-5). It is a short and generic global rating scale measuring subjective well-being through a questionnaire consisting of 5 simple and non-invasive statements stated below, which tap into the subjective well-being of the respondents:

- (1) "I have felt cheerful and in good spirits";
- (2) "I have felt calm and relaxed";
- (3) "I have felt active and vigorous";
- (4) "I woke up feeling fresh and rested";
- (5) "My daily life has been filled with things that interest me".

The respondent is asked to rate how well each of the 5 statements applies to him or her when considering the last 14 days. The above statements were scored by the respondents from 0 (none of the time) to 5 (all of the time) each and summarized at the end on the scale from 0 (absence of well-being) to 25 (maximal well-being) [20].

Questionnaire of self-evaluation of appearance, body mass and height

Self-evaluation of appearance, body mass and height were by assessed by administering a self-report questionnaire prepared by the Department of Axiology of the Jan Kochanowski University in Kielce. The questions covered leisure-time physical activity as well as commuting activity. Construct validity of the questionnaire for cross-sectional analysis was confirmed with a Cronbach alpha of 0.81 [21].

The possibilities among which the respondents could choose were as follows:

- self-evaluation of appearance: "excellent", "good", "indifferently", "bad";
- self-evaluation of body mass: "too slim, " "just right", "too fat";
- self-assessment of body height: "too small", "just right", "too tall".

Statistical Analysis

Shapiro – Wilk method was used to determine normality of distribution of quantity parameters studied in the research (p>0.4). Because Gauss distribution was noticed, parametric statistics were applied in mathematics elaboration of anthropometric parameters. According to the Three Sigma Rule border values, research samples were selected regarding compacted values of corresponding parameters. Pearson correlation has been used with a purpose to study an interaction between anthropometric parameters of subjects. Two pare t-test for arithmetic means was applied to compare mean values of the anthropometric parameters of the subjects. Factor analysis has been used with a purpose to study body building of students. Calculations were done using Data Analysis from MS Excel Offices and computer package Statistica (StatSoft Inc.).

Results

Body height and body mass among females' students

The studied group has been statistically elaborated according to the BMI values. Using the Three Sigma Rule border values were calculated by formula as follows:

$$BMI = M \pm 3*SD, \quad (1)$$

where M=22.0 is arithmetic mean; SD=4.2 is standard deviation. Lower and upper values have been determined: BMImin=9.5; BMImax=34.4. Two subjects (8K and 95K) showed BMI values bigger than upper border (35.4 and 44.0) were eliminated from the studying group. A total number of subjects with valid result appeared 9.

Accuracy of estimation of a body height among female subjects was determined as a difference between results of subject's answer and results of measurement. Two groups of subjects have been formed: 58 subjects presented their knowledge (I know my body height it is ...) of values of body height and 38 subjects – estimated their own hypothetic values (I suppose my body height is ...).

Two paired t-test for means have been used to compare subject's estimations with results of measurements (Table 1).

Mean values of difference in the first and second tests were -0.2 (on knowledge) and 0.4 cm (supposition) correspondingly. This is that in average subjects had images regarding their body height smaller than it is in reality. Contrary, the subjects who did not know their body height estimated this parameter greater. Means of absolute values of the differences appeared the same:

$$\frac{\sum |x_K - x_M|}{n} = 1.0 \text{ cm},$$

where x_K is subject's knowledge or evaluation regarding a body height; x_M is results of measurements; n are samples' numbers.

Statistical hypothesis about a common general set of the subject's results and results of measurements have been accepted on the levels of significance as follows: p=0.383 – for the first subjects' sample ("I know ...) and p=0.094 – for the second ("I suppose ...).

The same calculations regarding body mass values have been done; corresponding results are presented bellow (Table 2).

Statistical hypothesis about a common general set of the subject's results and results of measurements have been accepted on the levels of significance as follows: p=0.226 – for the first subjects' sample ("I know ...) and p=0.232 – for the second ("I suppose ...). Mean value of difference in the first and second tests were -0.3 and -0.4 cm correspondingly. Significant validity of both studied tests has been determined as excellent (r_1=0.988, r_2=0.974; p<0.01).

In average subjects have images regarding their body height smaller than it is in reality. Contrary, the subjects who do not know their body height estimate this parameter greater. Means of absolute values of the differences appeared smaller 1 cm in both tests.

Factor analysis of body building composition

Because a lot of parameters described body compositions of studied patients, Factor analysis

Table 1. Two pair t-test for means of female body height (cm)

Statistics	Knowledge	Measurement	Supposition	Measurement
Arithmetic means	165.7	165.9	165.4	165.0
Variance	44.5	46.6	34.2	34.1
Sample number	58		38	
Pearson correlation	0.981		0.976	
Degree of freedom	57		37	
t-statistics	-0.879		1.719	
P(T<=t) one tail	0.192		0.047	
t one tail boarder	1.672		1.687	
P(T<=t) two tail	0.383		0.094	
t- two tail boarder	2.002		2.026	

Table 2. Two pair t-test for means of female body mass (kg)

Statistics	Knowledge	Measurement	Supposition	Measurement
Arithmetic means	54.8	55.1	60.2	60.6
Variance	51.9	43.0	90.7	110.9
Sample number	22		74	
Pearson correlation	0.988		0.974	
Degree of freedom	21		73	
t-statistics	-1.248		-1.207	
P(T<=t) one tail	0.113		0.116	
t one tail boarder	1.721		1.666	
P(T<=t) two tail	0.226		0.232	
t- two tail boarder	2.080		1.993	

has been used with a purpose to reduce a number of corresponding variables. Forty parameters related to the problem have been collected among others (Table 3).

