BioMed Research International

Physical Fitness, Motor Competence and Physical Activity: Mediators and Interventions in School Children

Lead Guest Editor: Nebojsa Trajkovic
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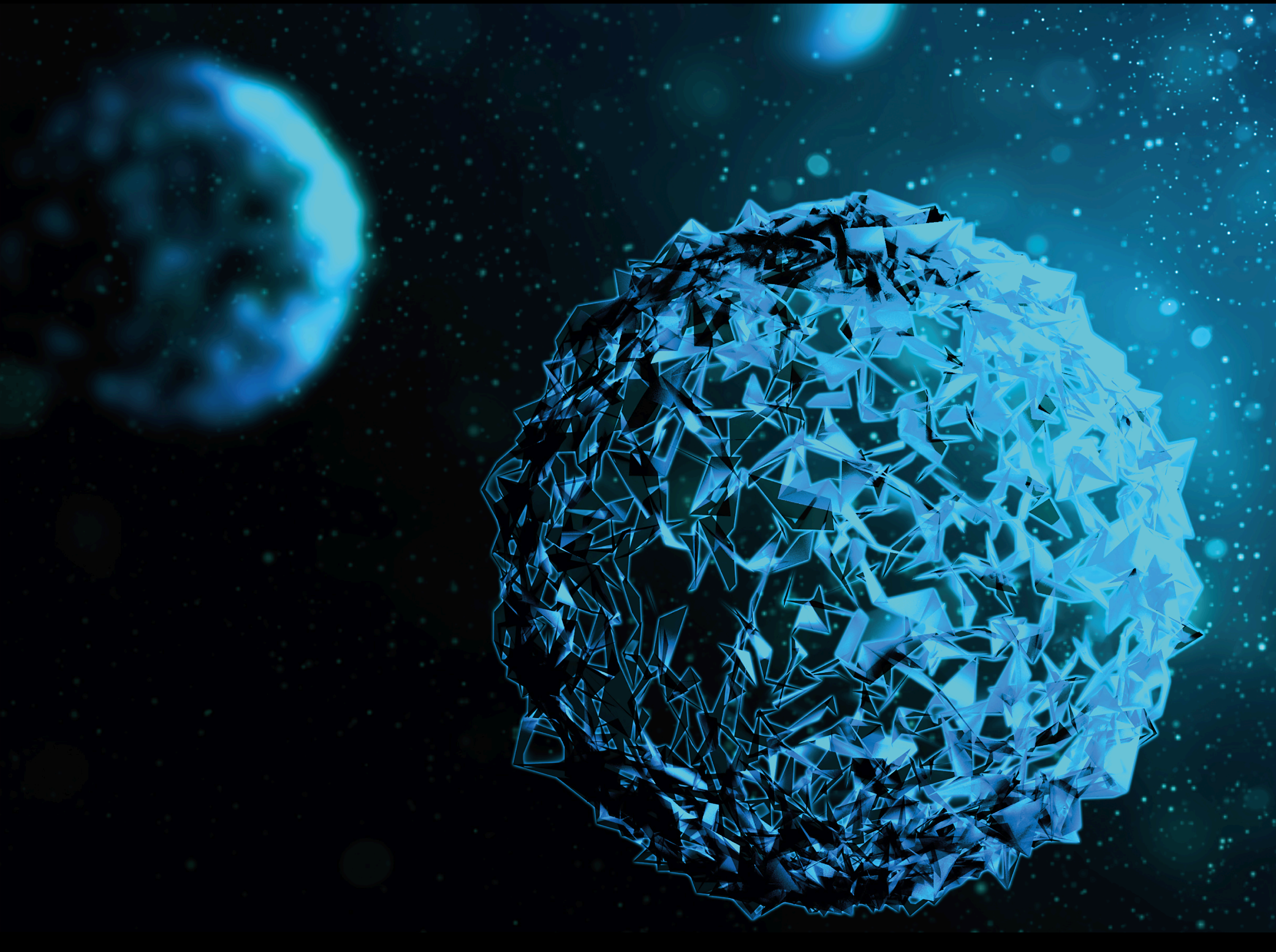

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Research Article

The Applicability of Provocative Functional Tests in the Diagnosis of Rotator Cuff Muscle Injuries of the Best University Athletes

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Rotator cuff disease, external and internal impingement syndromes, low shoulder stability, various types of trauma, and overuse injuries are all related to sports activities. In order to check symptoms in patients with disability and shoulder pain, clinicians use different methods and diagnostic imaging assessment. The research is aimed at evaluating whether there is a difference between provocation function tests (PFT) and ultrasonographic (US) testing of muscles within the rotator cuff in elite collegiate athletes. Patients ($n = 184$) were recruited from university team sports selections and tested with a standardized US examination of the shoulder and five PFTs (Speed's test, Neer's test, Hawkins test, lift-off test, Yergason's test). Based on the VAS pain assessment scale, 60 subjects had some pain, which was taken for further processing in the work (124 subjects did not have the presence of pain and were excluded from further processing). The US examination was conducted using Voluson 730 apparatus, by a linear probe, with the frequency in the range of 6-12 MHz. The chi-square test showed significant differences between PFT and the occurrence of shoulder muscle tendinitis for the following variables: Speed's test and subscapularis tendinitis ($p = 0.02$) and Speed's test and infraspinatus tendinitis ($p = 0.01$); Neer test and biceps brachii caput longum tendinitis ($p = 0.01$), Neer test and supraspinatus tendinitis ($p = 0.02$) and Neer test and infraspinatus tendinitis ($p = 0.01$); lift-off test and subscapularis tendinitis ($p = 0.05$); and Yergason's test and biceps brachii caput longum tendinitis ($p = 0.03$) and Yergason's test and subscapitis tendinitis ($p = 0.01$). The greatest effect of differences was observed in Neer's test and biceps brachii caput longum tendinitis ($\varphi = 0.60$), while the other effects can be described as medium and small in most cases. It can be concluded that functional tests are good predictors of soft tissue changes in the muscles of the rotator cuff of the shoulder. Further monitoring and analysis are needed on a larger number of athletes.

1. Introduction

Rotator cuff disease is usually associated with different traumatic and mechanical causes, as well as vascular and degenerative problems. Most rotator cuff injuries are a result of the rotator cuff tendon degeneration, and this is considered to be a primary cause. However, some disorders such as smoking, steroid use, diabetes, renal disorder, and collagenvascular disease weaken the tendon and could contribute to rotator cuff pathology. Likewise, external and internal impingement syndromes, low shoulder stability, different types of trauma, and overuse injuries are all related to athletic, sport, or occupational activity. It is one of the most common defects that can be seen in 30% of asymptomatic persons aged 60 years and over [1] and 65% of asymptomatic persons aged 70 years and over [2].

Today, athletes undertake training and participate in competition systems as the earlier generations of athletes did. Sports that require more arm strength, especially where throwing and hitting are important in the game (e.g., volleyball and handball), may cause shoulder pain more often and can lead to the occurrence of various pathological changes [3]. Some other cause, such as degenerative joint disease, glenohumeral instability, calcific tendinitis, cervical radiculitis, isolated acromioclavicular osteoarthritis, adhesive capsulitis, and nerve compression could have similar symptoms as subacromial impingement syndrome [4]. Injuries can be symptomatic but also asymptomatic and can be undetected in examination [5]. The joint surfaces and ligaments provide static joint stability, while dynamic stability is maintained by muscles and tendons [6], and such a great number of involved shoulder joints and their static and dynamic stability in the shoulder region require a complex examination. Furthermore, shoulder impingement syndrome is also found in the literature as rotator cuff disease or tendinopathy [7, 8].

In order to check the symptoms in patients with shoulder disability and pain, we may use various methods, and diagnostic imaging assessment is important when diagnosing soft tissue disorder management. Often, tests and protocols that are described in literature have not enough information to support their use, and a practicing clinician finds it difficult to recognize what procedure is especially useful.

A wide variety of modalities have been used to assess the rotator cuff, one of them being ultrasound assessment (US), computed tomography (CT), magnetic resonance imaging (MRI), and arthrography [9]. The advantages and utility of US are low-cost real-time imaging, nonappearance of radiation, and the dynamic examination possibility that is especially significant in the shoulder evaluation [10]. In the last decades, with various technical improvements that permit good resolution and higher Doppler signal power, US signal processing technique has become an important screening tool in the musculoskeletal structure examination. Also, this method could detect inflammation, injury, and hyperemia [11]. Moreover, clinicians repose trust in imaging data obtained from ultrasound and MRI in order to diagnose and detect rotator cuff disorders [12].

Previous research has documented over twenty-five special tests for the rotator cuff examination and several physical examination maneuvers that could isolate specific pathology of the shoulder, with widely ranging specific sensitivity [13, 14]. For several years, great effort has been devoted to sensitivity and specificity of functional prescanning test that are used in clinical practice in order to diagnose rotator cuff tears and impingement syndrome [2, 10, 12, 15–20]. Provocative functional tests frequently used in physical examinations and clinical evaluation (Speed's test, Neer's test, Hawkins test) are also available to coaches and physiotherapists at the sports field courts. Sometimes, it is not possible to make a difference between a full-thickness tear and a partial tear or tendinopathy using PFTs. Positive results of the functional tests (Neer's test, Hawkins test) can be confirmed by more detailed examinations, primarily MR and MRI in a significant correlation [21]. The two abovementioned tests have shown a significant similarity to ultrasound examinations in the diagnostic of BB tendinitis [22], while the sensitivity of the tests was absent in the diagnostic of changes in other articular cartilage and the tendon in the shoulder joint.

The validity of Yergason's test, Speed's test, and the bicipital groove point tenderness when determining biceps tendon disorder has been examined before [20]. MRI or surgical findings were used as the gold standard; however, no specific combination of tests has been reported to give a reliable positive predictive value. Moreover, to the author's best knowledge, very few publications that discuss the issue of correlation between provocation tests and US can be found available in literature. Hence, the objective of this study was to assess correlation between PFTs and US testing of the rotator cuff muscles in top-level university athletes.

2. Materials and Methods

2.1. Sample Description. A total of 184 male athletes from the University of Novi Sad, Serbia, have voluntarily participated in this study. Out of a total of 184 surveyed respondents, using the VAS pain assessment scale, 60 respondents had some pain, which were taken for further processing in the work, while 124 subjects did not have the presence of pain and were excluded from further processing.

They were also involved in different top-level university sports such as soccer, volleyball, handball, kick-boxing, dancing, and fitness, and all of them have practiced a minimum once a day, four times a week. The study was conducted according to the criteria outlined by the Declaration of Helsinki, by the ethical permission and approval from the university's Institutional Review Board (235/2-013).

2.2. Sample of Measuring Instruments/Variables. All the participants in the study came to a special hospital for rheumatic diseases in Novi Sad, Serbia. The US examination was conducted using Voluson 730 apparatus, by a linear probe, with the frequency in the range of 6-12 MHz. US has shown to be accurate as a diagnostic triage tool used to diagnose rotator cuff tears and soft tissue disorders [23]. The study compared the US and the MRI and found that they achieve accuracies similar in both sensitivity and specificity [23]. Ultrasound allows us to register pathological conditions of the rotator cuff not only in the painful shoulder conditions but also in asymptomatic cases. Ultrasound is particularly effective in assessing the dynamic stabilizers of the rotator cuff [24]. It is widely available, cost-effective, noninvasive, and well-tolerated [8]. The tests were used to assess long head of the biceps brachii muscle (m BB), the supraspinatus muscle (m SSP), the infraspinatus muscle (m

ISP), the subscapularia muscle (m. SSB), and the teres minor muscle (m. TSM). The same doctor examined all the subjects' dominant arm, and the duration of the examination was about 20 minutes. For the purpose of processing, the results from US examination were divided into four criteria similar to the ones in Alan's [24] study:

(i) There are no signs of disease

(ii) Initial signs of tendinitis

(iii) Clear signs of tendinitis

(iv) Clear signs of tendinitis with calcification

2.3. Description of the Procedure. In the case of functional provocation tests, the results are presented in the form of a dichotomous qualitative variable with two possible answers:

(i) Absence of pain

(ii) Presence of pain

Before the examination, every subject's shoulder was tested using PFTs [25]:

Speed's test: to perform Speed's test, the examiner starts with the patient's arm in shoulder flexion, continues with external rotation, which is followed by full elbow extension, and finally, forearm supination; the examiner applies resistance by performing a downward movement. The test will come positive if the patient feels pain in the bicipital tendon or bicipital groove [26]

Neer's test: this test demonstrates pain during passive abduction of the arm while the scapula is stabilized. The examiner positions the arm in the scapular plane and internally rotates the arm. The test was initially described in 1977 and did not describe a painful arc. However, a painful arc that occurs in abduction is often connected with the eponym. As an addition to this maneuver, the examiner administers an injection of local anesthetic into the subacromial space and reduces the pain, which represents Neer's test. The test is positive in case a significant reduction or abolition of pain is detected [27]

Hawkins test: this test was first described in 1980, and again, it is a passive test. The examiner positions the patient's arm at 90° in the scapular plane, then bends the elbow to 90°, and passively internally rotates the arm. Pain created by this maneuver is a clear indication that the test is positive [27]

Lift-off test: the test starts with the patient lifting the dorsum of the hand to the position of the mid-lumbar spine. After that, the patient tries to lift the dorsum of the hand off of the back. The patient should be able to maximally internally rotate the shoulder, but that is not always doable due to shoulder pain or tightening of the posterior shoulder capsule. The test will come positive if the patient cannot lift the hand away from the back, or if they lift the hand by extending the shoulder or elbow. A rupture or neurological involvement can result in the absolute loss of strength, while pain inhibition or actual weakness can lead to diminished strength

Yergason's test: the patient can be in a seated or standing position, the humerus should be in a neutral position, and the elbow should be at the position of 90 degrees flexion. The patient is instructed to externally rotate and supinate their arm while the therapist manually applies resistance. Yergason's test is positive if pain is experienced in the bicipital groove during the test

2.4. Data Analysis. Determining the differences between the PFT and the level of tendinitis in subjects with pain ($n = 60$), which were obtained using the VAS pain scale, the parametric statistical method chi-square test was used with a level of statistical significance of $p \leq 0.05$. In order to determine the size of the effects of the differences, the Phi indicator of the size of the effects (φ) was used. The classification of effects was determined according to [27]: 0.10-0.30 small effect, from 0.30 to 0.50 medium effect, and >0.50 large effect.

3. Results

The total sample of participants and their descriptive parameters is shown in Table 1. All the respondents are high university level athletes; all of them are in the training process and have over 9 years of experience in a specific team sport.

Table 2 shows the results of the chi-square test, which tested the significance of the differences in the distribution of the results of subjects of different groups, with the absence and presence of pain during the PFT, on certain items related to the occurrence of tendinitis of the shoulder rotator cuff muscles. The obtained results show that there is a statistically significant difference in the following variables:

(1) Speed's test and tendinitis subscapularis ($p = 0.02$) and Speed's test and tendinitis infraspinatus ($p = 0.01$)

(2) Neer's test and biceps brachii caput longum tendinitis ($p = 0.01$), Neer's test and tendinitis supraspinatus ($p = 0.02$), and Neer's test and tendinitis infraspinatus ($p = 0.01$)

(3) Lift-off test and tendinitis subscapularis ($p = 0.05$)

(4) Yergason's test and biceps brachii caput longum tendinitis ($p = 0.03$) and Yergason's test and tendinitis subscapularis ($p = 0.01$)

No statistically significant differences were observed in other analyzed variables.

The greatest effect of differences is noticeable in Neer's test and biceps brachii caput longum tendinitis of $\varphi = 0.60$, while the other effect can be mostly described as medium and small.

Figure 1 shows the percentage representation of subjects with and without pain in Speed's functional test in the presence of subscapularis tendinitis. Significant differences between Speed's test and subscapularis tendinitis variables were observed ($p = 0.02$; $\chi^2 = 5.88$). According to Cohen [28], the medium effect of differences was observed ($\varphi = 0.31$). Initial signs of tendinitis were observed in 30.8% of subjects with pain and 6.4% of subjects without pain.

Table 1: Participants' characteristics.

$n = 60$	$M \pm SD$
Age (years)	22.21 ± 1.64
Height (cm)	180.84 ± 8.21
Weight (kg)	75.20 ± 9.41
Sports experience (years)	8.72 ± 3.99
Practiced a day (1-3 times per week)	1.13 ± 0.39
Practiced a week (3-6 times per week)	4.76 ± 1.40
Shoulder injuries (*n*)	48
Pain in shoulder (VAS scale) (*n*)	60
Speed's test (*n*)	14
Neer's test (*n*)	9
Hawkins test (*n*)	41
Lift-off test (*n*)	11
Yergason's test (*n*)	15

Legend: *M*: arithmetic mean; SD: standard deviation; *n*: number of cases.

Figure 1 shows the frequencies of the results for subjects with and without pain in Speed's functional test in the presence of infraspinatus tendinitis. The results indicate significant differences between the variables Speed's test and infraspinatus tendinitis ($p = 0.02$; $\chi^2 = 19.81$). According to Cohen [28]. the large effect of differences was observed ($\varphi = 0.58$). Clear signs of tendinitis are present only in 4.3% of subjects with absence of pain, while initial signs of tendinitis are present in 53.8% of subjects with presence of pain and only 4.3% of subjects with absence of pain.

There are significant differences between the two groups of subjects with and without pain and the occurrence of biceps caput longum tendinitis ($p = 0.01$) at a value of $\chi^2 = 21.24$ (Figure 2). Clear signs of tendinitis were observed in 37.5% of subjects with pain while no clear signs were observed in the group of subjects without pain (0%). Initial signs of tendinitis were observed in 17.3% of subjects without pain. A large effect of differences was observed ($\varphi = 0.60$) [28].