Table 3. Mass parameters presented a body mass composition

No	Measurements
1	Fat free mass (kg)
2	Bone mineral mass (kg)
3	Protein mass(kg)
4	Muscle mass (kg)
5	Skeletal muscle mass (kg)
6	Skeletal muscle percentage (%)
7	Body fat mass (kg)
8	Body fat percentage (%)
9	Visceral fat (level)
10	Total body water (kg)
11	Extra-cellular water (kg)
12	Intra-cellular water (kg)
13	Extra-cellular water / Total body water (%)
14	Basal metabolic rate (kJ)
15	Basal metabolic rate (kcal)
16	Impedance (ohm)
17	Trunk fat percentage (%)
18	Trunk fat mass (kg)
19	Trunk fat free mass (kg)
20	Trunk muscle mass (kg)
21	Right arm impedance (ohm)
22	Right arm fat percentage (%)
23	Right arm fat mass (kg)
24	Right arm fat free mass (kg)
25	Right arm muscle mass (kg)
26	Left arm impedance (ohm)
27	Left arm fat percentage (%)
28	Left arm fat mass (%)
29	Left arm fat free mass (kg)
30	Left arm muscle mass (kg)
31	Right leg impedance (ohm)
32	Right leg fat percentage (%)
33	Right leg fat mass (%)
34	Right leg fat free mass (kg)
35	Right leg muscle mass (kg)
36	Left leg impedance (ohm)
37	Left leg fat percentage (%)
38	Left leg fat mass (%)
39	Left leg fat free mass (kg)
40	Left leg muscle mass (kg)

Correlation matrix as a first step of the Factor analysis has been constructed for these 40 parameters (Table 3). Significance of correlation was evaluated using the critical absolute values of correlation coefficients by formula as follows:

$$|r| = \frac{t}{\sqrt{t^2 + \nu}},$$

where r is Pearson correlation, t is Student statistics, $\nu = n - 2$ is degree of freedom, n=40.

According to the Method of Principal components, the Factor analysis has been done (Table 4). A number of variables were reduced to twenty-three (11 – 33). Three Eigenvalues appeared greater than one (17.4; 3.3; 1.1). Number of factors extracted equals 3. Corresponding part of variation forms 94.7% of the total. The rest of variation (5.3%) presents other factors. The main factor (the first one) forms more than three quarters of variation – 75.7%.

Table 4. Results of the Factor analysis

Variables	Factor 1	Factor 2	Factor3
11	-0.876	-0.451	-0.059
12	-0.924	0.240	0.265
13	-0.926	0.239	0.261
14	0.631	-0.604	0.334
15	-0.776	-0.572	-0.179
16	-0.923	-0.317	-0.088
17	-0.943	0.199	0.195
18	-0.940	0.202	0.199
19	0.646	-0.564	0.353
20	-0.776	-0.573	-0.169
21	-0.925	-0.315	-0.083
22	-0.946	0.198	0.169
23	-0.943	0.200	0.172
24	0.671	-0.505	0.419
25	-0.795	-0.512	-0.134
26	-0.945	-0.287	-0.054
27	-0.956	0.171	0.164
28	-0.955	0.171	0.168
29	0.679	-0.475	0.439
30	-0.803	-0.499	-0.130
31	-0.947	-0.281	-0.051
32	-0.960	0.146	0.160
33	-0.959	0.149	0.164
Eigenvalues	17.4	3.3	1.1
Prp.Totl.%	75.7	14.2	4.8

Factor 1 – fat factor. Loadings (Unrotated) Extraction: Principal components ($|r|$>0.939): left arm fat percentage (%); left arm fat mass (kg); right leg fat percentage (%); right leg fat percentage (kg); trunk fat percentage (%); trunk fat mass (kg); right arm fat percentage (%); right arm fat mass (kg); left arm impedance (ohm); right leg impedance (ohm).

Factor 2 – fat-free factor. Loadings (Unrotated) Extraction: Principal components (|*r*|>0.504): basal metabolic rate (kJ); basal metabolic rate (kcal); trunk fat free mass (kg); trunk muscle mass (kg); right arm fat free mass (kg) right arm muscle mass (kg).

Factor 3 – combined factor. Loadings (Unrotated) Extraction: Principal components (|*r*|>0.333): basal metabolic rate (kJ); trunk fat free mass (kg); right arm fat free mass (kg); left arm fat free mass (kg).

Principal components were extracted as fat factor (75.7%) and no fat factor (14.2%). The third, combine, factor (4.8%) could not be presented as a sum of homogenous principal components. Therefore, only two factors – the first and the second one – should be taking into consideration in solving theoretical problems. Other variations could be eliminated because their negligible income to the total account.

Fitness parameters correlation

Four fitness parameters have been selected with a purpose to study the validity of self-evaluation of well-known methods with BMI, WHO-5 and others. Test results were collected at columns of the Excel file as follows:

- (AJ) Intense physical exertion (minutes per week),
- (AU) How many minutes per day did a student spends sitting or lying down on average?
- (BA) WHO - 5 sum of points,
- (BI) Body-Mass Index (kg/m^2).

Results of Pearson correlation are presented in Table 5: coefficients of correlation are situated left–down of the correlation matrix diagonal and t-Student statistics – right–top. Only two from six pares showed practically significant correlation: |*r*|=0.250. "Intense physical exertion" (AJ) was correlated with results of the "Sum of points WHO – 5" and "Body-Mass Index" (BI).

The self-evaluation study based on "Intense physical exertion" is valid relatively WHO 5 as well as and BMI tests (p<0.05).

Body mass self-evaluation vs. appearance

Interdependence between attributive features regarding self-evaluation of body mass and appearance was studied using χ^2 Pearson statistics; and Cramer coefficient of conjugation. The results of evaluation were collected in Table 6. The attributive values were situated in the rows and columns according to ranged marks in the questionnaire form.

Because there were empty cells (i.e. sells with zero frequencies) in three cells of the Table 6 (lean-bad, lean-excellent, and exactly-bad), this table has been reorganized with a purpose to avoid the empty cells. Two rows (lean and fat) as well as two columns (indifferently and bad) have been united so that the table has been transformed into the table with three columns and two rows (Table 7).