The obtained results indicate that there are significant differences between the two groups of subjects with and without pain and the occurrence of supraspinatus tendinitis ($p = 0.02$; $\chi^2 = 9.40$) (Figure 2). Clear signs of tendinitis with calcification were observed in 1.9% of subjects without pain while they were not observed in the group with pain. Clear signs of tendinitis were observed in 25% of subjects with pain and 1.9% of subjects without pain. Initial signs of tendinitis were observed in 37.5% of subjects with pain and 23.1% of subjects without pain. The effect of differences was at medium level ($\varphi = 0.60$) [28].

Figure 3 shows the results for subjects with and without pain in the Neer functional test with the occurrence of infraspinatus tendinitis. The obtained results indicate the existence of a significant difference ($p = 0.01$; $\chi^2 = 8.98$). The medium effect of differences was observed [28] (φ =0.58). Clear signs of tendinitis were observed in 3.8% of subjects without pain, and there were no subjects with pain in this category. However, 50% of the subjects with pain had initial signs of tendinitis and only 9.6% of the subjects without pain.

The results obtained in Figure 3 show that there are significant differences ($p = 0.05$) between the two groups of subjects with and without pain in the lift-off test and the occurrence of subscapularis tendinitis at the value $\chi^2 = 3.91$. Initial signs of tendinitis were observed in 30% of subjects with pain and only 8% of subjects without pain. The correlation effect according to Cohen [28] presented and calculated using the Phi coefficient indicates a large effect ($\varphi = 0.26$).

The obtained results from Figure 4 show that there are significant differences between the two groups of subjects in Yergason's test with and without pain and the occurrence of biceps brachii caput longum tendinitis ($p = 0.03$, $\chi^2 = 6.95$). Initial signs of tendinitis were observed in 40% of subjects with pain and 10% of subjects without pain. Clear signs of tendinitis were observed in 10% of subjects with pain and 4% of subjects without pain. The effect of differences was at medium level ($\varphi = 0.26$) [28].

The obtained results from Figure 4 show that there are significant differences between the two groups of subjects in Yergason's test with and without pain and the occurrence of subscapularis tendinitis ($p = 0.01$; $\chi^2 = 9.35$). Initial signs of tendinitis were observed in 40% of subjects with pain and only 10% of subjects without pain. The correlation effect according to Cohen [28] presented and calculated using the Phi coefficient indicates a medium effect ($\varphi = 0.40$).

4. Discussion

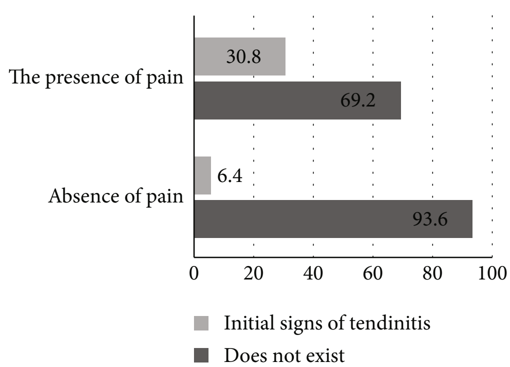
Athletes often suffer from rotator cuff disorders, which are the cause of shoulder pain. Shoulder pain is also a common symptom in musculoskeletal clinics. There is extensive literature available [12] on special tests and other physical examination maneuvers and some of the tests described in the literature lack sufficient information to support their use. Diagnostic and evaluation procedures for detecting rotator cuff injuries and their goal to assess the extent of injuries and morphological characteristics of the same are tested daily. For this reason, the basic clinical methods and their application in everyday examinations of university-level athletes should not be neglected or denied.

The aim of the study was to evaluate the correlation between PFT and muscle testing within the US rotator cuff in elite collegiate athletes. Looking at the results, we noticed that there were significant differences between PFT and US which revealed tendinitis of the rotator cuff muscle of the dominant hand. A relationship was established between some functional tests (Speed's test, Neer's test, lift-off test, and Yergason's test) and tendinitis of the biceps brachii muscle of the long head (caput longum), tendinitis subscapularis, tendinitis infraspinatus, and tendinitis supraspinatus, as determined using US. However, it should be noted that the effects were small or medium, which could affect the final conclusions regarding the abovementioned associations between the tests and shoulder pain. Contrary to this, there is no statistically significant relationship between functional tests and the occurrence of subscapularis muscle tendinitis and infraspinatus muscle tendinitis detected by US [22].

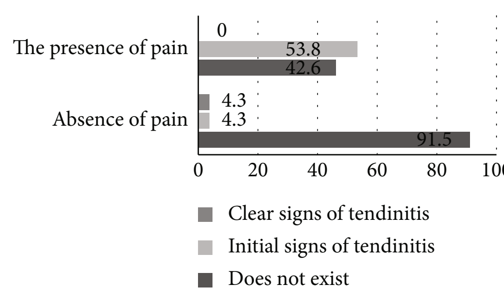
Table 2: Results of the differences between subjects with the presence and absence of pain in PFT and the occurrence of tendinitis of the shoulder rotator cuff muscles.

	Biceps brachii caput longum tendinitis ($n = 16$)	Tendinitis subscapularis ($n = 12$)	Tendinitis supraspinatus ($n = 31$)	Tendinitis infraspinatus ($n = 17$)
Speed's test				
χ^2 (df)	3.82 (2)	5.88 (1)	6.25 (3)	19.81 (2)
p (φ)	0.15 (0.25)	0.02 (0.31)	0.10 (0.32)	0.01 (0.58)
Neer's test				
χ^2 (df)	21.24 (2)	1.59 (1)	9.40 (3)	8.98 (2)
p (φ)	0.01 (0.60)	0.21 (0.16)	0.02 (0.40)	0.01 (0.39)
Hawkins test				
χ^2 (df)	3.43 (2)	3.02 (1)	6.42 (3)	4.91 (2)
p (φ)	0.18 (0.24)	0.08 (0.22)	0.09 (0.33)	0.09 (0.29)
Lift-off test				
χ^2 (df)	5.75 (2)	3.91 (1)	1.04 (3)	2.00 (2)
p (φ)	0.06 (0.31)	0.05 (0.26)	0.79 (0.13)	0.37 (0.18)
Yergason's test				
χ^2 (df)	6.95 (2)	9.35 (1)	0.93 (3)	2.69 (2)
p (φ)	0.03 (0.34)	0.01 (0.40)	0.82 (0.12)	0.26 (0.21)

Legend: χ2: chi-square test value; p: level of statistical significance chi square test; df: degrees of freedom; φ: Phi coefficient of effects.



x^2 (2, N = 60) = 5.88, p = 0.02, φ = 0.31



x^2 (2, N = 60) = 19.81, p = 0.02, φ = 0.58

Figure 1: Functional Speed's test and subscapularis tendinitis and functional Speed's test and infraspinatus tendinitis.

We can say with great certainty that the mentioned provocation tests are applicable for the evaluation of pathological changes in the tendons around the long head of the biceps muscle. However, observing the pathological changes in the tetra supraspinatus, the lift-off test and the Yergason test indicated changes; so, the application of these tests is justified. This is also the case with tendinitis of the subscapularis muscle as well as the infraspinatus muscle. These facts impose an additional need to test for pathological changes using some other tests (external sign of 0-degree lag rotation, drop signal, Jobe's test (empty can test), arm drop test, abdominal pressure test, bear hug test) and diagnostic procedures [6, 17], as well as the application of magnetic resonance. Various provocative test maneuvers have been created to help identify biceps tendon lesions. The Yergason, Neer, Hawkins, and Speed tests are often used to isolate biceps tendon pathology by creating an impingement below the coracoacromial arch [29, 30].

The occurrence of tendinitis in young athletes can be explained by the excessive volume and intensity of training in younger age categories and inappropriate dosing of loads that is not in accordance with physical growth and development during long-term sports (the average number of sports participants was about 8 years), but we should not forget some changes in the soft tissues that could have occurred as a result of inadequate intake of supplements (D and K vitamins) and some hereditary or acquired diseases. These phenomena were not included during the evaluation of the external validity of the research; so, they represent a shortcoming and limitation of the research.

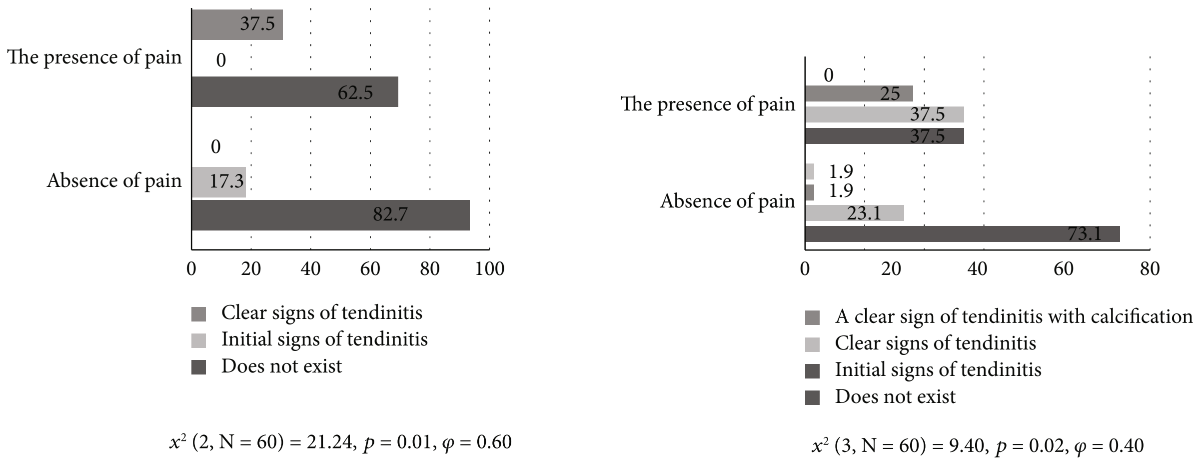


Figure 2: Neer test and biceps brachii caput longum tendinitis and functional Neer test and supraspinatus tendinitis.

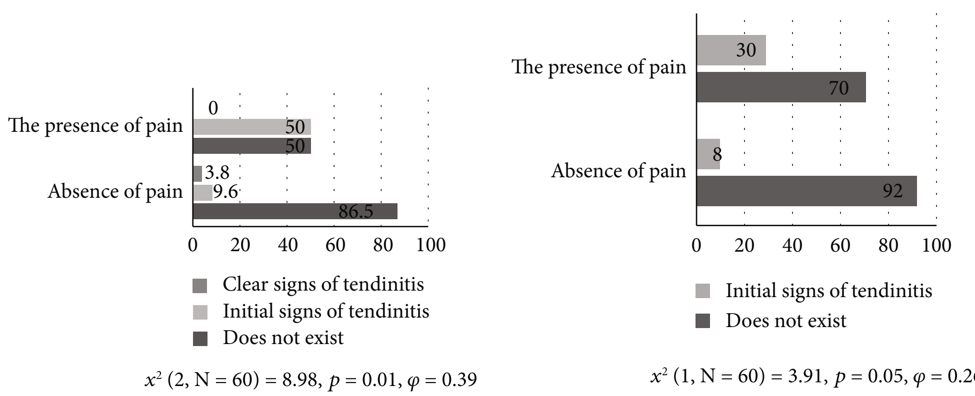


Figure 3: Functional Neer test and infraspinatus tendinitis and functional lift-off test and subscapularis tendinitis.

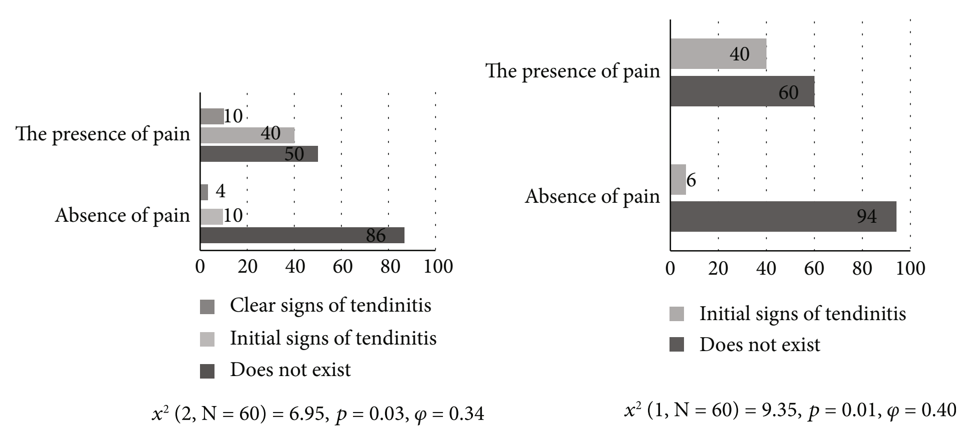


Figure 4: Functional Yergason's test and biceps brachii caput longum tendinitis and functional Yergason's test and subscapularis tendinitis.

The advantages of using provocation tests in the diagnosis of pathological changes in the tendons of the shoulder joints are multiple. First of all, they do not require much time and practically no apparatus and, if used correctly, can be a good prescanning technique in detecting pathological changes in the rotator cuff of the shoulder. Another important advantage of provocation tests is that they can be relatively easily learned and applied in the field, outside of medical facilities. Consequently, medical professionals are not the only people who should be doing these tests, but coaches and other professional sports professionals can also use them. Although it is often enough to determine the clinical picture [16], it is necessary to be careful and to remove the suspicion of pathological changes in the shoulder joint with a more detailed medical examination. Furthermore, a physical examination protocol can be used in patients with suspected rotator cuff tears, impingement syndrome, and biceps tenosynovitis [12, 13, 16], and these are common tests and our work was to determine how much the tests helped or did not help the examiner to understand what the actual pathology of a rotator cuff injury is. The main limitation of the experiment is defining the classification of ultrasound images, reliability, and presentation of the pathology itself. Addressing this limitation, the authors suggest examining American images by a large number of professionals. Moreover, as a limitation, we must mention the strength of the correlation between the variables. Therefore, future studies should keep this in mind when designing their studies.

The results of the research indicated justified use of PFT on the muscles of the shoulder rotator cuff, especially on changes in the muscles of m. subscapularis, biceps brachii caput longum, and m. infraspinatus, because any change reduces the volume and amplitude of movement that is necessary for normal functioning. The research is even more significant since it dealt with a population of athletes, where the injuries to the muscles of this region are more pronounced than in persons who do not play sports. And any change can remove them from training and further competition, thus hampering their further careers. This study showed the presence of a set of changes that can be detected by the ultrasound and through provocative functional tests in athletes, which were more frequent in people who reported pain in the shoulder joint. Because of this, a lot of similarities can be observed with the results of other authors' research [29–32]; although, they dealt not only with athletes but also adults. The absence of any clinical sign of local pathology cannot rule out the presence of local abnormalities and constant checking of the muscles of the shoulder rotator cuff is required, since these are quite young athletes with a career ahead of them [33–35].

It should be noted that there are a lot of asymptomatic conditions in the rotator cuff muscles as well as evidence of tissue changes in people who have not even reported frequent pain [36, 37]. Our research nevertheless pointed out the importance in athletes who have reported the occurrence of pain to certain provocative functional tests, but it would be justified to conduct research on the population of people who have not reported pain in order to determine whether there might be some changes in tissues by applying ultrasound or better yet, magnetic resonance imaging. Also, in some earlier studies [38], it was pointed out that the pathology of the rotator cuff muscle was still unclear and not understood completely, and even that certain asymptomatic changes can eventually become chronic. Therefore, the thickening of the tendon, the change in the form of tendinitis, determines the duration of treatment, as well as the time of recovery that will be required for the athlete to return to training [38, 39].

Musculoskeletal shoulder adaptations can be typical for athletes; so sometimes, there are changes that are not detected by PFT but can be observed through ultrasound imaging. In our research, as well as in the research of other authors [40], such changes in tendons that have not previously been detected by PFT, namely, the thickened dominant tendon of m. subscapularis and m. biceps brachii, may also be leading risk factors for shoulder injury in athletes [29, 41, 42].

The limitation of the study is the lack of a control group of respondents, as a limited number of respondents of university age. PFTs were not compared with magnetic resonance tests, because the subjects did not feel too much pain, no connective tissue rupture was suspected nor was this expected from the aim of the study. The study was aimed at validating of the PFT in the assessment of potential shoulder rotator cuff muscle injuries. Magnetic resonance was not planned in the work methodology, because US was used as a screening method [43]. Students, if necessary, underwent MRI and were excluded from the study. It should be emphasized that US is easily available, cheaper, has no negative radiation, and is repeatable [44]. Also, the US method is used to monitor local findings, and larger partial and total ruptures can be seen; so, a differential diagnosis can be made in relation to inflammatory rheumatic diseases.

5. Conclusions

Certain differences in the manifestation of tendinitis were found in athlete subjects who reported pain. Based on the obtained and presented research results, it can be concluded that PFTs are good indicators of changes in soft tissues and different degrees of damage, and that they can be used as initial indicators of these conditions. Knowledge of common locations of this condition, for rotator cuff tendons, can enable focusing medical examinations and increase the sensitivity of this field of work of sports and medical workers.

Data Availability

Data will be available from the corresponding author if required.

Ethical Approval

Approval was taken from the Ethics Committee of the University's Institutional Review Board (235/2-013) (Serbia, Novi Sad).

Consent

Written informed consent was obtained from all participants.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

Conceptualization was contributed by D.U. and M.C. Methodology was contributed by K.F. Software was contributed by J.ZS. Validation was contributed by M.N. Formal analysis was contributed by A.Đ. Investigation was contributed by R.JM. Resources was contributed by S.P. Data curation was contributed by S.J. Writing—original draft preparation was contributed by V.Š. Writing—review and editing was contributed by D. M and B.P. Visualization was contributed by D.R. Supervision was contributed by D.M. Project administration was contributed by S.A. All authors have read and agreed to the published version of the manuscript.

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Research Article

School-Based Comprehensive Strength Training Interventions to Improve Muscular Fitness and Perceived Physical Competence in Chinese Male Adolescents

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Purpose. This research was to see how effective and feasible school-based comprehensive strength training programs are in improving muscular fitness and perceived physical competence in Chinese male adolescents. *Methods.* A total of 123 participants (13.46 ± 0.60 years) were randomized to comprehensive strength training intervention group (CST) ($n = 62$) and the control group (CON) ($n = 61$). The training sessions were performed three times a week for ten weeks in CST. Muscular fitness (i.e., muscular strength, power, and muscular endurance) and perceived physical competence were assessed at initial testing and final testing. *Results.*The subjects in the CST significantly improved their mean performance in standing long jump ($p < 0.05$), vertical jump ($p < 0.05$), 1 min push-ups ($p < 0.05$), 1 min sit-ups ($p < 0.05$), handgrip strength ($p < 0.05$), and perceived physical competence ($p < 0.05$) after the intervention. Moreover, the CST were greater in standing long jump ($p < 0.05$), vertical jump ($p < 0.05$), 1 min sit-ups ($p < 0.05$), handgrip strength ($p < 0.05$), and perceived physical competence ($p < 0.05$) compared to the CON, but no in 1 min push-ups ($p > 0.05$). *Conclusions.* The comprehensive strength training interventions designed in this study can significantly increase male adolescents' muscular fitness, especially in the lower extremity muscle power and abdominal core endurance, and can enhance their perceived physical competence.

1. Introduction

The World Health Organization (WHO) recommends that children and adolescents should engage in a minimum of 60 min of moderate-to-vigorous physical activity (MVPA) every day and at least three days per week of muscle-strengthening exercises (MSE) [1–3]. The health benefits of meeting MVPA and MSE exercises during adolescence are well known such as aerobic fitness[4], muscular fitness[5, 6], skeletal health[4, 7], mental health[8, 9], and metabolic function[10]. However, current data emphasizes the global prevalence of inadequate physical activity among school-aged adolescents, with research indicating that 84.3% of Chinese students (global 81% students) aged 11-17 years were insufficiently physical active in 2016[11]. Furthermore, less than two-fifths of Chinese children and adolescents met the World Health Organization muscle-strengthening exercise recommendations in 2021[12]. Since children and adolescents do not engage regularly in a variety of physical activities, they may be prone to the inevitable consequences of lower muscular fitness and low motor competence.

The term "muscular fitness" refers to three elements of musculoskeletal functioning, namely, maximal strength, muscular power, and local muscular endurance[13]. A growing body of evidence has showed the many benefits of muscular fitness with for a variety of health-related outcomes in adolescents (i.e., body mass index, skinfold thickness, insulin resistance, triglycerides, cardiovascular disease risk score[14], quality of life, attenuate fatigue[15], skeletal health, self-esteem[16], and cognitive task)[17]. Despite the growing number of researches supporting the benefits of muscular fitness, it is often an overlooked element in physical activity guidelines[18]. Many studies have shown a downward continuous trend in muscular fitness among school children in different countries or regions such as the U.S.[19], Britain[20], Canada[21], Spain[22], China[23], and New Zealand[24]. Low muscular strength in teenagers is a developing risk factor for major causes of mortality in early adulthood, such as suicide and cardiovascular diseases[25], and muscular strength in males is inversely and independently associated with death from all causes and cancer[26]. Poor muscular fitness has been linked to pediatric dynapenia in modern-day youth[27] and sarcopenia in elder individuals (i.e., the loss of skeletal muscle mass associated with aging, neuromuscular factors independent of muscle size contribute to muscle weakness, fall risk, declining quality of life, and loss of functional movement)[28, 29]. Furthermore, lower muscle strength was linked to lower cardiorespiratory capacity and motor competence[30, 31]. A number of negative effects of poor muscle strength highlight the need to address the downward continuous trend in muscular fitness among school-aged children.

Perceived physical competence refers to the assessment of adolescents' self-perception in the physical domain[32]. In the physical activity domain, perceived competence is often associated with the confidence in one's ability to take part in sports and outdoor games[33]. Perceived physical competence was positively and substantially connected to physical activity (PA) in males; changes in perceptions may be crucial elements of motivation for PA in school children[34]; it was regarded as a significant factor of behavior[35]. Muscular fitness or cardiorespiratory fitness is associated with motor competence from childhood to early adulthood[36], children with low motor competence demonstrated lower perceived competence[37], and low values in perceived motor competence and actual motor competence and fitness will show a higher probability of maintaining unhealthy lifestyles[38]. Previous studies have looked into the link between motor competence, physical fitness, and perceived motor competence. However, longitudinal intervention studies to increase perceived motor ability are relatively limited. Because boosting male teens' perceived physical competence will be an effective technique for addressing the problem of insufficient physical activity, it is crucial to explore how to improve perceived physical competence.

According to those reviews that summarize the substantial effects of school-based interventions for promoting muscular fitness[18, 39], strength training appears to be one of the most successful PA in teenage boys. Schools are ideally placed to introduce young people to a multitude of lifelong physical activities (including strength training)[40]. However, most school-based PA programs have emphasized aerobic exercises, with relatively few targeting strength training[7]. To find out why, we conducted in-person or phone interviews with 58 secondary school physical education (PE) teachers. Considering the safety of strength training (ST) and the lack of interest of students, they rarely do strength training in PE lessons, despite strength training is safe. Additionally, there is a lack of understanding and knowledge of strength training, and teachers are unclear how to incorporate strength training into regular physical education sessions. Given the importance of muscular fitness for health, there is a need to find a practical and sustainable program. Although recent studies have shown that comprehensive school-based PA interventions are efficiently to improve the cardiorespiratory fitness, muscle strength, and PA[41, 42], the effects of comprehensive school-based strength training interventions on muscular fitness and perceived physical competence of adolescent boys are uncertain. Thus, the purpose of this paper was to determine the impact of comprehensive strength training interventions on muscular fitness of secondary school-aged teenagers (main outcome). The secondary goals were to see if comprehensive strength training interventions affected perceived physical competence. It was hypothesized that after completing the comprehensive strength training interventions program, participants' muscular fitness and perceived physical competence would increase.

2. Methods

2.1. Participants. The subjects recruited for our study were convenience sample. Participants were required to be healthy adolescents with no history of orthopedic, musculoskeletal, or neurological issues that may have impaired their ability to complete the strength training program and the strength tests. None of the students were athletes, and none of them had ever engaged in organized resistance training. A total of 143 students were recruited for this study. Two were removed because they did not meet the inclusion requirements, leaving 141 healthy boys aged 12-14 years to participate in this study. All eligible students provided written informed permission from their legal guardians. By drawing lots, students were allocated to either comprehensive strength training intervention group (CST) or control group (CON). The CST contained 70 individuals, whereas CON had 71 participants. At any time, any participant might withdraw from the research. Because some students were missing in the posttest or transferred to another school for health reasons, 18 students were omitted from the final analysis after a 10-week intervention. Finally, the effects of the intervention were examined in 123 pupils. At baseline, there were no significant variations in age, body height, body mass, or body mass index (BMI) across groups, as shown in Table 1. The study protocol was approved by the Ethics Committee of Capital University of Physical Education and

Table 1: Descriptive characteristics of the study participants.

Variables	All ($n = 123$)	CST ($n = 62$)	CON ($n = 61$)
Age (year)	13.46 (0.60)	13.46 (0.55)	13.45 (0.64)
Body height (cm)	165.13 (8.21)	166.45 (7.81)	163.78 (8.45)
Body mass (kg)	58.20 (15.22)	59.79 (14.00)	56.57 (16.32)
BMI (kg/m^2)	21.23 (4.87)	21.50 (4.45)	20.95 (5.29)

Values are the observed mean (SD); CST: comprehensive strength training group; CON: control group.

Sports (code 2022A20), abiding by the Helsinki Declaration amended in Fortaleza (Brazil) in 2013.

2.2. Study Protocol. Subjects were recruited from 4 separate physical education classes at the same secondary school. Classes were assigned at random to either a CST or CON. The intervention was founded on the theory of planned behavior[43] and social ecology model[44], and it intended to satisfy students' psychological needs for interpersonal contact, confidence, and intention to engage in school sports and strength training. Before the experimental intervention, PE teachers in the CST were trained to implement the intervention plan. Professional development and equipment (such as resistance bands or dumbbells) were offered to teachers in order to deliver resistance-based exercise. Based on past research, the CST program was particularly designed to be time-efficient, developmentally suitable for teenagers[45, 46]. A graduate student and two PE teachers were on hand to help during the intervention. The CST program included a circuit of 6–8 exercise stations aiming to strengthen muscular fitness (i.e., upper body muscle, low body muscle, and core muscle). Before starting interventions, the subjects in the CST received two weeks of strength training videos, approximately 20 minutes each time, twice weekly, learning by Internet in the classroom to understand the benefits of strength training and master the right skills or methods of RT through power point shows (PPT). After that, a 10-week strength training program was conducted on the playground, with strength training taking place three times a week, on nonconsecutive days, during the first 20-25 minutes of the 45-minute PE class. Participants completed two workouts at each station on the circuit while listening to music, chosen by the adolescents.

According previous studies, youth strength training plans should begin with 1 to 2 sets of 6 to 15 repetitions of each exercise [47]. Starting a strength training program for youths with 10 to 15 repetitions not only brings positive changes in muscular performance but also makes suitable adjustments [6]. In general, when a youngster can comfortably accomplish 15 repetitions, resistance can be raised by 5% to 10% [48]. If the individual fails to finish at least 10 repetitions on each set or maintain appropriate technique[49, 50], the weight is likely too heavy and should be adjusted. It is critical to realize that not all workouts require the same number of sets and repetitions. Thus, participants of this study work in pairs to finish 2 sets of each exercise for 10–12 repetitions in 1-5 weeks (6 exercises including 2–3 resistance band exercises and 3–4 body weight exercises). In weeks 6–10, they did 3 sets of 8–10 repetitions for each exercise using dumbbells (i.e., 0.75 kg, 1.5 kg, and 2 kg) and body weight exercises (for more details, see Table 2). Following a warmup that included dynamic movements or stretching, participants always worked in pairs so that one student was training and the other was observing the partner's performance. Further, all teachers used positive or encouraging phrases to raise the students' perceived of their motor competence. All sessions were recorded and monitored by the authors of this study.

During the 10-week intervention period, participants in the CON went to their regular physical education classes (also three times a week) and were mostly taught volleyball and football. In general, in Chinese regular PE classes, students run for 2-3 laps around the playground before the PE teachers teach them ball skills or other sport programs. During their physical education lessons, no specific resistance exercises were undertaken. Following the study's completion, participants in the CON were provided the strength training courses. All subjects were not allowed to change their daily sports activities during the intervention.

2.3. Study Procedure. Within the first minutes of their PE class, the participants in the CST undertook a series of exercises, while the participants in the CON attended their regular PE class as part of the school's curriculum. Data was obtained before and after the intervention. Measurements were chosen to complete a full body muscle strength assessment and to overcome typical challenges to establish a school-based fitness assessment (e.g., lack of resources and insufficient time). Permission to conduct the study was secured from school principals and PE teachers, and participants were informed that their participation was completely voluntary and that they might withdraw at any moment.

2.4. Measures

2.4.1. Muscular Fitness. The standing long jump was used to assess the lower body's explosive strength. Participants were asked to stand shoulder-width apart behind a line drawn on the ground and attempt to jump as far as possible they could without falling backwards. A two-foot take-off and landing was used, with forward force produced by swinging of the arms and bending the knees. The distance between the take-off line and the back of the participant's heels was measured. The longest distance was measured to the nearest centimeter after three attempts. The standing long jump is a component of the physical fitness test battery in China, and it is regarded as a valid and reliable field-based assessment of muscular fitness in teenagers[51].

The vertical jump test was used to assess the lower body power. The vertical jump was started at a semisquat position (90° knee flexion), confirmed by eye inspection. Participants held this stance for 2 seconds before jumping vertically for maximal height at the tester's instruction[52]. During the semisquat jump, each participant was carefully examined to ensure that no countermovement was used. Participants lined up at the starting line and leapt as far as they could when the tester signaled. Hands were kept on the hips during the exercise, and participants were advised to keep their

Table 2: The comprehensive strength training program of the CST.

Week	Content
Week 1	TheraBand–horizontal pull; TheraBand–arm front raises; TheraBand–lunges; TheraBand–squats; single leg hops; sit-ups; partial curls; double crunches
Week 2	TheraBand–horizontal pull; TheraBand–lat pull downs; TheraBand–squats; TheraBand–squat with shoulder press; lateral hops; plank; partial curls; double crunches
Week 3	TheraBand–shoulder lateral raises; TheraBand–lunges with biceps curls; modify push-ups; tuck jumps; jumping lunges; double crunches; double leg raises; plank
Week 4	TheraBand–rowing (sit); TheraBand–shoulder overhead press (sit); TheraBand–calf raises; squats & bicep curls with TheraBand; squat jumps; double leg raises; plank; seated Russian twist
Week 5	TheraBand–triceps kickbacks; TheraBand–lunges with biceps curls; TheraBand–squat with shoulder press; TheraBand–calf raises; tuck jumps; seated Russian twist; double leg raises; plank
Week 6	Dumbbell–biceps curls; dumbbell–reverse fly; dumbbell–squats; dumbbell–lunges; single leg hops; V crunches; reverse curls; plank
Week 7	Dumbbell–lat pull downs; dumbbell–overhead shoulder press; dumbbell–lunges; dumbbell jump squats; jumping lunges; reverse curls; sit-ups with a dumbbell; plank jacks
Week 8	Dumbbell–squat with shoulder press; dumbbell–lunges with biceps curls; dumbbell–split squats; standard push-ups/advanced push-ups; mountain climbers exercise; sit-ups with a dumbbell; plank jacks; advanced Russian twist with a dumbbell
Week 9	Dumbbell–front raises; dumbbell–triceps kickback; dumbbell–lunges with bicep curls; dumbbell–squat with shoulder press; mountain climbers exercise; sit-ups with a dumbbell; leg throw downs; plank jacks
Week 10	Dumbbell–lateral raises; dumbbell–reverse fly; standard push-ups/advanced push-ups; dumbbell–squat with front raises; dumbbell–lateral hops; sit-ups with a dumbbell; leg throw downs; sit-ups

lower limbs completely extended throughout the flight. On the portable contact mat, participants were instructed to accomplish 5 consecutive maximum vertical rebounds. Participants were instructed to maximize jump height and minimize ground contact time. All jumps were done on a movable contact mat.

The push-ups were developed to assess upper-body physical endurance[53]. All males were encouraged to do push-ups on their toes, and each student repeated as many push-ups as possible (set at 40 beats per minute), consecutively without rest. The beginning position is in a high plank posture, hands pointing forward and under the shoulder, back straight, head up, using the toes as the crucial point. They had to lower themselves in a controlled way until their elbows formed a 90° angle before returning to the starting position. The test was halted, when the participants strained violently or were unable to maintain the right technique after two repetitions. The maximum number of successfully executed push-ups was recorded, independent of duration.

One-minute sit-up test was used to assess abdominal strength[54]. Participants sat in a supine posture, knees bent at a 90° angle, feet flat on the floor, legs slightly apart, and fingers interlaced behind the head, with a partner holding their ankles firmly to maintain the feet on the ground. The participant's elbows had to contact the knees with an upward movement, and then the two sides of the scapula should return to touch the floor. During 60 seconds, the goal was to repeat this exercise as many times as possible. The test was not counted if the individual failed to contact the knees with his or her elbows, maintain fingers clasped behind the head, or return his or hers to the floor. In 60 seconds, the maximum number of accurately done sit-ups was recorded. Sit-ups, which are also part of the physical fitness test battery in China, are a common way to assess abdominal/core endurance and are safe for children and adolescents to undertake.

A portable handgrip dynamometer was used to test grip strength (CAMRY EH101, China). It is inexpensive and may be utilized in a timely manner. They were instructed to squeeze the dynamometer as hard as they could for 3 seconds after calibrating the dynamometer handle to meet each participant's hand size and their elbow fully extended and adjacent to their torso[53]. All individuals completed three trials of their dominant hand with at least 60 seconds of rest between attempts, and the best performance was recorded. In children and adolescents, handgrip strength has been demonstrated to be associated with muscular strength[55] and has high validity and reliability[56].

2.4.2. Perceived Physical Competence. A French scale was chosen to assess perceived physical competence[57]. It includes endurance, physical strength, and sports competence items, on a 6-point Likert-type scale. A composite score (i.e., average of the four items) was employed for analysis.

2.5. Statistical Analysis. The statistical analysis was carried out in IBM SPSS version 24.0. Descriptive data was presented as the mean ± standard deviation ($M \pm SD$) for all variables. To examine if the changing body mass and height of this rising population will impact any outcome factors, a t-test was used to look for group differences in demographic parameters (age, body weight, body height, and BMI) as well as all baseline outcome variables. The interactions and main effects of time (pre- *vs.* posttest) and group (CST *vs.* CON) on the dependent variables were investigated using a repeated measure analysis of variance (ANOVA) (2×2). If interactions and main effects were significant, Tukey's LSD post hoc t-tests were employed to find specific between-group differences. Partially, eta-squared (η_p^2) effect sizes were estimated within and between groups, and η_p^2 was graded as modest (0.01), medium (0.06), or large (0.14) by Cohen [58]. Statistical significance was set at $p < 0.05$.

3. Results

A total of 123 participants finished the 10 weeks strength training program and none of them had a training-related injury. The CST had an 89% attendance at training sessions, whereas the CON had an 86% participation rates in regularly PE class. The demographic factors including age, body weight, body height, and BMI showed no changes between the CST and CON (age: $t(121) = -0.1, p = 0.92$; body height: $t(121) = -1.82, p = 0.07$; body weight: $t(121) = -1.18, p = 0.24$; BMI: $t(121) = -0.62, p = 0.54$). Repeated measures variance results showed that the standing long jump ($F(1, 121) = 28.03, p < 0.001, \eta_p^2 = 0.19$), vertical jump ($F(1, 121) = 37.21, p < 0.001, \eta_p^2 = 0.24$), 1 min push-ups ($F(1, 121) = 17.07, p < 0.001, \eta_p^2 = 0.12$), 1 min sit-ups ($F(1, 121) = 16.02, p < 0.001, \eta_p^2 = 0.12$), handgrip strength ($F(1, 121) = 17.55, p < 0.001, \eta_p^2 = 0.13$), and perceived physical competence ($F(1, 121) = 18.12, p < 0.001, \eta_p^2 = 0.13$) had significantly interaction effects.