Table 5. Correlation matrix of self-evaluation and two international indexes

Tests	AJ	AU	BA	BI
AJ	1	0.004	2.720	2.540
AU	0.000	1	1.244	0.500
BA	**0.266**	0.125	1	1.072
BI	**0.250**	0.051	0.108	1

*Note: |*r*|=0.312 (p=0.05); |*r*|=0.403 (p=0.01); |*r*|=0.501; (p=0.001).

Table 6. Self-evaluation results of body mass and appearance

Self-evaluation of body mass	Self-evaluation of appearance				Total
	excellent	good	indifferently	bad	
Lean	0	7	1	0	8
Exactly	16	31	19	0	66
Fat	2	12	6	5	25
Total	18	50	26	5	99

Table 7. Reorganized results of self-evaluation

Body mass \ appearance	Excellent	Good	Indifferently & bad	Total
Exactly	16	31	19	66
Lean + Fat	2	19	12	33
Total	18	50	31	99

The research hypothesis assumed functional interdependence between body mass and appearance. Hypothesis criterion (χ^2 – statistics) was calculated using the formula bellow:

$$\chi^2 = \sum_i \sum_j \frac{(f_{ij} - F_{ij})^2}{F_{ij}} , \quad (2)$$

where f_{ij} are empirical frequencies of evaluation; $F_{ij}=f_{i0}f_{0j}/n$ are theoretical frequencies proportional to the total; x and y are attributive features; total number of frequencies.

Empirical value of the Pearson statistics was calculated using the simplified formula (2) as follows:

$$\chi^2 = 99\left(\frac{16^2}{18\times 66} + \frac{2^2}{18\times 33} + \frac{31^2}{66\times 50} + \frac{19^2}{33\times 50} + \frac{19^2}{31\times 66} + \frac{19^2}{31\times 66} + \frac{12^2}{33\times 31} - 1\right) = 4.89 , \quad (3)$$

According the degree of freedom $k=(m_x-1)(m_y-1)=2$, significance of consistency of variation of attributive features x and y was determined as follows: $p=0.043$, where $m_x=2$ and $m_y=3$ are numbers of groups x (rows) and y (columns) correspondingly. As relative measure of density of this stochastic correlation a reciprocal conjugation coefficient was determined as follows:

$$C = \sqrt{\frac{\chi^2}{n(m_{\min} - 1)}} , \quad (4)$$

where $m_{min}=2$ is a smaller value of groups' numbers (m_x or m_y); $C=0.222$ that shows a weak density of stochastic interdependence.

Self-evaluation of body mass vs. body height

All the three tests' evaluation has been done using the same form of the attributive features into three columns and two rows (Table 8). Significance of interdependence appeared at the statistical level $p=0.05$. A conjugation coefficient ($C=0.208$ – 0.222) showed a weak mean density of stochastic interdependence.

A stochastic interdependence between body mass and body height was studied comparing an empirical distribution with the theoretical distribution common for the body mass and body length. The empirical variances were borrowed from results of body mass and body height evaluation. The theoretical variances were calculated as an arithmetic mean of the corresponding empirical variances (Table 9).

An empirical value of the Pearson statistics was calculated as follows:

$$\chi^2 = \frac{(16-16)^2}{16} + \frac{(31-36.5)^2}{36.5} + \frac{(19-20)^2}{20} + \frac{(2-2)^2}{2} + \frac{(19-13.5)^2}{13.5} + \frac{(12-11)^2}{11} + \frac{(16-16)^2}{16} + \frac{(42-36.5)^2}{36.5} + \frac{(21-20)^2}{20} + \frac{(2-2)^2}{2} + \frac{(8-13.5)^2}{13.5} + \frac{(10-11)^2}{11} = 6.42 , \quad 5)$$

A conjugation coefficient ($C=0.255$) showed a weak mean density of stochastic interdependence (see Table 8). Significance of acceptation of zero hypotheses regarding equal distribution of body mass and body height evaluation has been shown with $p=0.844$.

Discussion

People with an attractive physical appearance are happy, healthy, watch their diet and are physically active [22]. A review of the literature regarding self-assessment of appearance by female students shows that over 50% of respondents declare dissatisfaction with their appearance [23].

In this study, 68.7% of surveyed medical students chose "good" or "excellent", 26.3% chose "differently" in relation to their appearance, and only 5.1% chose "bad". At the same time, the last

Table 8. Statistics of self-evaluation results with appearance

Anthropometric parameters	χ^2	*k*	*C*	*p*
Body mass	4.89	2	0.222	0.043
Body height	4.27	2	0.208	0.059
BMI	4.50	2	0.213	0.053
x / y	6.42	11	0.255	0.844

Table 9. Empirical (*f*) and theoretical (*F*) variances of body mass (*x*) and height (*y*)

f	x	16	31	19	2	19	12
	y	16	42	21	2	8	10
F	x / y	16	36.5	20	2	13.5	11
		16	36.5	20	2	13.5	11

mentioned group qualified themselves as "fat" in their self-assessment of body weight, thus indicating that being overweight is a problem in their perception of their appearance.

On the other hand in relation to self-assessment of body weight, 67% of respondents assigned themselves to the "exactly" category, 25.3% to the "fat" category and 8% to the "lean" category. It is noteworthy that as many as seven out of eight students from the "fat" category associated their slimness with their "good" appearance, and only one with the "indifferently" category. This may indicate that they adhere to the ideal of a slim appearance.

The above thesis is confirmed by the BMI results based on objective measurements, where as many as 71.7% of the surveyed students were classified in the "normal" group, 13.1% in the "underweight" group, and 15.2% in the "overweight" group. After self-assessment, overweight was stated in 25 cases, and after assessment only in 15. Therefore, as many as 10 students showed too critical self-assessment.