Regarding the mean within-group changes, CST significantly increased the mean changes of standing long jump ($p < 0.001$), vertical jump ($p < 0.001$), 1 min push-ups ($p < 0.001$), 1 min sit-ups ($p < 0.001$), handgrip strength ($p < 0.001$), and perceived physical competence ($p < 0.001$) from pre- to posttests. However, although each outcome variable in the CON increased, no significant differences were found ($p > 0.05$) (Table 3).

With respect to mean between-group differences, CST significantly increased the mean of standing long jump ($p < 0.05$), vertical jump ($p < 0.01$), 1 min sit-ups ($p < 0.01$), handgrip strength ($p < 0.05$), and perceived physical competence ($p < 0.001$) compared with those in the CON after intervention. But no significant interaction and main effects were found in 1 min push-ups ($p > 0.05$) (Table 3, Figure 1).

4. Discussion

The main goal of this study was to see how effective a comprehensive school-based intervention was at enhancing muscular fitness and perceived physical competence among secondary school students. The current study discovered that performing three sessions of comprehensive strength training per week for ten weeks during normal school PE classes was effective in improving muscular fitness and perceived physical competence. No injuries were reported in the CST during the trial.

Muscular fitness is an important aspect of physical fitness. Our findings indicate that a regular school-based comprehensive strength training program can help male adolescents significantly enhance their muscle fitness. The evidence for the effectiveness of a regular RT program in the physical education curriculum for improving muscular fitness in adolescents is increasing[54, 59–61]. Furthermore, a review also showed that strength training can be applied safely and effectively in secondary education[39]. In this study, the CST significantly improved their standing long jump and vertical jump performance in two tests compared with the CON. The standing long jump and the vertical jump field-tests are typically used to evaluate lower body explosive muscular strength in children and adolescents[62]. Previous studies utilizing strength training in secondary school PE lessons have found that the lower body muscle strength improves. In the six-week plyometric training program[59] or in the resistance and combined training groups (plyometric exercises and traditional strength training exercises)[61], horizontal jump distance and vertical jump height increased significantly. Push-ups and sit-ups were used to assess upper-body muscular endurance and abdominal strength. Our study found that the CST increased their sit-up performance in two tests and substantially varied from the CON, but push-ups only found significant improvement in within group effect. The results are partly support by one study[63] which found significant differences between the resistance training group and the control group, when a manual RT program was performance for 20-30 minutes within the PE class, as measured by a pre- to posttest in the push-ups and curl-ups tests. Additionally, a suspension training program twice a week for a total of eight weeks during the physical education class, which included sit-ups and push-ups, resulted in significant variations in baseline values between the intervention group and control group[64]. Another study found that twelve weeks of strength training in PE courses improved push-up and curl-up performance much more than the control group[65]. However, no significant changes in push-ups were seen between the resistance training intervention and control group in another study[66]. The handgrip test is a reliable indicator of upper-body maximum strength in teenagers[51]. The CST improved their handgrip strength in two assessments, and they varied substantially from the CON. This suggestion is in line with the findings of others who have seen substantial improvement in handgrip strength in youth[64, 67]. Contrary to the findings of the present study, no significant gain in handgrip strength was reported following a four-week intervention, when three different programs (aerobic training, RT, and combined training) were compared to a control group [68]. Likewise, after eight weeks of the CrossFit Teens™ resistance training program, there were no changes in handgrip strength in adolescents[69]. This might be related to the fact that the bulk of works with ST equipment requires a strong grip (i.e., resistance bands). Grip strength can also be affected by changes in upper body strength[70]. In addition, we try to understand the significant strength gains from the mechanisms. According to one study, the observed strength gains in youngsters are due to the neural factors rather than muscle hypertrophy[71]. Though training increased muscle strength, intrinsic muscle adaptations (such as changes in excitation or contraction coupling,

Table 3: Effects of the intervention on muscular fitness and perceived physical competence according to group ($n = 123$).

Variables	Pretest $M \pm SD$	Posttest $M \pm SD$	Δ change (95%CI)[a]
Muscular fitness			
Standing long jump (cm)			
CST	189.50 ± 3.46	198.34 ± 3.40	8.84### (6.70~10.98)
CON	186.44 ± 3.49	187.15 ± 3.43	0.71 (-1.46~2.87)
Δ change (95%CI)[b]	3.06 (-6.68~12.79)	11.19* (1.63~20.75)	
Vertical jump (cm)			
CST	24.89 ± 5.85	29.70 ± 6.13	4.81### (3.83~5.79)
CON	25.98 ± 6.85	26.52 ± 6.80	0.54 (-0.49~1.52)
Δ change (95%CI)[b]	1.09 (-1.19~3.36)	3.18** (0.88~5.50)	
1 min sit-ups (rep)			
CST	39.16 ± 9.52	45.02 ± 9.07	5.86### (4.07~7.64)
CON	39.90 ± 10.10	39.62 ± 10.66	0.72 (-1.08~2.52)
Δ change (95%CI)[b]	0.26 (-3.24~3.76)	5.40** (1.86~8.92)	
1 min push-ups (rep)			
CST	20.08 ± 10.02	23.24 ± 10.33	3.16### (2.29~4.03)
CON	20.62 ± 8.35	21.20 ± 7.65	0.57 (-0.31~1.45)
Δ change (95%CI)[b]	0.54 (-3.84~2.75)	2.04 (-1.21~5.30)	
Handgrip strength (kg)			
CST	29.65 ± 6.36	31.75 ± 6.83	1.74### (0.99~2.48)
CON	28.02 ± 7.72	27.69 ± 7.30	0.05 (-0.70~0.79)
Δ change (95%CI)[b]	1.58 (-0.97~4.12)	3.36* (0.82~5.90)	
Perceived physical competence			
CST	3.17 ± 0.95	4.05 ± 0.75	0.87### (0.61~1.13)
CON	3.15 ± 1.08	3.23 ± 1.04	0.08 (-0.18~0.34)
Δ change (95%CI)[b]	0.02 (-0.34~0.38)	0.81*** (0.49~1.14)	

CST: comprehensive strength training interventions group; CON: control group; $M \pm SD$: means and standard deviation; CI: confidence interval; Δ change: mean change prepost treatment; [a]between-group difference with 95% CI; [b]within-group difference with 95% CI; *$p < 0.05$ difference between CON *vs.* CST; **$p < 0.01$ difference between CON *vs.* CST; ***$p < 0.001$ difference between CON *vs.* CST; #$p < 0.05$ difference between pre- *vs.* posttest; ##$p < 0.01$ difference between pre- *vs.* posttest; ###$p < 0.001$ difference between pre- *vs.* posttest.

myofibrillar packing density, and muscle fiber composition) and improvements in motor skill performance and the coordination of the involved muscle groups may also have contributed to the observed strength gains[47]. During and after puberty, adolescents are capable of greater absolute gains owing to higher levels of circulated male hormones [48].

Our findings show that a regular school-based comprehensive strength training program may considerably increase male adolescents' perceived physical competence. This result supports prior findings: higher levels of physical fitness may protect a kid from developing poor motor competence, and low motor competence was associated with lower perceived competence [31, 37]. Adolescence is a critical time for developing lifelong exercise habits, and physical competence appears to be particularly crucial for them. In addition, Jaakkola and colleagues [72] found that moderate-to-vigorous physical activity, perceived physical competence, and health-related fitness (i.e., shuttle run, push-up, and abdominal muscles endurance tests) explained 53% of the variation in motor competence for the boys. Low motor skills, on the other hand, are linked to higher BMI and worse muscle fitness [31]. Many researchers have shown that resistance training may enhance muscular fitness [18, 39, 73]. Therefore, the CST participants' perceived physical competence improved following a brief intervention.

There were several limitations in this study. First of all, due to the teaching arrangement of the school, there was no transit test in this experiment, which meant we could not observe the changes in the experimental group at 5 weeks. In later longitudinal studies, transit testing should be performed if conditions permit. Second, we merely utilized ratings of perceived exertion to determine the intensity of the intervention and did not use objective measures. Finally, there was no follow-up to observe if the changes in muscle fitness (i.e., upper body muscle endurance) and perceived physical competence were sustainable after the intervention.

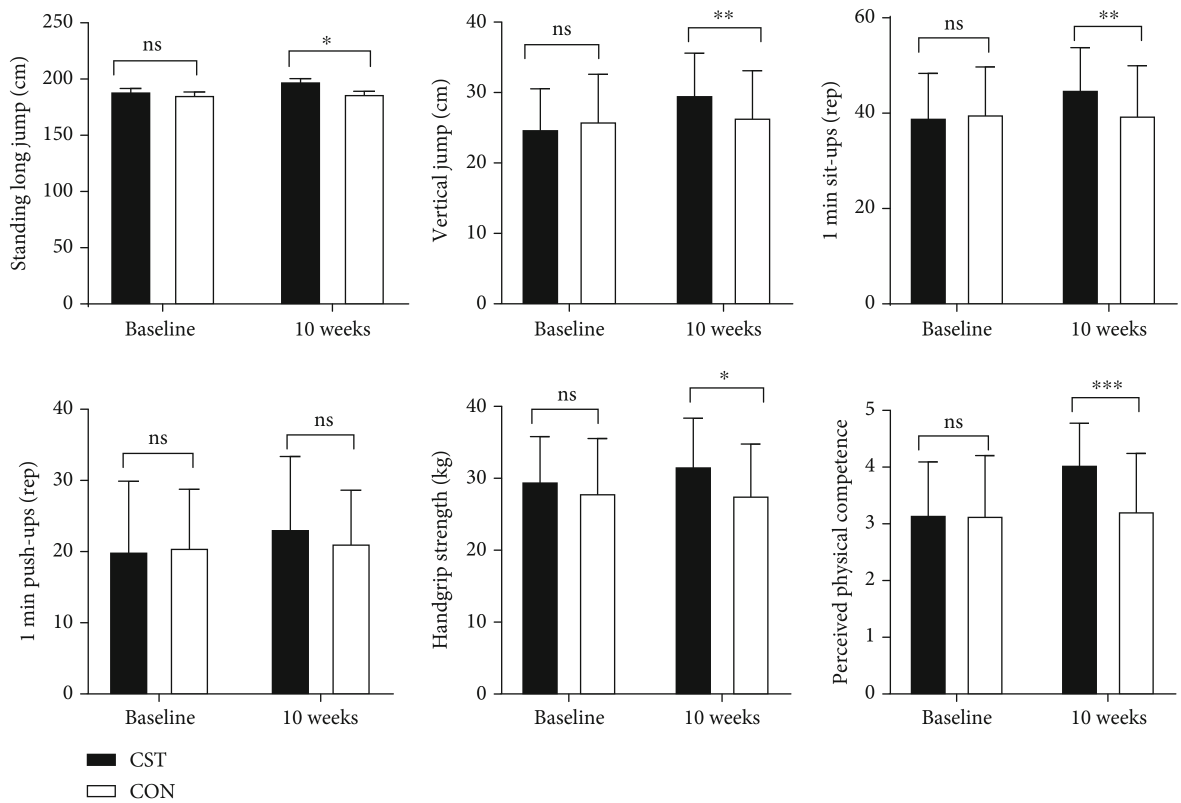

Figure 1: Intervention effects on muscular fitness and perceived physical competence. CST: comprehensive strength training interventions group; CON: control group; ns: no significant group differences; $^{*}p < 0.05$ difference between CON *vs.* CST; $^{**}p < 0.01$ difference between CON *vs.* CST; $^{***}p < 0.001$ difference between CON *vs.* CST.

5. Conclusions

It is concluded that the comprehensive strength training interventions designed in this study can significantly increase male adolescents' muscular fitness, especially in the lower extremity muscle power and abdominal core endurance, and can enhance their perceived physical competence.

However, due to the lack of a transit test in this study, we could not obtain valid data on changes in muscle fitness and perceived physical competence at the middle stage of the experiment for male adolescents. Future research should add a transit test to examine the effects of combined interventions. In addition, the exercises of upper body muscle endurance may be insufficient in this programme. It should be paid attention to optimizing the upper body muscle strength training program in future practical application. Finally, considering the importance of muscle strength and perceived physical competence for adolescents, school teachers and policymakers should take effective measures to enhance the muscle strength and perceived physical competence of young people so as to adequately prepare them to participate in higher levels of physical activity.

Data Availability

The data used to support the findings of this study are included within the article. Further information is available from the corresponding authors upon request.

Ethical Approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Capital University of Physical Education and Sports.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authors' Contributions

Meiling Zhao and Siling Liu contributed equally to this work and should be regarded as co-first authors.

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Research Article

Body Fat Evaluation in Male Athletes from Combat Sports by Comparing Anthropometric, Bioimpedance, and Dual-Energy X-Ray Absorptiometry Measurements

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Multiple anthropometric equations have been developed aiming to provide accurate and affordable assessment of body fat composition in male athletes. This study examined correlations of values obtained from seventeen different anthropometric equations to DXA as well as BIA and DXA values. Male athletes ($n = 101$) from three different combat sports, wrestling ($n = 33$), judo ($n = 35$), and kickboxing ($n = 33$), with an average age of 20.9 ± 4.2 were included. Body fat percentage was estimated using anthropometry, BIA, and DXA. Correlations between anthropometric methods and DXA, as well as BIA and DXA, were determined using Spearman's rank correlation. Sixteen out of seventeen estimates of body fat percentages using existing anthropometric equations showed strong positive correlation with the values derived from DXA measurements ($r = 0.569 - 0.909$). The highest correlation was observed using the equation derived by Yuhasz, $r = 0.909$, followed by the equations from Oliver et al., Evans et al., Faulkner, and Thorland et al. ($r \approx 0.9$). Statistical analysis of body fat percentages from DXA and BIA measurements also showed high positive correlation ($r = 0.710$). Correlation of seventeen anthropometric equations with BIA and DXA methods revealed that equations by Yuhasz, Oliver et al., Evans et al., Faulkner, and Thorland et al. are suitable alternative for assessing body fat percentage among male athletes from combat sports, showing even stronger correlation than BIA method.

1. Introduction

Body composition of athletes has a paramount effect on physiology and physical performance and provides information on the overall health [1]. The body fat percentage (%BF) is an important component of the athlete's body since adipose tissue has a complex effect on the health in general [2]. Adipose tissue is a vital endocrine organ [3], but both low and high %BF pose a threat for athlete's performance [4]. Previous studies have showed that high levels of body fat have negative impact on aerobic and anaerobic capacity of soccer players [5] and present serious cardiometabolic risk [6]. On the other hand, low body fat percentage (less than recommended 12%) is associated with low energy availability and both micro- and macronutrient deficiency in female gymnasts, thus posing threat to athlete's health and performance [7].

Body composition can be quantified at multiple levels: atomic level (measurement of carbon, calcium, potassium, and hydrogen quantity), molecular level (assessment of amounts of water, protein, and fat), cellular level (assessment of extracellular fluid and body cell mass), and at the tissue level (determination of amounts and distributions of adipose, skeletal, and muscle tissues) [8]. Accurate quantification of body composition has been the subject of intense research for decades. This scientific effort resulted in developing a large number of quantification methods, which include direct (cadaver dissection) and an array of indirect methods [1]. Indirect assessment of body properties, such as density, distribution of skeletal muscle, and adipose tissues, is performed using computed X-ray tomography (CT), magnetic resonance imaging (MRI), and dual-energy X-ray absorptiometry (DXA) [1]. These methods, referred to as second level of validity methods, are complex and performed in highly specialized facilities and require substantial financial means. Accordingly, less complex indirect methods of body composition assessment (third level of validity methods) such as bioelectrical impedance analysis (BIA) and anthropometry have been developed as more accessible to wider user population to provide an estimate of body composition [8]. However, to be applied accurately for a specific population, these methods have to be validated against the direct or second level of validity methods such as DXA. Moreover, BIA and anthropometry have larger predictive errors than the direct and second level of validity methods and are significantly affected by the sample population specificity [8]. However, they are still often considered as a suitable replacement and used among sports coaches and experts in practice. In circumstances such as travel to preparation camps or competition, these lower cost and portable methods are widely used due to their practicality, portability of measuring devices, and the fact that they do not require highly skilled staff to perform the measurements.

Wrestling, judo, and kickboxing are classified as weight-sensitive sports, in which athletes tend to undergo extreme dieting associated with extreme dehydration in order to reduce body mass, more specifically %BF, aiming to be moved to a lower weight category [1]. Therefore, regular measurements of body composition for this specific athlete population are extremely important. Taking into account that previous studies have already established that anthropometric equations developed for general nonathlete population are not applicable for professionals [9] and that the ones developed for athletes are highly specific for the specific sport [9–11], there is a pressing need to validate existing anthropometric equations, developed for both general and specific athlete population, and BIA against a reference gold standard method DXA in general athlete population.

The aim of this study was to explore the correlations of different developed anthropometric equations with DXA measurements as well as the correlations of BIA with DXA measurements in determining the percentage of body fat in male athletes.

2. Materials and Methods

2.1. Study Design. The study was designed as a cross-sectional observational analysis of competitive, successful, and world-class elite male athletes competing in wrestling, judo, and kickboxing [12]. All participants were assessed within three days in 2021. The study was approved by the Ethical Committee of the Faculty of Medical Sciences, University of Kragujevac (License number 01-14980) in accordance with the current national and international laws and regulations controlling the use of human participants (Declaration of Helsinki II).

2.2. Participants. Analyzed population sample consisted of 101 athletes ($N = 101$), 17-33 years of age, recruited from three different combat sports: wrestling ($n = 33$), judo ($n = 35$), and kickboxing ($n = 33$). Recruited athletes showcased similarities related to their body composition, preparation, and monitoring prior to attending and during competitions. Inclusion criteria consisted of athletes who fulfilled classification criteria for "eliteness" or expertise defined by Swann et al. [12]. In brief, athletes who were competing for more than 3 years at national and/or international level and did not have any long training breaks or any rest caused by an injury or any other factor within the last six months were included in the study. After detailed explanation of the procedure and study goals, athletes who decided to participate in this study signed a voluntary consent document.

2.3. Procedures. Participants were divided into three groups and scheduled to come to DXA cabinet room at the Department of Orthopedy, Clinical Centre of Vojvodina, Novi Sad, between 9 and 10 h in the morning for three consecutive days. They were instructed to follow standard food and fluid intake so they are in a rested, overnight fasted (at least 8 h), and hydrated state before testing. Moreover, they were asked not to perform any physical activity prior to their evaluations and to bring light cotton clothing. Complete testing of every individual athlete was conducted on the same day. Participants were evaluated by BIA, anthropometric measurement, and a whole body DXA scan, respectfully. All the equipment was calibrated each morning on the day of analysis prior to measurements.

2.4. Anthropometric Measurements. Anthropometric measurement of skinfolds, circumferences, and joint bone diameters was conducted according to ISAK guidelines and recommendations [13]. Body weight was measured during BIA test. After BIA analysis was completed, anthropometric measurements of body height, skinfolds, circumferences, and joint diameters were conducted. An anthropometrist (>10 years of experience) was recruited to perform anthropometric measurement.

Firstly, skinfolds (subscapular, midaxillary, chest (pectoral), abdominal, biceps, triceps, suprailiac, supraspinale, quadriceps, and medial calf) were located and labeled with a marker as determined by ISAK guidelines [13]. Then, skinfolds were measured using Harpenden caliper (HSB-BI, HaB Direct, UK). The caliper has measuring range of 0-80 mm (caliper needle is made to go four full circles around a dial scale graduated from 0 to 20 mm), measuring pressure of $10\,g/mm^2$, and reading accuracy of 0.2 mm. The height was measured using roll-up measuring tape (SECA, Germany) with measuring range of 0-220 cm (1 mm graduation). Circumferences were determined using a flexible steel tape calibrated in centimeters with millimeter graduations (Lufkin metal tape). Small sliding caliper (Rosscraft) was used to measure biepicondylar breadths of humeri and femurs. The

Table 1: Selected existing anthropometric methods and equations developed for assessing body fat in different male athletes and general and specific populations.

Author(s)/method	Anthropometric equation
Yuhasz [14]	Equation using 6 skinfolds: %BF = 3.64 + (0.097 (Ch + Tr + Sb + Si + ab + Th))
Faulkner [33]	Equation using 4 skinfolds. Today considered a modified Yuhasz method: %BF = 5.783 + (0.153 (Tr + Sb + Si + ab))
Forsyth and Sinning 1 [9]	Equation using 2 skinfolds (equation no. 2a): BD = 1.103 − (0.00168 × Sb) − (0.00127 × ab)
Forsyth and Sinning 2 [9]	Equation using 4 skinfolds (equation no. 2b): BD = 1.10647 − (0.00162 × Sb) − (0.00144 × ab) − (0.00077 × Tr) + (0.00071 × ma)
Forsyth and Sinning 3 [9]	Equation using 2 skinfolds and height (equation no. 3a): BD = 1.02415 − (0.00169 × Sb) + (0.00444 × Ht) − (0.00130 × ab)
Forsyth and Sinning 4 [9]	Equation using 4 skinfolds and height (equation no. 3b): BD = 1.03316 − (0.00164 × Sb) + (0.00410 × Ht) − (0.00144 × ab) − (0.00069 × Tr) + (0.00062 × ma)
White et al. [11]	Equation using 2 skinfolds: BD = 1.0958 − (0.00088 × Si) − (0.0006 × Th)
Thorland et al. 1 [16]	Equation using 7 skinfold: $\text{BD} = 1.1091 - (0.00052\,(\text{Tr} + \text{Sb} + \text{ma} + \text{Si} + \text{ab} + \text{Th} + \text{ca})) + \left(0.00000032\,(\text{Tr} + \text{Sb} + \text{ma} + \text{Si} + \text{ab} + \text{Th} + \text{ca})^2\right)$
Thorland et al. 2 [16]	Equation using 3 skinfolds: $\text{BD} = 1.1136 - (0.00154\,(\text{Tr} + \text{Sb} + \text{ma})) + \left(0.00000516\,(\text{Tr} + \text{Sb} + \text{ma})^2\right)$
Withers et al. [19]	Equation using 7 skinfolds, not fully published in the original 1987 paper by Withers et al., but can be found in Reilly et al. study derived from Withers et al. data. BD = 1.0988 − (0.0004 (Tr + Sb + Bc + Sp + ab + Th + ca))
Evans et al. 1 [20]	Equation using 7 skinfolds, gender and race: %BF = 10.566 + (0.12077 (Sb + Tr + Ch + ma + Si + ab + Th)) − (8.057 × gender) − (2.545 × race)
Evans et al. 2 [20]	Equation using 3 skinfolds, gender and race: %BF = 8.997 + (0.24658 (ab + Th + Tr)) − (6.343 × gender) − (1.998 × race)
Oliver et al. [10]	Equation using 7 skinfolds (equation model number 3): %BF = 3.53 + (0.132 (Ch + Tr + Sb + ma + Si + ab + Th))
Reilly et al. [17]	Equation using 4 skinfolds: %BF = 5.174 + (0.124 × Th) + (0.147 × ab) + (0.196 × Tr) + (0.13 × ca)
Civar et al. [21]	Equation using 3 skinfolds and weight: %BF = (0.432 × Tr) + (0.193 × ab) + (0.364 × Bc) + (0.077 × Wt) − 0.891
Stewart and Hannan [30]	Equation using 2 skinfolds and weight. This equation estimates body fat in grams, which are then converted into body fat percentage for BIA comparison: BFM = (331.5 × ab) + (356.2 × Th) + (111.9 × Wt) − 9108
Zuti and Golding [15]	BD = 1.0806 − (0.001187 × WC) − (0.001076 × Ch) + (0.015306 × WD)

Ht: height; Wt: weight; BD: body density; %BF: body fat percentage; BFM: body fat mass in grams; Tr: triceps skinfold; Ma: midaxillary skinfold; Sb: subscapular skinfold; Ab: abdominal skinfold; Si: suprailiac skinfold; Sp: supraspinale skinfold; Th: quadriceps skinfold; Ca: calf skinfold (medial calf); Ch: chest skinfold; Bc: biceps skinfold; gender: *man* = 1, woman = 0; race: African American = 1, Caucasian = 0; WC: waist circumference; WD: wrist diameter.

instrument has a branch length of 10 cm, an application face width of 1.5 cm, and an accuracy of 0.05 cm.

Seventeen anthropometric methods [9–11, 14–21] developed for different male athlete populations through regression analysis were used in this study (Table 1). Selected anthropometric equations were developed for either a specific or general sport population, based on skinfold measurements alone or skinfold measurements combined with some basic anthropometric/descriptive features such as age, body height and weight, and body mass index. Moreover, equations selected for our study presented the highest multiple correlation coefficients between a dependent variable and a group of independent variables (R), or the largest variance in dependent variable by using independent variables (R^2) (depending on what was reported in a particular study, R or R^2), when correlated with referent methods. Furthermore, the Siri equation was used to convert body density to body fat percentage in cases where anthropometric equations estimated only body density [22]. The test-retest reliability of anthropometric measurement was determined using the method of technical measurement error (TEM) of an evaluator, where a deviation of up to 7.5% for skinfolds and up to 1.5% for other anthropometric measures was considered acceptable. The calculation of the TEM was carried out according to the recommendations by Norton [23].

2.5. Bioelectrical Impedance Analysis (BIA). Upon arrival, participants were subjected to the bioelectrical impedance analysis (BIA) for measurement of the body fat percentage and body weight as described in our previous study [24]. The measurement was conducted according to the manufacturer's instructions for model InBody 230 using BIA pretest guidelines [24, 25]. In brief, prior to measurement, every participant had their palms and soles wiped with a tissue containing electrolyte solution. Next, the participants stood on the scales with their soles in contact with the foot electrodes for weight measurement. Then, age, sex, and height were entered into the instrument. The participants were then instructed to firmly grasp hand grips by placing their thumb

Table 2: Athlete descriptive characteristics.

Variable	Wrestlers $X \pm SD$	Judokas $X \pm SD$	Kickboxers $X \pm SD$	Total $X \pm SD$
Age (years)	18.6 ± 1.9	23.9 ± 4.2	22.8 ± 5.4	20.9 ± 4.2
Height (cm)	177.2 ± 8.6	178.1 ± 7.1	183.8 ± 6	179.8 ± 7.8
Weight (kg)	77.7 ± 15.5	79.0 ± 15.9	83.0 ± 13.3	$80, 0 \pm 14.0$
BMI (kg/m^2)	24.6 ± 3.3	24.8 ± 3.4	24.5 ± 3.3	24.0 ± 3.3
WHR (cm^2)	0.85 ± 0.06	0.85 ± 0.6	0.84 ± 0.07	0.85 ± 0.06
$\%BF_{BIA}$	11.4 ± 4.9	11.0 ± 5.5	11.3 ± 5.3	11.2 ± 5.2
$\%BF_{DXA}$	16.1 ± 5.1	16.5 ± 6.1	18.2 ± 5.6	17.0 ± 5.7

X: mean; SD: standard deviation; BMI: body mass index; WHR: waste-to-hip ratio; $\%BF_{BIA}$: body fat estimated with bioelectrical impedance; $\%BF_{DXA}$: body fat estimated with dual-energy X-ray absorptiometry.

and fingers on the designated locations, and the impedance was measured. The measurements were conducted by an experienced InBody 230 operator.

2.6. Dual-Energy X-Ray Absorptiometry (DXA) Scanning. DXA scanning was performed for each participant on Lunar iDXA scanner (GE Healthcare, UK) according to the current guidelines for best practice [26]. Quality control was assured by calibration procedure according to the manufacturer's instructions. In brief, the apparatus was calibrated every morning, or whenever the temperature in the room changed for 5°C, by using appropriate calibration blocks (three for bone density and three for whole body measurements). The participants wearing light cotton clothing were positioned in a stationary, supine position on the scanning table with keeping hands in the hip level and feet slightly apart. Upon taking a proper position, the scan was initiated and lasted for about 6 minutes. All the measurements and calibration procedures were performed by an experienced, certified DXA technician to ensure consistency in measurement protocols. Technical error of DXA scanner measurement was 3%. Scans were analyzed using enCORE software V17 (GE Healthcare, UK).

2.7. Statistical Analysis. Statistical analysis was conducted using SPSS statistical program, package version 26 (IBM SPSS Statistics for Windows, Armonk NY: IBM Corp; 2018). Assessment of linearity for model validity, outliers, and data normality distribution was performed using scatter plot graph, Q-Q plot, histogram, skewness and kurtosis, and the Kolmogorov-Smirnov test. Based on the information obtained by these tests, assessment of the correlation of estimates obtained using anthropometric equations and BIA measurement was conducted using Spearman's rank correlation (r), where values of $r = 0.0 - 0.09$ were considered trivial, $r = 0.10 - 0.29$ small, $r = 0.30 - 0.49$ moderate, $r = 0.50 - 0.69$ high, $r = 0.70 - 0.89$ very high, $r = 0.90 - 0.99$ almost perfect, and $r = 1$ perfect correlation [27]. Descriptive data was presented through means and standard deviations (mean ± SD). Statistical significance (p values) was set at 0.05. Confidence interval was set at 95%. Graphs were created using GraphPad Prism 7.04.

Table 3: Correlation between existing anthropometric equations and DXA-derived estimates of assessing body fat percentage in male athletes from combat sports.

Anthropometric vs. DXA	r	p
Stewart et al.	0.876**	<0.001
Civar et al.	0.834**	<0.001
Reilly et al.	0.899**	<0.001
Oliver et al.	0.907**	<0.001
Evans et al. 2	0.907**	<0.001
Evans et al. 1	0.905**	<0.001
Withers et al.	0.890**	<0.001
Thorland et al. 2	0.840**	<0.001
Thorland et al. 1	0.906**	<0.001
White et al.	0.887**	<0.001
Forsyth and Sinning 4	0.886**	<0.001
Forsyth and Sinning 3	0.852**	<0.001
Forsyth and Sinning 2	0.877**	<0.001
Forsyth and Sinning 1	0.848**	<0.001
Zuti and Golding	0.569**	<0.001
Faulkner	0.904**	<0.001
Yuhasz	0.909**	<0.001

3. Results

Characteristics of participants are presented in Table 2. Anthropometric measurements of skinfolds were converted into body fat percentage (%BF) using seventeen equations listed in Table 1.

Sixteen out of seventeen estimates of %BF showed strong positive correlation ($r = 0.569 - 0.909$) with the values derived from DXA measurements (Table 3 and Figure 1). The highest correlation ($r = 0.909$) was observed using the equation derived by Yuhasz et al. [14]. Nevertheless, the equations from other authors (Oliver et al., Evans et al., Faulkner, and Thorland et al. [10, 16, 18, 20]) showed very similar correlation coefficients (r values over 0.9); only the r value obtained from the equation by Zuti and Golding was smaller than 0.6 [15]. Statistical significance of all anthropometric equations applied was high with $p < 0.001$. In addition, the 95% confidence intervals showed wide ranges and overlap (Table 4).

Statistical analysis of the %BF estimates obtained from DXA and BIA measurements also showed high positive correlation with high statistical significance ($r = 0.710$, $p < 001$) (Table 5).

4. Discussion

The aim of this study was to compare the accuracy of body fat assessment by anthropometric measurements and BIA, using DXA as a criterion (also referred to as one of the "gold standard" methods), in male athletes from combat sports.

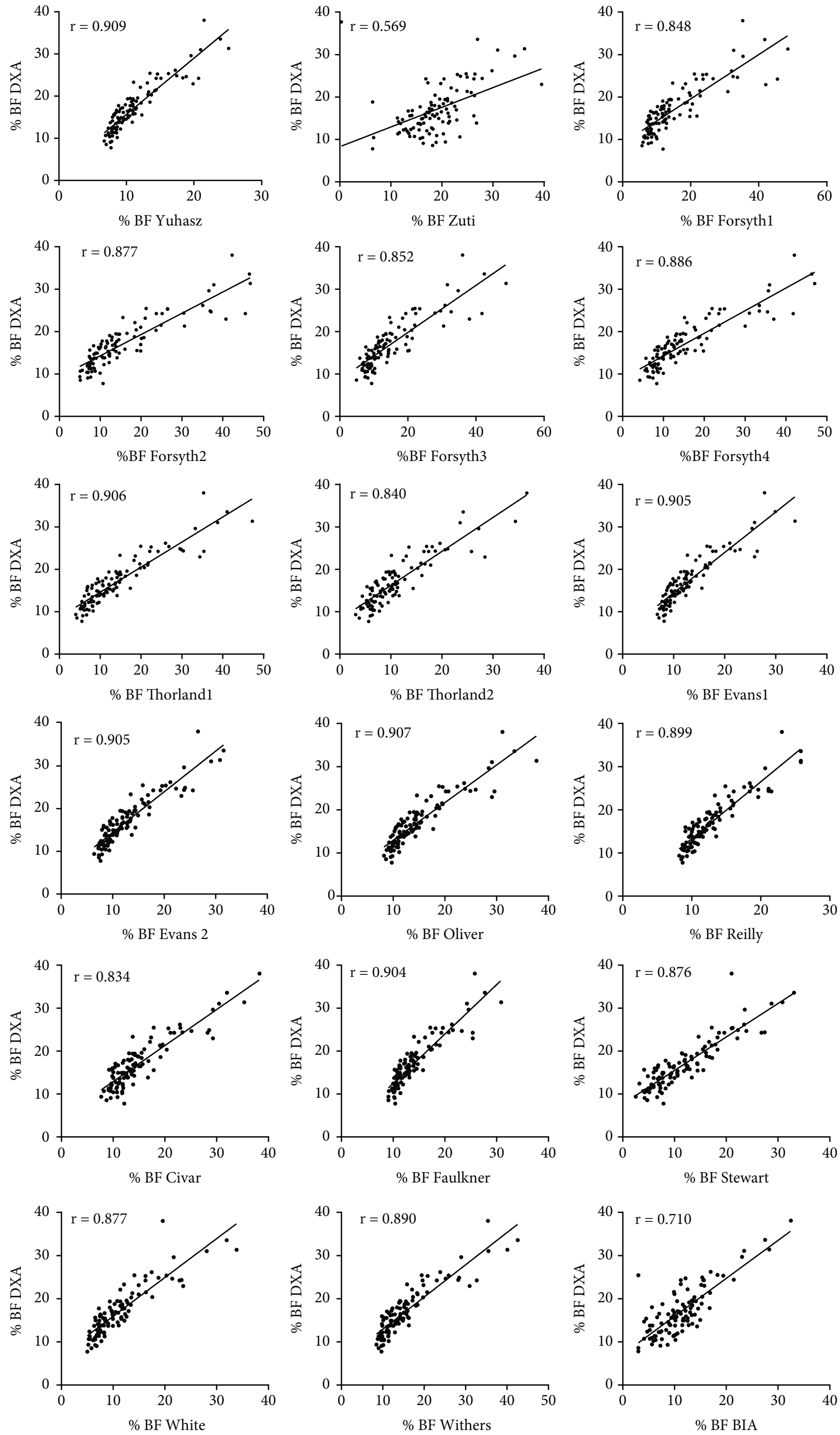

Figure 1: Graphs representing correlation between existing anthropometric equations and DXA-derived estimates of assessing body fat percentage of in male athletes from combat sports.