The results of this study do not correspond to reports that higher BMI was associated with perceptions of less personal control and responsibility [24].

A literature review shows that women usually underestimated their body weight in their self-esteem, which was explained by the desire to adapt to the cultural ideal of a slim body promoted by the media [25].

The results of this study confirm that female students care about the attractiveness of their appearance and associate it with a slim body, but they do not underestimate their body weight. This may prove their high awareness, which is the basis for effective action in taking care of their appearance and maintaining the appropriate body weight.

Body height, like body weight, can affect how people perceive themselves and others [26].

Typically, men overestimate body height in order to emphasize the need to be big and in line with the cultural gender pattern and women do not show such a tendency [27].

In our study, average body height was most often indicated as attractive, similarly to another new large Polish study [22].

The examined medical students who declared that they knew their body height made an underestimation error of an average of 0.2 cm (p=0.383), and those who did not know their body height and declared only an assumption made an overestimation error of an average of 0.4 cm (p=0.383). 0.094). These results, similarly to the self-assessment of weight, indicate high body awareness.

Our study, unlike other recent studies on medical students, shows a high percentage of students with distorted self-perception and dissatisfied with their appearance [28, 29] shows a favorable trend in this field. Awareness of one's body and adequate self-assessment of one's appearance are very positive factors in the context of personal development and future work as a doctor [30].

A limitation of this study is the narrow sample of medical students at the university, so one should be careful in generalizing the obtained results.

This research has been done among female medicine students. Young females are rather interested about their appearance. It will be an important research regarding the self-evaluation of appearance by male medical students as well as among students of other specialties [31].

Conclusions

In average, female students have images regarding their body height smaller than it is in reality. Contrary, the students' who do not know their body height estimate this parameter greater. Statistical hypothesis about a common general set of the subject's results and results of measurements have been accepted on the bigger level of significance (p=0.383) – for the subjects' sample who know their parameters than for another sample who suppose these parameters (p=0.094).

Highlights

During Factor analysis of a body composition, three factors included anthropometric parameters regarding body mass and body height have been derived. The main factor forms more than three quarters of variation – 75.7%. It was named as body fat factor because fat related parameters were correlated with this factor. The second significant factor included 14.2% of variation and was named as non-fat factor which correlates with parameters related to the no fat body mass.

The self-evaluation study based on "Intense physical exertion" is valid relatively WHO 5 as well as and BMI tests (p<0.05).

Significance of interdependence appeared at the statistical level p=0.05. A conjugation coefficient (C=0.208 – 0.222) showed a weak mean density of stochastic interdependence.

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PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Motivational correlates of sports and physical activity

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Abstract

Background and Study Aim The motivational aspect of athletes' commitment to training is an important indicator of their sports performance. However, there is insufficient understanding of the subtle dynamics that determine this commitment. The purpose of the study is to explore how athletes' motivation relates to their training duration across different sports. It also aims to identify the impact of intrinsic, extrinsic, and amotivation on training hours and to predict athletes' training commitment.

Material and Methods In the study, 60 college students participated. Data collection utilized the Sport Motivation Scale, which assesses three dimensions of motivation: intrinsic, extrinsic, and amotivation. Physical training hours were meticulously recorded by the instructor. A maximum of 14 hours of training was provided per week as part of a training module lasting one complete month. Players who were absent due to illness were excluded from the study.

Results A significant positive correlation was found between intrinsic motivation ($r = 0.93$) and extrinsic motivation ($r = 0.919$) with training duration per week ($p < 0.01$). Additionally, a significant negative correlation was observed between amotivation and training duration per week ($r = -0.873$, $p < 0.01$). Motivation accounted for 84.4% of the variance in predicting physical activity training duration. Furthermore, motivation demonstrated a significant positive relationship ($\beta = 0.921$) with physical activity training duration.

Conclusions The current research provides evidence that both intrinsic and extrinsic motivation are crucial for engaging athletes in physical training and activity. Furthermore, amotivation serves as a deterrent to good performance in sports. To foster continuous improvement, coaches and instructors must intervene by providing athletes with positive feedback and maintaining their interest in the game through a variety of sports skills.

Keywords: sports motivation, physical training, intrinsic -extrinsic motivation, amotivation

Introduction

The motivation in relation to sports refers to an individual's drive to excel, accomplish goals, and succeed in their athletic endeavors. Hellriegel and Woodman state that motivation is a functional relationship between effort and perceived levels of performance on one aspect and the reward expectations on the other [1]. It involves the psychological factors that influence a person's behavior, effort, and persistence in sports activities with the aim of attaining success, recognition, and personal satisfaction. Motivation as a derivate of human emotions which neuropsychologically operates from amygdala structure of brain [2]. It can be categorized into two main types: intrinsic and extrinsic motivation. Intrinsic motivation comes from within the individual, driven by personal enjoyment, satisfaction, and the inherent pleasure of participating in the sport. It refers to engaging in an activity purely for the pleasure and satisfaction derived from doing the activity [3]. When a person is intrinsically motivated, he or she will perform the behavior voluntarily, in the absence of material rewards or extrinsic constraints. This motivation originates from the autonomy provided to the players during training [4]. A three classes taxonomy of Intrinsic motivation (IM) has been postulated [5]. This taxonomy is based on literature that signifies the presence of three types of IM: to Know, to Accomplish Things, to Experience Stimulation. IM to know relates to constructs of exploration, curiosity, learning, and the need to know and understand. For e.g. intrinsic need in athletes to learn new techniques and experience sheer pleasure in them. The second construct is when players interact with their environment and feel competent to acquire unique accomplishments. Third construct explains how an athlete engages in sports activity to experience stimulating sensations of pleasure, aesthetic experiences, along with fun and excitement.

Extrinsic motivation, on the other hand, involves extrinsic factors like rewards, recognition, and reinforcement. The three constructs have been given to classify Extrinsic motivation: extrinsic regulation, introjection and identification [5]. Extrinsic regulation refers to behavior that is

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controlled by extrinsic sources such as material rewards or constraints imposed by others [4]. Sports is mostly performed to gain praise by other people and to avoid criticisms. Athletes who participate in sport in order to receive praise from their coach or because they feel urged to do so by their parents are externally motivated.

With introjection, the formerly extrinsic source of motivation has been internalized for e.g. playing sports due internal pressures of guilt or anxiety to look aesthetically in good shape or perform exceptionally well. Identification construct signifies how a player attaches to their extrinsic identity which they gain from sports. Achievement oriented individuals set specific, measurable, achievable, relevant, and time-bound goals for themselves in sports. These goals provide direction and purpose, fueling their drive to work hard and make progress. Third form of motivation identified in players is amotivation [5]. These individuals experience feelings of incompetence and lack of control. They are neither intrinsically motivated nor extrinsically motivated. When athletes are in such a state, they no longer identify any good reasons for why they continue to train. Eventually they may even decide to stop practicing their sport and give up sports career.

Sports motivation often correlates positively with competitiveness [6]. Athletes with high motivation are willing to invest a significant amount of effort and time in practice and training. They are more likely to persist through challenges, setbacks, and failures because they view these as opportunities for growth and improvement. It can be enhanced when athletes feel a sense of autonomy, competence, and relatedness. When athletes have control over their training and choices, feel competent in their skills, and have a sense of belongingness for a supportive team or community, their motivation to achieve increases.

Research studies demonstrate that intrinsic motivation is associated with higher levels of self-reported physical activity [7, 8] and maximum attendance in the physical activity class [9, 10]. On the contrary, amotivation is linked to negative outcomes such as boredom [11], unpleasant emotions and minimal intentions to participate in physical activity [12]. Attribution theory explores how individuals attribute success and failure [13]. Athletes with sports motivation tend to attribute their successes to intrinsic factors of effort and skill, while attributing failures to extrinsic factors like bad luck or tough competition. They feel that this mindset can lead to increased motivation to improve and succeed. Coaches, mentors, and role models can significantly influence an athlete's motivation. Positive reinforcement, constructive feedback, and effective coaching strategies can help nurture and sustain high levels of sports motivation [14].

Research Problem. The study aims to study the relationship of intrinsic motivation, extrinsic motivation and amotivation to the duration of physical activity training. Further, it aims to establish role of motivation in predicting the duration of physical activity training hours for players in various games.

Materials and Methods

Participants

Sample of the study consists of 60 undergraduate physical education trainees (males =36, females =24) from Government Arts and Sports College in Jalandhar (Punjab, India) training for their respective games. Their age range of the players is 18-25 yrs.($\bar{x}$ =21.5). They were observed during their physical activity training sessions held every day for complete one month. Informed consent was obtained from all individual participants included in the study. The study was conducted in accordance with ethical standards. Student participation was voluntary, data confidentiality was ensured, and the study was approved by the College ethics committee.

Research Design

The research incorporated the inferential approach using the questionnaire method to collect data for the research. The basic study was conducted from 1st September- 1st October, 2023.

In the study, a sports motivation scale [5, 15] was utilized, comprising seven subscales. These subscales measure three types of intrinsic motivation: 'to Know,' 'to Accomplish Things,' and 'to Experience Stimulation'. The score on each subscale ranges from 4-28. The total score of the entire scale ranges from 28- 196.It assesses three forms of regulation for Extrinsic Motivation -Identified, Introjected, and External. It also provides a score of Amotivation. Adequate internal consistency, with alpha scores of the seven subscales ranging from .74 to .80. For the present study the three combined scores of intrinsic motivations, extrinsic motivation and amotivation along with total score have also been incorporated.

The standardized sports motivation scale was administered to student groups after providing clear instructions regarding how to answer the statements in the questionnaire. Participants provided their responses on the response sheet, and scoring was conducted according to the norms provided in the manual.

The physical activity hours were recorded over a period of 31 days by the instructor, who observed the players objectively during activity training sessions and maintained a record of the same. The average training hours per week devoted by each player were then calculated for further data analysis.

Statistical Analysis

The Statistical Package for the Social Sciences

(SPSS) software, version 21, was utilized for the following calculations and statistical operations: descriptive statistics, Pearson's product-moment coefficient of correlation, and simple linear regression with standardized (ß) coefficients.

Results

As per the Figure 1. the mean score of sixty students for activity hours devoted per week is 9. The maximum hours of the physical activity are 14. The mean score of intrinsic motivation is 40 and extrinsic motivation is 41. This conveys that both the types of motivation are moderately operational in the players to bring out optimal training duration in players. The mean score of amotivation is 15, which signifies presence of some factors that are causing boredom/ loss of interest towards training in players. The total motivation mean score of 97 indicates moderate motivation level of players. To analyze the variables in detail the constructs of Intrinsic and Extrinsic motivation have been discussed separately.

Figure 2 depicts that the Mean score of Construct – '*to know*' is 11.83. The construct '*to accomplish*' mean score is 13.8. The third construct '*stimulation*' is 14.8. The mean score of intrinsic motivation