Furthermore, the ultimate objective was to uncover the most precise existing anthropometric equation developed using specific anatomical landmarks for skinfolds, circumferences, joint diameters, and basic physical measurements and characteristics (such as weight, height, age, BMI, and WHR) applicable to the male athletes from combat sports. Correlation results of seventeen anthropometric equations with BIA and DXA methods revealed that equations by Yuhasz, Oliver et al., Evans et al., Faulkner, and Thorland et al. showed very high correlation with the values obtained by DXA method, even stronger than the BIA values. Therefore, these equations are considered as a suitable alternative for assessing body fat percentage in male athletes from combat sports.

To date, many studies proposed novel anthropometric measurements and equations for body fat assessment.

Table 4: Median values of body fat percentages measured with DXA and BIA and estimated by anthropometric equations.

Method	Median (25th-75th percentile)
DXA	15.80 (12.70-19.45)
BIA	10.50 (7.45-13.35)
Stewart et al.	10.50 (6.95-15.80)
Civar et al.	13.00 (10.85-16.65)
Reilly et al.	11.60 (10.10-13.90)
Oliver et al.	12.70 (10.55-16.35)
Evans et al. 2	10.90 (8.90-14.25)
Evans et al. 1	10.80 (8.85-14.30)
Withers et al.	13.5 (11.00-17.05)
Thorland et al. 2	9.40 (6.60-12.25)
Thorland et al. 1	11.30 (7.90-16.80)
White et al.	9.70 (7.25-12.60)
Forsyth and Sinning 4	11.90 (8.40-18.05)
Forsyth and Sinning 3	11.80 (8.80-18.50)
Forsyth and Sinning 2	12.00 (8.30-19.25)
Forsyth and Sinning 1	11.80 (8.40-19.10)
Zuti and Golding	18.00 (15.45-21.35)
Faulkner	12.50 (10.80-14.80)
Yuhasz	18.00 (15.45-21.35)

BIA: bioelectrical impedance; DXA: dual-energy X-ray absorptiometry; r: Spearman's rank correlation coefficient; p: statistical significance; $^{**}p < 0.001$.

Table 5: Correlation between BIA and DXA-derived estimates of body fat percentage in male athletes from combat sports.

Methods	r	p
BIA vs. DXA	0.710^{**}	<0.001

BIA: bioelectrical impedance; DXA: dual-energy X-ray absorptiometry; r_s: Spearman's rank correlation coefficient; p: statistical significance; $^{**}p < 0.001$.

However, these methods are mostly population-specific developed for a particular sports or nation-specific, i.e., applicable to anthropometric characteristics of a particular nation studied [10, 17, 21, 28–33]. Moreover, this myriad of methods may cause bewilderment in coaches and sports experts in selecting a correct method for their athletes. Therefore, inadequate choice of method may lead to significantly inaccurate assessment of body fat, thus affecting management of body fat regulation, especially in weight-sensitive sports.

Prior to choosing the adequate anthropometric measurement for their athletes, the coaches/sports experts should take into account gender, race, age, nation, condition and competition level, protocols for skinfolds, and other anthropometric measurements as well as other specific characteristics of athlete population used for the development of the chosen method. Even if all the criteria are met, it is not a guarantee that the selected method would be accurate enough for their particular athletes, most likely affected by slight or more significant differences between the athlete sample used for anthropometric method development and their athletes. This suggests that practically every coach should develop an equation specific for his team which is cumbersome and time-consuming task. Therefore, for athlete body composition assessment, DXA is still the "gold standard" method, while BIA has been the preferred field method over anthropometry. However, anthropometric measurements still have significant advantages over DXA and BIA, since anthropometric instruments take up less space, are not performed in specialized facilities, do not have complicated electronics prone to damage, and cannot be affected by potential physiological oscillations in human body caused by air travel or change of time zone. Moreover, anthropometric measurements do not require strict preparation protocols prior to testing (BIA) or highly skilled operator to perform the measurement (DXA). Taking into account all the above, this study was aimed at assessing which of the existing anthropometric measurements and equations has the correlation coefficient closest to both BIA and DXA, which are second-level validity referent methods, and thus be suggested as an accurate alternative in the field practice. To the best of our knowledge, more than hundreds of anthropometric methods and equations have been developed to date. In this study, estimates obtained by using seventeen well-known methods/equations used for a number of decades were correlated with DXA. Sixteen estimates of %BF showed strong positive correlation with the values derived from DXA measurements. This is an intriguing finding considering that the anthropometric methods/equations analyzed in this study have been diverse. They were developed over more than a fifty-year span either for athletes from different sports or on more general athlete population, using different references and criterion methods or applying different models for body composition assessment. Therefore, greater variability in correlation coefficients with DXA method was expected. Surprisingly, the majority of the correlation coefficients of anthropometric measurements were higher than the correlation coefficient of BIA with DXA method. However, considering relatively wide ranges and overlap between the 95% confidence intervals, the comparison between the correlation coefficients should be done with special attention.

The study has several limitations. For example, even though widely used as a reference method in estimation of body fat content, DXA method is known to have moderate precision and accuracy in assessing percentage of body fat [34]. Also, DXA results can vary from different machines and software [35]. Furthermore, readings from BIA apparatus are generated by proprietary prediction equations unknown to users. Even though this study included relatively large number of participants, all of them were young Caucasians; therefore, the future studies are required to validate our findings on population of different ethnicity or even gender. Despite the described shortcomings, the study has been performed using wide variety of methods to estimate body fat percentage in a population of elite athletes. Most importantly, the presented findings have shown that anthropometry is an accessible and a suitable alternative to DXA and BIA methods for assessing %BF in combat sports such as wrestling, judo, and kickboxing.

5. Conclusions

The aim of this study was to find which of the existing anthropometric equations can be used as an accurate yet affordable replacement for BIA and more importantly DXA method in male athletes from combat sports. The highest correlation was observed using the equation derived by Yuhasz; however, the equations from Oliver et al., Evans et al., Faulkner, and Thorland et al. showed very similar correlation coefficients. Moreover, all the equations with exception of Zuti and Golding seem to be more reliable than BIA method. Therefore, anthropometric equations derived by Yuhasz [14], Oliver et al. [10], Evans et al. [20], Faulkner [18], and Thorland et al. [16] appear to be more affordable alternatives to DXA and BIA to which coaches and sports experts can resort to when these more complex methods are not a suitable option.

Data Availability

The data (anthropometric, BIA, and DXA measurements compiled in Excel file, SPSS database, and readings from BIA and DXA scanner) used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Research Article

Differences and Associations between Physical Activity Motives and Types of Physical Activity among Adolescent Boys and Girls

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Interventions aimed at motivation for physical activity (PA) are mostly beneficial, but the effects on preventing the decrease in PA are not entirely clear, especially in girls. The main aim of this study was to identify the differences and associations between PA motives and types of PA in boys and girls and between low and high motivated boys and girls. Another aim is to identify the types of motivation and PA that increase the likelihood of achieving PA recommendations and to propose ways of increasing PA among low motivated adolescents. The research carried out before the COVID-19 pandemic (2010–2019) and involved 2,149 Czech and 1,927 Polish adolescents aged 15–19 years. The International Physical Activity Questionnaire-Long Form was used to identify the level of PA types, while PA motivation was examined through the Motives for Physical Activities Measure-Revised. During the ten years, a decline was observed in enjoyment, fitness, and social motives. An increase in appearance motives was observed in girls, while no significant changes were seen in boys. Boys showed a higher motivation for PA than girls in enjoyment, competence, fitness, and social motives, while girls were high motivated in appearance motives. The greatest statistically significant differences between low and high motivated individuals were found in the associations between recreation/vigorous PA and between all types of motivation in boys and girls in both countries. The strongest associations in both genders were observed between enjoyment/competence motives and recreation/vigorous PA. Respecting and using the associations between the types of PA motives and types of PA in low and high motivated boys and girls can support feelings of PA enjoyment, increase PA, support the achievement of PA recommendations, and positively affect adolescents' healthy lifestyles.

1. Introduction

The increasing importance of successful physical activity (PA) motives is unequivocal for a healthy lifestyle [1], mental and physical fitness [2–4], increased participation in organized and group-based PA [5, 6], suitable climate for PA in physical education lessons [7], and children's and adolescents' well-being [8, 9]. The number of interventions that use PA motives to support children's and adolescents' PA is similarly increasing [10–12]. Interventions aimed at motivation for PA and increase in PA are mostly beneficial, but the effects are not entirely clear in terms of their effectiveness [13–15]. Various studies suggest that a high degree of heterogeneity [16] and evidence is often limited [17]. Furthermore, there is limited evidence suggesting that interventions aimed at children, adolescents, and young adults are effective when provided that PA-related enjoyment increases [11].

There is abundant evidence concerning suitable approaches to PA motives based on the self-determination theory [18] and proposals for the use of a combination of the affective-reflective theory of physical inactivity and exercise [19] and the theory of energy cost minimization [20]. These theories emphasize the need for deeper research concerning the types of PA motives and the importance of physical load optimization. They also assert feelings of PA satisfaction, immediate identification, and use of positive or negative PA assessment or physical inactivity, as well as clear identification of positive assessment in association with pleasure or negative assessment in association with displeasure [21]. Furthermore, in line with the self-determination theory, Dishman et al. [22] accentuate the need to focus on autonomous motivation while respecting external motivation and support a parallel focus on specific objectives such as appearance, competence, enjoyment, fitness, or social factors. Numerous studies also emphasize the need for further research aimed at intrinsic motivation to enhance adolescents' daily moderate to vigorous PA (MVPA) [23], identifying individuals with low intrinsic motives for PA [24] and removing gender imbalance in PA levels and autonomous forms of motivation to encourage physical activities in adolescent girls [25].

In a ten-year cross-section research study, we strive to create starting points that can support more effective motivation of girls and boys for PA in challenging postpandemic times. Due to the unsatisfactory findings in the trends of PA in adolescents [26], we focus more on girls and adolescents with less motivation for PA. Furthermore, PA motives and types of PA are characteristics of these adolescents. We consider respecting different motives and different types of PA to be essential. To increase the strength of the study, we conducted the same research in different educational environments of Czech and Polish adolescents. The research is aimed at answering the following questions:

(i) What changes took place during the long-term monitoring of PA motives and PA types in boys and girls?

(ii) What are the associations of PA types and PA motives with low-and high-motivated boys and girls?

(iii) What are the associations between PA motives, PA types, and achievement of PA recommendations?

The study should help to resolve the question for supporting the right selection of the type of motivation in boys and girls to different types of physical activity.

The main aim of this study was to identify the differences and associations between PA motives and types of PA in boys and girls and between low and high motivated boys and girls. Another aim is to identify the types of motives and PA that increase the likelihood of achieving PA recommendations and to propose ways of increasing PA among low motivated adolescents.

2. Materials and Methods

2.1. Participants and Setting. This retrospective cross-sectional study was carried out in 68 secondary schools in the Czech Republic and 76 secondary schools in Southern Poland between 2010 and 2019. The schools were selected based on long-term cooperation with the university departments. Two coeducational classes of students were randomly selected from each selected school. The entire research was performed by the same research teams in both countries, always accompanied by a responsible administrator designated by the school management. Each year, the research, involving 1,558 boys and 2,518 girls (Table 1), was carried out in five to eight schools on an average in both countries.

Body mass index (BMI) was calculated using the WHO BMI z-scores for adolescents [27]. Out of the total, 19.3% of boys and 11.4% of girls were observed to be overweight or obese. The numbers of participants in fall (September–November) and spring (March–May) during the study periods were similar. School management, parents, and participants provided their written consent to participate in the study. Regarding the fact that the research was presented as part of education and a source of important information for school management, the research included all students in the selected groups, who were present on the day of the research.

2.2. Measures. The PA motives were identified using the Motives for Physical Activity Measure-Revise (MPAM-R) scale [28]. Both the Czech and Polish versions underwent the required translation procedure pursuant to the EORTC Quality of Life Group [29]. The internal consistency of the scale was found to be high (Cronbach's alpha above 0.87 for each subscale) [30, 31]. The scale comprises 30 items (list of reasons why people engage in physical activities, sports, and exercise) in 5 categories: interest/enjoyment (referred to as enjoyment), competence, appearance, fitness, and social factors. The categories were assessed on a 7-point Likert scale (1 = "not at all true for me" to 7 = "very true for me"). In each category, the participants were segregated according to the median into low and high motivated individuals, separately for boys and girls.

The structure of weekly PA was determined by the Czech and Polish versions of the International Physical Activity Questionnaire-Long form (IPAQ-LF) [32, 33]. Both language versions underwent the required translation procedure and were in the long term empirically verified in previous studies [34, 35]. Pearson's correlation coefficient of concurrent validity between total PA (METs-min) and weekly step counts ranged from $r = 0.231$ to 0.283. Cronbach's alpha, as an indicator of internal consistency reliability, was 0.848 for the Polish version and 0.845 for the Czech version. The IPAQ-LF questionnaire included PA types (school, transport, housework, home, recreation, vigorous, moderate, and walking) and time spent sitting. Contrary to the guidelines for the IPAQ-LF, METs-min of vigorous PA (VPA) was assessed using a multiple of six instead of the recommended eight to avoid overestimation of time spent by PA and to not disrupt the proportional structure of weekly PA that is as objective as possible; the average daily sum of minutes of PA, transport, and sitting was set at a maximum of 960 min/day, and the maximum number of METs-min per week was set at 16,000 METs-min/week. A total of 191 respondents were excluded because of noncompliance with predetermined criteria.

The weekly PA recommendations were in accordance with the IPAQ-long questionnaire [36] determined in compliance with the generally acknowledged recommendations [37]. Meeting the stringent PA recommendations required the achievement of 60 minutes of MVPA on at least five days a week (in at least one of the PA types specified in the questionnaire)

Table 1: Sample characteristics.

Gender	Country	n	Age (years)		Weight (kg)		Height (cm)		PA (METs-min/day)		Sitting (min/day)	
			M	SD	M	SD	M	SD	M	SD	M	SD
Boys	Czech Republic	705	16.6	1.2	68.7	12.5	177.9	8.6	803	578	382	123
	Poland	853	16.3	0.7	67.7	12.7	176.8	7.6	879	604	367	151
Girls	Czech Republic	1444	16.8	1.2	59.1	9.2	167.1	6.7	679	508	395	118
	Poland	1074	16.3	0.7	56.9	8.6	165.9	6.1	773	556	371	143

M: mean; SD: standard deviation; PA: physical activity.

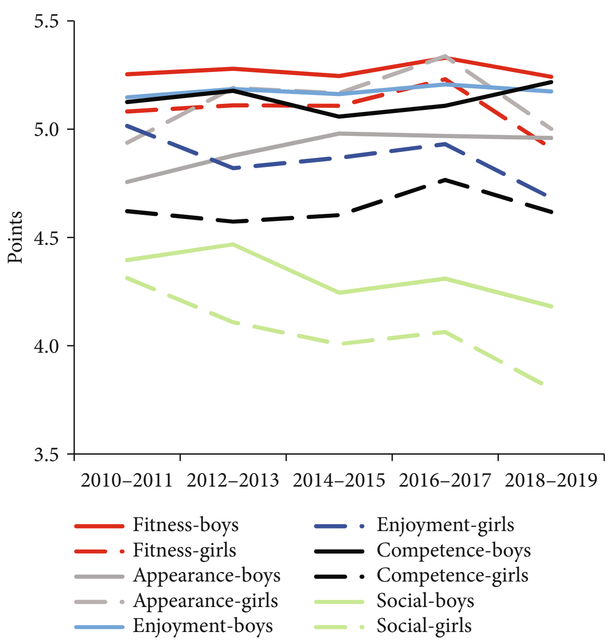


Figure 1: Gender-stratified estimated physical activity motives over five two-year periods.

and at the same time 20 or more minutes of VPA on three or more days a week (5×60 min MVPA + 3×20 min VPA) [38]. This PA recommendation was selected because the greatest statistically significant correlations were observed between the types of motivation and VPA in adolescents (enjoyment $r_p = 0.313$, competence $r_p = 0.347$, appearance $r_p = 0.247$, fitness $r_p = 0.206$, social $r_p = 0.168$, and sum motivation $r_p = 0.315$).

2.3. Procedure. The introductory session concerning the completion of the questionnaires was held in a school computer lab. All participants were registered in the "International Database for Research and Educational Support" (Indares) (http://www.indares.com/). They were informed of the methods for maintaining data confidentiality and feedback concerning the average research results. First, the participants completed the IPAQ-LF questionnaire, followed by the MPAM-R scale. For reporting purposes, the ten-year monitoring period was divided into five two-year periods (2010–2011, 2012–2013, 2014–2015, 2016–2017, and 2018–2019) to document the trend in behavior changes.

2.4. Data Analysis. Statistical analyses were performed with the help of software Statistica, version 13 (StatSoft, Prague, Czech Republic), and SPSS, version 25 (IBM Corp., Armonk. NY). Basic descriptive statistics were applied to characterize the sample (mean, standard deviation, median, and interquartile range); one-way ANOVA was applied to assess gender differences in PA motives and types of PA; Kruskal-Wallis test was applied to identify the differences between low and high motive boys and girls, and nonparametric Spearman's correlation coefficient was used to identify the associations between types of PA and motivation types. Differences in the responses were assessed using the Mann–Whitney *U* test. To identify the differences in meeting the PA recommendations, cross-tabulation and percentage difference tests were conducted. The data distribution in the assessment of weekly PA and PA motives was presented using categorized scatter plots. Binary logistic regression with the standard entry method (where all independent variables are simultaneously entered into the equation at the same time) was used to assess the likelihood of achieving PA recommendations. The η_p^2 and η^2 effect size coefficients were evaluated as follows: $0.01 \le \eta_p^2\ (\eta^2) < 0.06$ indicated a small effect size, $0.06 \le \eta_p^2\ (\eta^2) < 0.14$ indicated a medium effect size, and $\eta_p^2\ (\eta^2) \ge 0.14$ indicated a large effect size. Statistical significance was set at $p < 0.05$.

2.5. Ethics. The study was conducted in accordance with the WMA Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Faculty of Physical Culture at Palacký University Olomouc for research projects (No. MSM6198959221 and No. 37/2013). School management, parents, and participants confirmed their agreement to participate in the research by providing written consent.

3. Results

3.1. Characteristics of Physical Activity Motives and Physical Activity Types among Boys and Girls over Five Two-Year Periods. During the time periods of this research, a decline was observed among girls in enjoyment motives ($F_{(4,2513)} = 3.66, p = 0.006, \eta_p^2 = 0.006$), fitness motives ($F_{(4,2513)} = 3.08, p = 0.015, \eta_p^2 = 0.005$), and social motives ($F_{(4,2513)} = 8.58, p < 0.001, \eta_p^2 = 0.013$). However, an increase in appearance motives was observed

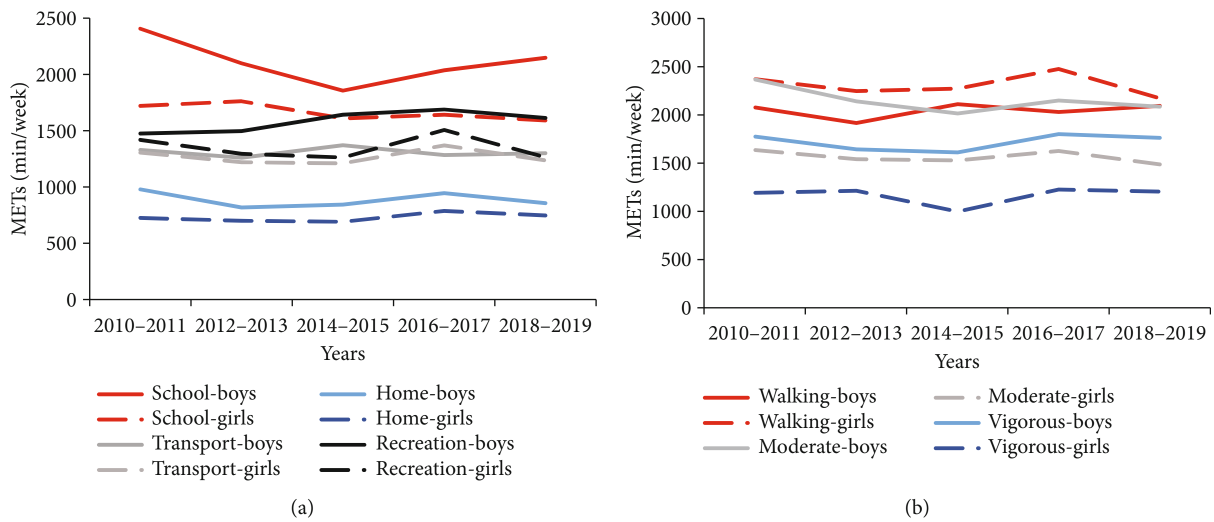


Figure 2: Structure of physical activity by implementation (a) and intensity (b) over five two-year periods.

($F_{(4,2513)} = 5.41, p < 0.001, \eta_p^2 = 0.009$) (Figure 1). No significant changes in PA motives were identified in boys during the study.

For the entire period, statistically significant gender differences were observed in enjoyment motives ($p < 0.001$), competence motives ($p < 0.001$), fitness motives ($p < 0.001$), and social motives ($p < 0.001$), among boys. Girls showed greater motivation than boys only in appearance motives ($p < 0.001$). Additionally, girls demonstrated greater motivation for PA than boys only in their responses to following motives: No. 17 to which they responded with the option, "Because I want to improve my appearance" ($U = 6.15, p < 0.001, \eta^2 = 0.024$); No. 20, to which they responded, "Because I want to be attractive to others" ($U = 1.88, p = 0.061, \eta^2 = 0.002$); No. 21, where they responded with "Because I want to meet new people" ($U = 1.96, p = 0.049, \eta^2 = 0.002$); No. 24, where they responded with "Because I want to improve my body shape" ($U = 8.46, p < 0.001, \eta^2 = 0.046$); and No. 27, with the option, "Because I will feel physically unattractive if I do not" ($U = 2.10, p = 0.036, \eta^2 = 0.003$).

Concerning the structure of PA, a decrease was observed only in recreation PA among girls over the two five-year periods ($F_{(4,2513)} = 2.41, p = 0.048, \eta_p^2 = 0.004$) (Figure 2). In boys, no statistically significant changes in the types of PA were found during the study period. In total, a statistically significant gender difference was observed in favor of boys in school PA ($p < 0.001$), home PA ($p < 0.001$), recreation PA ($p < 0.001$), walking ($p < 0.001$), and moderate PA ($p < 0.001$), with the greatest difference being in VPA, where boys achieved 1,723 METs-min/week while girls reached 1,166 METs-min/week ($F_{(1,4074)} = 94.55, p < 0.001, \eta_p^2 = 0.023$). It was found that only in the transport PA, the gender differences were not statistically significant ($p = 0.741$).

3.2. Differences in Weekly Physical Activity between Low and High Motivated Boys and Girls (by Types of Physical Activity and PA Motives). The greatest statistically significant differences between low and high motivated individuals were found between recreation PA and all types of motivation in both sexes in the two countries (Table 2). It should be noted that only in recreational PA, low motivated Czech boys were found to be more active than low motivated Czech girls. This applies to all PA motives. The smallest impact of PA motives was observed in transport PA (except for appearance motivation in Polish boys).

The greatest impact on vigorous PA was observed in low and high motivated boys and girls in all types of motivation; however, statistically significant values were observed in all groups only in enjoyment, competence, and fitness motives (Table 3). Additionally, the differences between boys and girls were statistically significant in all low and high motivated groups in vigorous PA in competence motives. The smallest impact of PA motives was observed during walking. Girls reported more walking than boys but was statistically significant only for Polish low motivated girls compared with low motivated Polish boys in motives of enjoyment, competence, and appearance and compared with Czech low motivated girls in competence motives, as opposed to low motivated Czech boys.

3.3. Associations between Recreation PA and PA Motives and between Vigorous PA and PA Motives. The greatest impact of PA motives on the types of PA was documented by the correlation analysis (Figure 3). In boys, the strongest associations were between recreation PA with enjoyment ($r_s = 0.266$) and competence motives ($r_s = 0.263$) and between VPA with enjoyment ($r_s = 0.278$) and competence motives ($r_s = 0.313$). In girls, the strongest associations were between recreation PA with enjoyment ($r_s = 0.272$) and competence motives ($r_s = 0.253$) and between VPA with enjoyment ($r_s = 0.304$) and competence motives ($r_s = 0.313$). The smallest correlations were reported for boys between social motives and recreation ($r_s = 0.151$) and vigorous PA ($r_s = 0.128$) and for girls and between appearance motives and recreation ($r_s = 0.128$) and vigorous PA ($r_s = 0.139$).

Table 2: Associations between the types of weekly PA (METs-min/week) and types of motivation in low and high motivated Czech and Polish boys and girls.

Types of motivation	Czech Boys ($n = 705$) Low Mot Mdn (IQR)	Czech Boys ($n = 705$) High Mot Mdn (IQR)	Czech Girls ($n = 1444$) Low Mot Mdn (IQR)	Czech Girls ($n = 1444$) High Mot Mdn (IQR)	Polish Boys ($n = 853$) Low Mot Mdn (IQR)	Polish Boys ($n = 853$) High Mot Mdn (IQR)	Polish Girls ($n = 1074$) Low Mot Mdn (IQR)	Polish Girls ($n = 1074$) High Mot Mdn (IQR)	H	p	η^2
School PA											
Enjoyment	690 (2286)	1174 (3079)	549 (1864)	719 (2320)	1313 (3351)	1998 (4118)	956 (2672)	1601 (3454)	139.17[d,e]	<0.001	0.032*
Competence	690 (2304)	1120 (2969)	540 (1835)	765 (2227)	1440 (3500)	1911 (4065)	952 (2723)	1560 (3544)	134.71[a,d,e]	<0.001	0.031*
Appearance	690 (2555)	1079 (2624)	542 (1938)	715 (2303)	1321 (3355)	2160 (4100)	1188 (2873)	1187 (3227)	115.81[f]	<0.001	0.027*
Fitness	707 (2455)	932 (2850)	563 (1935)	665 (2244)	1393 (3550)	1862 (3867)	973 (2812)	1511 (3450)	122.47[d,e]	<0.001	0.028*
Social	658 (2268)	1155 (3095)	565 (1980)	650 (2071)	1515 (3758)	1715 (3776)	1054 (2599)	1438 (3379)	123.01[a,e]	<0.001	0.029*
Transport PA											
Enjoyment	675 (1370)	757 (1378)	693 (1349)	825 (1539)	693 (1788)	990 (2126)	693 (1535)	774 (1782)	22.27	0.002	0.004
Competence	693 (1340)	756 (1451)	693 (1329)	792 (1396)	720 (1925)	930 (1956)	714 (1593)	743 (1832)	8.48	0.292	0.001
Appearance	693 (1320)	705 (1392)	693 (1320)	816 (1535)	611 (1646)	1071 (2061)	792 (1716)	693 (1755)	21.17[c]	0.004	0.003
Fitness	684 (1323)	746 (1332)	693 (1370)	809 (1389)	693 (1881)	930 (1928)	693 (1716)	774 (1698)	11.86	0.105	0.001
Social	693 (1311)	743 (1452)	693 (1320)	792 (1386)	743 (1749)	924 (2163)	707 (1485)	746 (1900)	4.78	0.687	0.001
Home PA											
Enjoyment	435 (1150)	545 (1494)	270 (740)	360 (785)	385 (985)	360 (1010)	365 (790)	420 (848)	30.86	<0.001	0.006
Competence	333 (1073)	630 (1513)	280 (750)	360 (776)	375 (988)	360 (1010)	325 (775)	480 (860)	46.88[a,d,f]	<0.001	0.010*
Appearance	375 (1080)	613 (1443)	300 (750)	360 (790)	355 (1013)	390 (960)	375 (785)	420 (865)	27.18	<0.001	0.005
Fitness	368 (1093)	630 (1380)	270 (760)	374 (760)	360 (973)	378 (1045)	320 (818)	485 (820)	47.59[a]	<0.001	0.010*
Social	424 (1170)	570 (1510)	280 (790)	360 (720)	355 (865)	380 (1165)	360 (810)	450 (800)	29.47	<0.001	0.006
Recreation PA											
Enjoyment	837 (1630)	1569 (2379)	657 (1232)	1392 (2034)	462 (1485)	1389 (2673)	429 (1230)	955 (2052)	298.62[a,b,c,d,e,]	<0.001	0.072**
Competence	806 (1601)	1650 (2388)	682 (1292)	1326 (1978)	489 (1519)	1422 (2771)	462 (1179)	980 (2096)	276.08[a,b,c,d,e]	<0.001	0.066**
Appearance	1002 (1958	1302 (2526)	788 (1535)	1098 (2772)	534 (1610)	1169 (2724)	537 (1284)	809 (1912)	130.10[a,b,c,d,e]	<0.001	0.030*
Fitness	922 (1878)	1476 (2437)	742 (1526)	1155 (1880)	534 (1569)	1169 (2715)	500 (1252)	855 (1913)	155.39[a,b,c,d,e]	<0.001	0.036*
Social	949 (1869)	1485 (2317)	756 (1453)	1179 (1941)	616 (1727)	931 (2620)	577 (1380)	803 (1946)	119.63[a,b,c,d,e]	<0.001	0.028*

Note: H: Kruskal-Wallis ANOVA; p: significance; η^2: effect size coefficient; PA: physical activity; $^{*}0.01 \le \eta^2 < 0.06$ small effect size; $^{**}0.06 \le \eta^2 < 0.14$ medium effect size; $^{***}\eta^2 \ge 0.14$ large effect size; [a]Czech boys low motivation–Czech boys high motivation; [b]Czech girls low motivation–Czech girls high motivation; [c]Polish boys low motivation–Polish boys high motivation; [d]Polish girls low motivation–Polish girls high motivation; [e]Czech boys low motivation–Czech girls low motivation; [f]Czech boys high motivation–Czech girls high motivation; [g]Polish boys low motivation–Polish girls low motivation; [h]Polish boys high motivation–Polish girls high motivation.

Greater motivation for PA had a positive effect on the achievement of PA recommendations in both low and high motivated boys and girls in all types of motivation (Figure 4). The greatest achievement of PA recommendation was observed in high motivated Polish boys, while the smallest achievement was found in low motivated Czech girls.

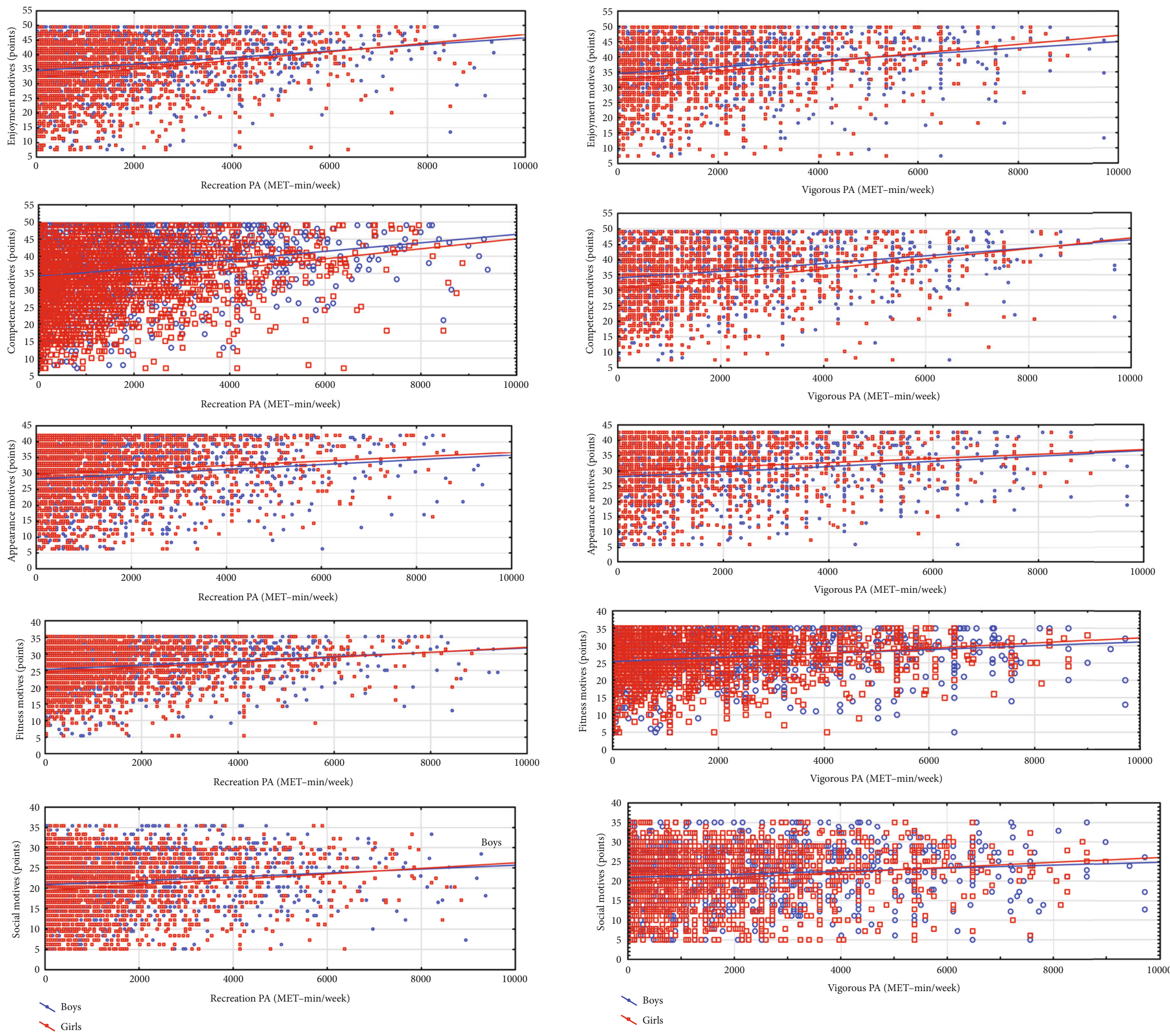
Table 3: Associations between weekly PA of different intensities (METs-min/week) and types of motivation in low and high motivated Czech and Polish boys and girls.