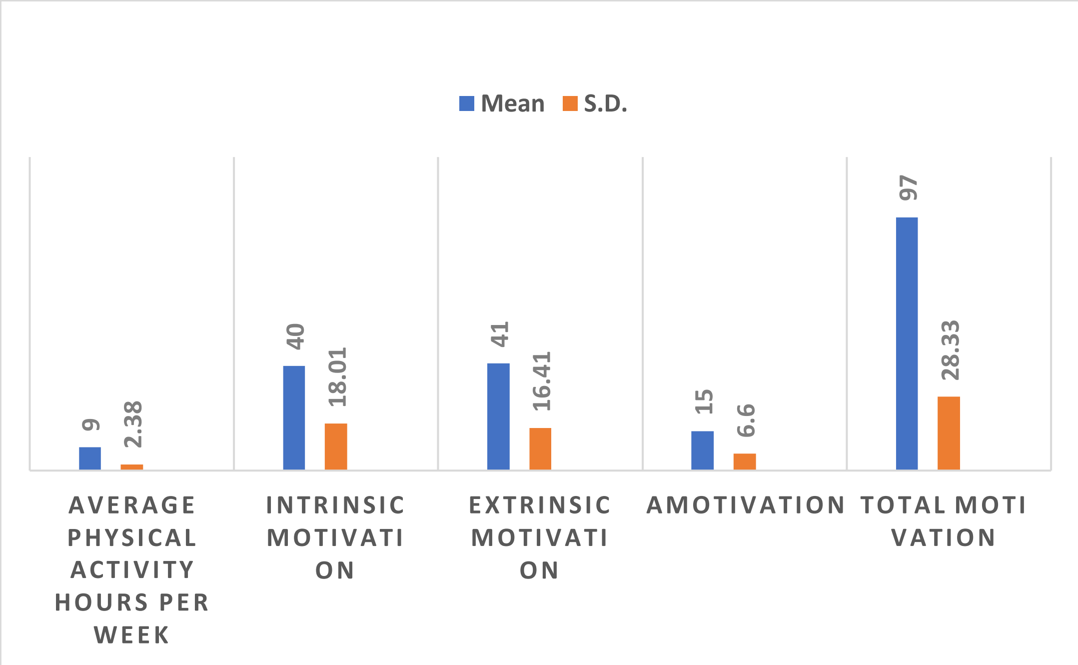

Figure 1. Descriptive statistics of the sample (N=60) under study

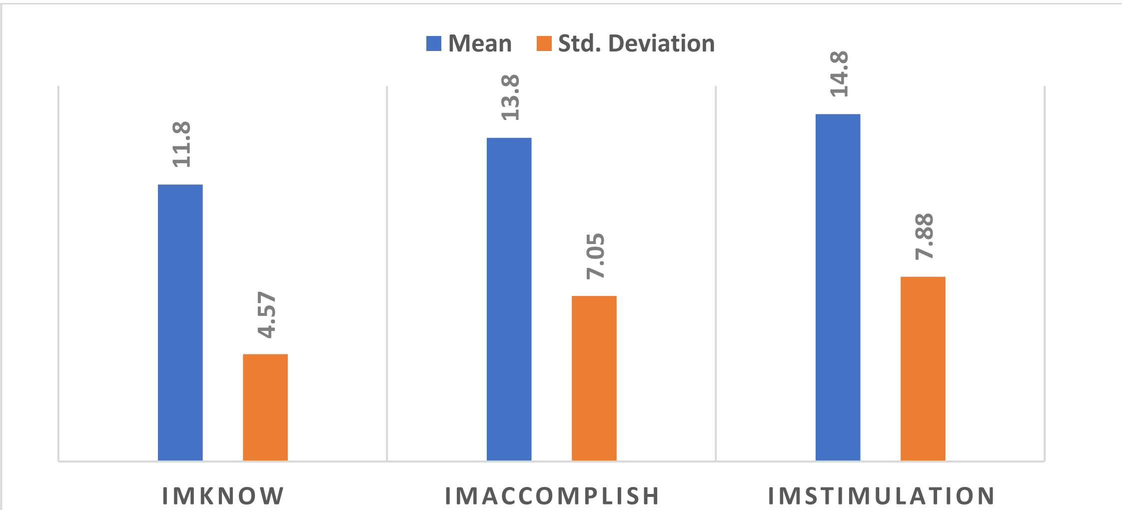

Figure 2. Descriptive statistics of Intrinsic motivation -3 subscales: IMKNOW - Intrinsic Motivation to Know; IMACCOMPLISH - Intrinsic Motivation to Accomplish; IMSTIMULATION - Intrinsic Motivation to Stimulation

derived from stimulating the senses is higher signifying that players engage in sports to derive pleasure during the play activity and it gives them feel good factor. Along with this second construct, motivation to accomplish is there where the players seek drive in how it feels to accomplish success through play activities. Most of the players focus on accomplishing goals in early stages of training but the process of training is most important. The drive 'to learn' is least focused upon by the players. If we analyze each construct score it is towards the moderate level as the subscales score ranges from 4-28. The findings highlight how coaches and instructors should make players aware of the internal motivational drives and the intrinsic patterns of performance.

The Figure 3 reveals the descriptive statistics of three constructs of Extrinsic motivation. The mean of extrinsic motivation of '*Identification*' is 14.77. The mean score pertaining to '*introjection*' is 14.20. Both signify that players are externally identifying with their roles as players and as well are performing due to the introjected feelings that they have to perform well. These can be driven either by guilt or by anxiety. The '*regulation*' component mean score is 12.83 meaning that rewards and incentives play secondary role. All the mean scores are near moderate level. The extrinsic motivation can be instilled through positive reinforcement by the coaches along with psychological rewards and incentives.

Further the data was analyzed using Pearsons's product moment correlation. As evident from Table 1; there is a significant positive correlation between intrinsic motivation and training duration per week (r= 0.932). the relationship between extrinsic motivation and training hours is positively correlated (r=0.919). the increase in one variable suggests a significant increase in the other variable. There is significant negative correlation between amotivation and training duration per week (r=-0.873). The total score of sports motivation shows significant positive correlation (r=0.921) indicating that motivation has significant role in determining the physical and exercise duration in players. This provides suitable answer to the Research question 1.

Further the data was analyzed using simple linear regression after fulfilling the assumptions. Sports motivation (total score) is the criterion to predict physical activity training duration of sixty players. The results obtained are depicted in Table 2.

Results of the analysis depict that Motivation shows significant positive relationship (ß=0.921) with physical activity training duration. Increase in motivation suggests significant increase in physical activity training. '*R square*' is the proportion of variance in the criterion explained by the predictor(/s) [16]. Motivation (total score) explains

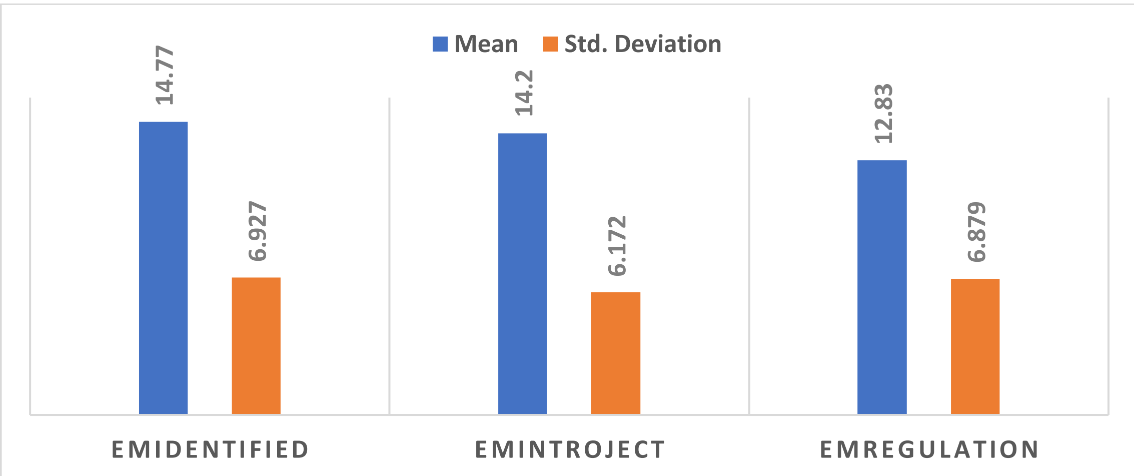

Figure 3. Descriptive Statistics of Extrinsic motivation -3 subscales: EMIDENTIFIED – Extrinsic Motivation Identified; EMINTROJECT – Extrinsic Motivation Introjection; EMRECULATION - Extrinsic Motivation Regulation

Table 1. Correlation coefficients of the intrinsic, extrinsic motivation and amotivation with average training duration per week

Variables duration per week	Average training
Intrinsic motivation	0.932 **
Extrinsic motivation	0.919**
Amotivation	-0.873**
Sports motivation (Total)	0.921 **

**significance level at 0.01

Table 2. Regression Coefficients to predict physical activity training hours from Sports motivation (n = 60).

Predictors	B	Std. Error	Beta (ß)	T	R^2	F	Sig. level
Motivation	.921	11.20	.921	12.54	.844	157.46	0.01

84.4% of the variance (R^2 =0.844) in predicting physical activity training duration. This research substantiates Research question 2 that motivation a significant predictor of duration of physical activity training.

Discussion

The aim of this study was to investigate the motivational correlates of sports and physical activity, focusing on the relationship between intrinsic and extrinsic motivation and training duration among athletes. The results revealed significant positive correlations between intrinsic and extrinsic motivation and training duration, indicating that athletes with higher levels of motivation tended to spend more time in training sessions. Additionally, a significant negative correlation was found between amotivation and training duration, suggesting that a lack of motivation negatively impacts the time spent on physical activity. These findings underscore the importance of understanding and nurturing athletes' motivation to enhance their engagement in sports and physical training.

The correlation analysis clearly establishes a relationship between motivation and the duration of physical activity and sports training. It highlights that both intrinsic and extrinsic motivation contribute positively to the training hours devoted by players, albeit at different levels. Conversely, amotivation emerges as a significant barrier to physical training in players. Research evidence supports the notion that amotivation can lead to burnout, decreased sports engagement, poor performance, and eventual dropout [17]. Consistent with our findings, existing literature suggests that perceptions of teacher, coach, and parental behavior can significantly affect players' arousal levels and performance [18]. Moreover, interventions aimed at promoting self-determined forms of motivation, such as providing feedback on competence and clear structure in physical activity and sports, have been shown to undermine amotivation. In comparison with previous research, our findings underscore the importance of understanding the nuanced dynamics of motivation in influencing athletes' engagement in physical activity and sports training. By elucidating these relationships, our study contributes to a deeper understanding of motivational factors in sports and physical activity settings.

Similar research supports our findings, which aimed to identify the five most important factors contributing to athletes' success [19]. The athletes ranked their innate athletic ability as the primary factor, followed by intrinsic motivation, practice efforts, coachability, and motor skills. Extrinsic motivation was ranked thirteenth out of fifteen factors. Similarly, a study examining the motivation and achievements of basketball players found that participants rated coach behavior and a learning-oriented climate as key determinants of motivation [20]. The motivation level of each player is influenced by individual differences, stemming from both nature and nurture factors [21]. Therefore, the training schedule should aim to enhance players' motivation levels. Physical activity training should nurture motivation through positive reinforcement, timely feedback, and motivational talks. It's crucial to recognize that players' behavior is shaped by the training modules they undergo in any game. The training schedule forms the foundation of their performance, and motivational drive determines their performance trajectory. Coaches and instructors should create a conducive atmosphere during games that fosters confidence and leadership [22, 23].

In comparison with previous research, our study adds to the understanding of motivational factors in athletic performance, particularly in highlighting the significance of intrinsic motivation and practice efforts over extrinsic motivation. While previous studies have emphasized coach behavior and a learning-oriented climate, our findings underscore the importance of individual differences and the role of nature and nurture factors in shaping athletes' motivation levels and performance outcomes.

In summary, our study provides valuable insights into the complex interplay between motivation and athletic performance. Future research could explore longitudinal studies to examine how motivational factors evolve over time and their long-term impact on athletes' development and success.

Conclusions

In light of the research results, the following conclusions can be drawn:

1. The current research holds a testimony that intrinsic and extrinsic motivation are imperative to engage the sportspersons in physical training and activity.
2. To encourage the players continuous interventions must be made by coaches, instructors to provide an objective feedback,

upkeep their interests in game alternating with variety of sports skills.

3. Systematic reinforcement and autonomy during practice sessions must be ensured to prevent amotivation in players and to stimulate them for their optimal performance by explaining the importance of optimal level of arousal.
4. Emotions serve as the base of motivation. Fostering positive emotions in players during training through peptalks automatically enhances their motivation.
5. The pre-competition and post-competition counseling sessions are essential with the psychologist and coach. They can be integrated with biofeedback training modules. It helps the players to learn how to manage autonomous body functions which enables them to control performance anxiety and stay motivated during training and competition as well.

Conflict of interest

The authors declare that there is no conflict of interests.

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03

ORIGINAL ARTICLE

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

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

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

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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.	*Chest pull with ball release* / 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.	*Throw preceded by quick steps* / 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.	*Chest press and overhead throw* / 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 (*Fire ball*). Exercises can also be performed in pairs, with alternating variations of throwing the ball.
4.	*Russian bounce* / 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.	*Tall slam and Tall rotational slam* / 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.	*Knees to feet slam* / 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 (*Jab step slam*). Idem from a forward lunge and hitting the ball into the ground with the torso twisting to the same side (*Split stance rotational slam*). Idem with lifting from a lunge, side step with hitting the ball on the ground, retrieving the ball and returning (*Kneeling side jump + slam*).
7.	*Catch and throw* / 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.	*Uppercuts* / 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	*Seated overhead throw* / 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 *supine chest press*.
10.	*Seated overhead scoop toss* / 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.	*Explosive push up* / 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.	*Fighter sit up* / 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.	*Monster slam* / 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 (*Step up to slam*).
14.	*Knees to feet scoop toss* / 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.	*Overhead throw and hip extension* / 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.	*Side to side press* / 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.	*Squat overhead throw* / 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.	*Kneeling lateral jump and shotput* / 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.	*Hipe drive and press* / 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.	*Kneeling overhead throw* / 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.	*Alternating step bass and toss* / 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.	*Side step and toss* / 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.	*Split stance side toss* / 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.	*Trunk jump to slam* / 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 (ε> 0.75) and Greenhouse-Geisser (ε <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

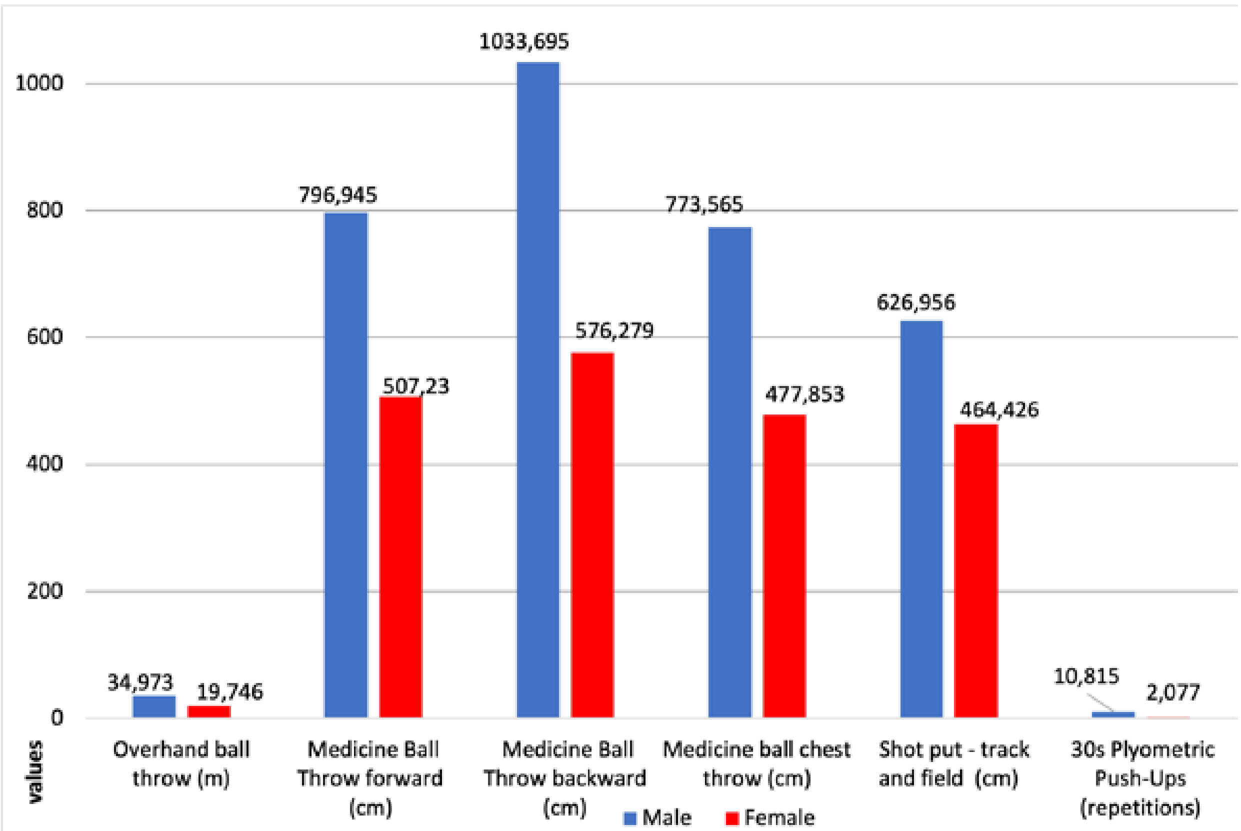

Figure 1. Mean values of final test results, comparatively presented by gender

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 shut 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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