Types of motivation	Czech				Polish				H	p	η^2
	Boys (n =705)		Girls (n =1444)		Boys (n =853)		Girls (n =1074)				
	Low Mot Mdn (IQR)	High Mot Mdn (IQR)	Low Mot Mdn (IQR)	High Mot Mdn (IQR)	Low Mot Mdn (IQR)	High Mot Mdn (IQR)	Low Mot Mdn (IQR)	High Mot Mdn (IQR)			
Vigorous PA											
Enjoyment	720 (1620)	1530 (2430)	150 (900)	840 (2070)	630 (2160)	1800 (3150)	225 (1140)	1080 (2595)	$409.82^{a,b,c,d,g,h}$	<0.001	0.099**
Competence	615 (1650)	1560 (2190)	165 (900)	840 (2055)	720 (2310)	1800 (3360)	240 (1260)	1050 (2700)	$406.42^{a,b,c,d,g,h}$	<0.001	0.098**
Appearance	720 (2160)	1260 (2250)	360 (1380)	540 (1710)	840 (2350)	1620 (3120)	420 (1650)	720 (2250)	$169.52^{a,c,d,h}$	<0.001	0.04*
Fitness	720 (2130)	1440 (2340)	270 (1080)	720 (1890)	735 (2430)	1560 (3000)	360 (1440)	930 (2460)	$247.28^{a,b,c,d,g,h}$	<0.001	0.052*
Social	735 (2070)	1320 (2370)	270 (1080)	720 (2160)	1080 (2520)	1260 (3120)	420 (1620)	840 (2520)	$197.39^{a,b,d,g}$	<0.001	0.047*
Moderate PA											
Enjoyment	1110 (2090)	1740 (2759)	690 (1415)	978 (1828)	1440 (2840)	1680 (3020)	973 (1870)	1260 (2108)	$162.48^{a,b,g}$	<0.001	0.038*
Competence	1040 (2033)	1820 (2780)	690 (1480)	953 (1715)	1560 (2806)	1670 (3113)	930 (1845)	1320 (2160)	$169.18^{a,b,d,e,g}$	<0.001	0.040*
Appearance	1110 (2130)	1680 (2573)	740 (1450)	900 (1700)	1438 (2828)	1725 (3090)	1120 (1835)	1210 (2255)	$137.38^{a,h}$	<0.001	0.032*
Fitness	1060 (2220)	1680 (2580)	720 (1515)	925 (1610)	1411 (2808)	1770 (3100)	980 (1853)	1270 (2170)	$159.31^{a,d,g}$	<0.001	0.037*
Social	1260 (2013)	1590 (2710)	730 (1580)	893 (1625)	1405 (2840)	1785 (3080)	1013 (1870)	1260 (2120)	138.48^{g}	<0.001	0.032*
Walking											
Enjoyment	1287 (2360)	1477 (2533)	1617 (2475)	1658 (2673)	1139 (2739)	1568 (2723)	1403 (2574)	1832 (2879)	$51.37^{c,g}$	<0.001	0.011*
Competence	1279 (2269)	1518 (2525)	1667 (2657)	1584 (2549)	1155 (2789)	1551 (2706)	1485 (2607)	1832 (2805)	43.08^{g}	<0.001	0.009
Appearance	1386 (2327)	1452 (2558)	1518 (2376)	1716 (2772)	1139 (2525)	1617 (3053)	1568 (2558)	1716 (2904)	$51.16^{c,g}$	<0.001	0.011*
Fitness	1353 (2384)	1452 (2525)	1625 (2508)	1634 (2640)	1188 (2764)	1403 (2706)	1502 (2558)	1815 (2855)	37.15	<0.001	0.007
Social	1320 (2211)	1518 (2706)	1617 (2574)	1650 (2607)	1254 (2574)	1436 (2970)	1485 (2426)	1782 (2921)	37.81	<0.001	0.008

Note: H: Kruskal-Wallis ANOVA; p: significance; η^2: effect size coefficient; PA: physical activity; $^*0.01 \le \eta^2 < 0.06$ small effect size; $^{**}0.06 \le \eta^2 < 0.14$ medium effect size; $^{***}\eta^2 \ge 0.14$ large effect size; [a]Czech boys low motivation–Czech boys high motivation; [b]Czech girls low motivation–Czech girls high motivation; [c]Polish boys low motivation–Polish boys high motivation; [d]Polish girls low motivation–Polish girls high motivation; [e]Czech boys low motivation–Czech girls low motivation; [f]Czech boys high motivation–Czech girls high motivation; [g]Polish boys low motivation–Polish girls low motivation; [h]Polish boys high motivation–Polish girls high motivation.

The greatest impact on the achievement of PA recommendations was observed in all groups, caused by enjoyment and competence motives. Notable differences in the achievement of PA recommendations were observed between low and high motivated Czech girls in enjoyment ($\chi^2 = 57.69, p < 0.001, \eta^2 = 0.040$) and competence motives ($\chi^2 = 56.19, p < 0.001, \eta^2 = 0.039$), achieving 15 p.p., and in the achievement of PA recommendations by Polish high motivated girls in all PA motives (28% social motives to 33% enjoyment motives).

3.4. Predictors of Meeting PA Recommendations. Enjoyment, competence, and appearance motives in boys and girls increased the likelihood of achieving rigorous PA recommendations (VPA 3×20 min + MVPA 5×60 min) (Table 4). Adjusted moderator variables (country, age, BMI, and



(a) Recreation PA

(b) Vigorous PA

Figure 3: Correlations between recreation PA and PA motives (a) and between vigorous PA and PA motives (b) between boys and girls.

organized PA) involved in the model did not show a significant effect on the achievement of the PA recommendation neither in boys nor girls. Active participation in organized PA as the most significant moderator variable did not decrease the significance of the predictors of enjoyment, competence, and appearance motives for meeting the PA recommendations.

4. Discussion

4.1. Trends and Gender Differences in PA Motives and Types of PA. The results found that during the ten-year period, girls showed a decline in enjoyment, fitness, and social motives and an increase was observed only in appearance motives. A significant decrease in enjoyment motives was also observed by Abi Nader et al. [39] in both girls and boys. However, in the study, appearance motives were in the last position among other PA motives, while in Czech and Polish adolescents in the present study, the motives with the lowest assessment were social motives. This is consistent with the results of a previous Polish study [30].

Only in appearance motives were the girls more motivated to engage in PA than boys. In Polish girls, a greater appearance motive was observed by [40]. Generally, most studies confirm higher PA motivation among boys compared to girls, in both adolescents [41] and young adults [42]. However, a Norwegian study showed that girls had higher scores in intrinsic motives for sports participation, compared to boys, and that boys had higher scores in more extrinsic motives, but gender had no influence on motivation for sustained exercise [43].

The decrease in PA motives in girls is consistent with the decrease in recreation PA on average from 1,424 METs-min/week in the first period to 1,271 METs-min/week in the latest. Nevertheless, the values extracted in this study are greater than those reported in previous studies on Czech (1,146 METs-min/week) and Polish (990 METs-min/week) girls [44]. It should be noted that a statistically significant positive impact of all types of motivation was confirmed in recreation PA in both girls and boys. Naturally, it should be taken into account that these positive associations may

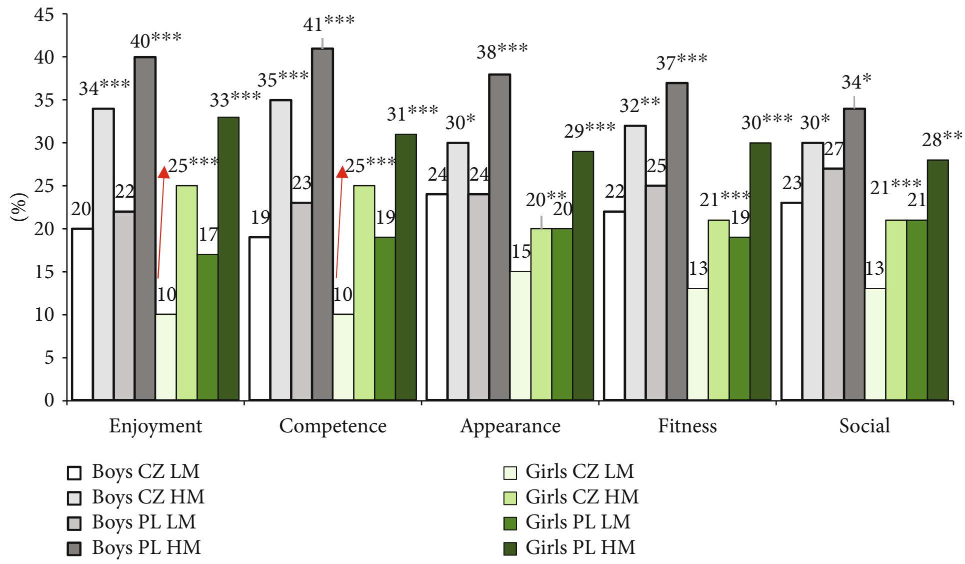


FIGURE 4: Achievement of PA recommendations (5 × 60 min moderate to vigorous PA + 3 × 20 min vigorous PA, no–yes) by low (LM: low motivation) and high (HM: high motivation) motivated Czech (CZ) and Polish (PL) boys and girls.

also be affected by other factors. Aaltonen et al. [24] particularly highlighted the effect of genetic influence and an even greater influence of environmental factors. Similarly, Hankonen et al. [45] emphasized the effect of socioeconomic and other factors.

4.2. Differences in Weekly Physical Activity between Low and High Motivated Boys and Girls (by Types of PA and PA Motives). The significant differences were observed between individuals with low and high motivation for PA, and the level of recreation PA in boys and girls emphasizes the importance of orientation of PA motives on preferred and pursued types of PA in leisure time. However, this requires respecting the preferences and possibilities for outdoor PA by less physically active adolescents in the context of their well-being [38] and provision of conditions/programs for less physically active adolescents and adolescents having a low socioeconomic status [46]. This also requires respecting the possibilities for active participation in organized PA by less physically active adolescents [34] and reversing the fact that four in every five adolescents do not experience the enjoyment motive and social, physical, and mental health benefits of regular PA [47].

The greatest impact on VPA was observed in low and high motivated boys and girls in all types of motivation; however, statistically significant values were observed in all groups only in enjoyment, competence, and fitness motives. The strong associations between enjoyment motives and VPA, as well as between competence motives and VPA in both genders, are a call for more intensive use of these types of motivation to support overall PA in adolescents. Similar conclusions were also formulated in a longitudinal study by Abi Nader et al. [39], who recommended that focus should be highlighted on enjoyment and competence motives in order to increase MVPA. According to Jakobsen and Evjen [43], intrinsic motives such as enjoyment and competence are vital for sustained exercise in Norwegian adolescent boys and girls. However, it also turns out that interventions to increase motivation for PA in schools may boost PA enjoyment motives, especially in girls [5]. Furthermore, perceived motor competence is an important factor to consider when attempting to promote an active and healthy lifestyle, primarily in students with low perceived motor competence, that is, with a lower level of motivation for PA [48]. It was confirmed that in 10- to 11-year-old Canadian children, targeting enjoyment and competence motives may be associated with increased participation in organized and group-based PA, as well as with an increased likelihood of meeting PA guidelines in youth [6].

The smallest impact of PA motives was observed in transport PA and walking (except for appearance motives in Polish boys). Simultaneously, transport to and from school represented as much as 36% of total daily MVPA on school days in high school [49], but interventions to increase the effects of walking to and from school are not sufficiently convincing [50]. It should be emphasized that active transport of Czech and Polish adolescents covers 22.5–24.9% of their overall weekly PA [51] and is the most efficient use of time for PA with respect to other school day segments [52]. Even the inclusion of a brief walking break during the routine school day helped direct the motivation to PA toward more intrinsic factors related to the possibility of staying with classmates and peer groups, as well as releasing surplus built-up energy [53]. The increase in autonomous motivation (i.e., intrinsic motivation, integrated, and identified regulation) in adolescents may improve active commuting to and from school [54].

Lawler et al. [55] drew attention to the dependence of psychological processes on the types of PAs performed. Girls actively participating in team or individual sports and boys participating in team sports demonstrated significantly higher self-determined motivational characteristics relative to other types of PA. This confirms the importance of respecting the differences in pursued but also preferred types

Table 4: Odds ratios for meeting the recommendation (3 × 20 min vigorous PA and 5 × 60 min moderate to vigorous PA) in boys and girls by low and high physical activity motives (enjoyment, competence, appearance, fitness, and social).

	Category	Model 1				Model 2			
		Boys		Girls		Boys		Girls	
		OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
PA motives									
Enjoyment	Low								
	High	1.52 (1.13–2.05)	0.005**	2.04 (1.56–2.67)	<0.001***	1.43 (1.06–1.93)	0.018*	1.99 (1.52–2.62)	<0.001***
Competence	Low								
	High	1.71 (1.27–2.31)	<0.001***	1.46 (1.12–1.91)	0.005**	1.67 (1.23–2.56)	0.001**	1.37 (1.04–1.79)	0.024*
Appearance	Low								
	High	1.29 (1.00–1.66)	0.046*	1.25 (1.01–1.55)	0.043*	1.30 (1.01–1.67)	0.044*	1.27 (1.02–1.57)	0.030*
Fitness	Low								
	High	0.95 (0.71–1.27)	0.719	0.48 (0.75–1.24)	0.780	0.94 (0.70–1.26)	0.69	0.96 (0.74–1.24)	0.754
Social	Low								
	High	0.95 (0.74–1.22)	0.683	0.98 (0.78–1.22)	0.845	0.93 (0.72–1.19)	0.549	0.94 (0.75–1.18)	0.575
Moderator variables									
Country	Czech								
	Poland					0.81 (0.64–1.02)	0.068	1.50 (1.23–1.83)	0.001**
Age	15-16								
	17–19					0.88 (0.70–1.11)	0.289	0.87 (0.71–1.07)	0.182
BMI	Normal								
	Overweight					0.91 (0.64–1.29)	0.600	0.67 (0.44–1.01)	0.053
Organized PA	No								
	Yes					1.75 (1.30–2.35)	<0.001***	1.77 (1.37–2.27)	<0.001***

OR: odds ratio; CI: confidence interval; $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$; PA: physical activity; Model 1: PA motives—enjoyment, competence, appearance, fitness, and social; Model 2: adjusted for country, age, BMI, and organized physical activity.

of PA in boys and girls [38] in selecting the methods of motivating for PA or in selecting interventions to increase adolescents' PA and well-being.

4.3. Associations between Types of PA and Motivation in Boys and Girls and Achievement of PA Recommendations and Suggestion for Improvement. The observed achievement of PA by low and high motivated boys and girls emphasizes the importance of focusing on enjoyment and competence motives which are mostly associated with the achievement of PA recommendations. In order for students to achieve PA recommendations in school, they need to have intrinsic motivation supported by all stakeholders, including teachers, staff, and parents, to improve autonomy, relatedness, and competence for PA participation [56]. In the promotion of suitable motivation and types of PA in the school environment, it is necessary to respect the significant effect of the school's physical, social, and political environment on increasing PA and limiting sedentary behavior [57]. Rosenkranz et al. [58] added that it is also important to consider the characteristics of settings and leaders, along with insights from behavioral theory, setting theory, and evidence-based effective interventions. It is equally important to promote the experience of a positive affective response to acute PA to improve intrinsic motivation for PA [59].

For decision-making about the types of motivation for PA, it is also important to consider that wearables (such as smart wristbands or smart watches) increase motivation to be physically active via self-monitoring, goal setting, feedback, and competition. However, it is also important to note that children and youth often report technical problems and a new effect in using wearables, which may impact the long-term use of wearables [10]. Motivation for PA using technology allows greater individualization and respect for personal and individual characteristics, especially among students with lower levels of self-perception. The positive effects of interventions to promote PA using smartphone-based PA are found by Emberson et al. [60] but, at the same time, point out the limits in acting on intrinsic PA motivation.

4.4. Suggestions to Improve the Effectiveness of Motivation for PA in Girls and Low Motivated Adolescents

(i) The greatest emphasis should be placed on intrinsic motivation through enjoyment and competence motives for encouraging PAs in girls and low motivated adolescents

(ii) Appearance motives should be used extensively to motivate girls for PA

(iii) Regarding the negative effects of the pandemic, the postpandemic period should be used to improve adolescents' readiness for home-based PA, decreasing digital space time, and maintaining mental health and well-being

(iv) In line with the findings of previous studies, the postpandemic era requires substantial changes in the approaches to PA motives and PA types

(v) Motivation for PA should be based on the knowledge of the preferences of PA types in the context of their achievement in the different segments of the school day, especially during leisure time

(vi) The selection of motivation for PA should respect the specifics of the segments of the school day and weekdays

Future research should focus not only on the basic types of motivation and types of PA but also on the most preferred types of PA, especially among low motivated and less physically active adolescents. Future research should also focus on the characterization of the changes in the associations between PA motives and types of PA that occurred as a result of the negative impacts of the pandemic.

4.5. Strengths and Limitations. The strength of the study is the implementation of the ten-year research in clearly defined and identical settings in schools of both countries for the entire period of the research, which was enabled by the Indares web-based application.

The limit is the cross-sectional nature of the study, because it was not appropriate for practical and organizational reasons to carry out an annual random selection of participants in the school environment. In addition, it was impossible to carry out the research always on the same school day of the week, but instead, all school days of the week were considered almost evenly.

5. Conclusions

In the study, we sought to identify differences and associations between PA motives and types of PA in low and high motivated boys and girls and further to identify types of motives and PA that increase the likelihood of achieving PA recommendations among low motivated adolescents. The highest differences between both the low and high motivated boys and girls are apparent between recreation PA and all types of motivation. Enjoyment, competence, and appearance motives in both boys and girls increased the likelihood of achieving PA recommendations. The decrease in PA motives among girls calls for an increased attention to gender differences and the greater application of appearance motives in girls. Enjoyment, competence, and appearance motives in boys and girls increase the likelihood of achieving PA recommendations. Respecting and using the associations between PA motives and types of PA in low and high motivated boys and girls can support feelings of PA enjoyment, increase PA, support the achievement of PA recommendations, and positively affect adolescents' lifestyles. The role of the school environment for effective motivation for PA among low motivated and less physically active adolescents is irreplaceable in national, school, and local policies.

Abbreviations

PA:	Physical activity
VPA:	Vigorous physical activity
MVPA:	Moderate to vigorous physical activity
BMI:	Body mass index
MET:	Metabolic equivalent
IPAQ-LF:	International Physical Activity Questionnaire-Long form
MPAM-R:	Motives for Physical Activity Measure-Revise
LM:	Low motivation
HM:	High motivation.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

No potential conflict of interest was reported by the authors.

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Research Article

Investigating the Relationship between Big Five Personality Traits and Sports Performance among Disabled Athletes

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Awareness of the psychological issues of different groups of society can help in the management of sports programs and thus improve their athletic performance. The aim of the present study was to investigate the relationship between the big five personality traits and the sports performance of disabled athletes in team sports. Three hundred and seventy-six team athletes participated in the study. Subjects completed a questionnaire of five major personality factors, and based on the information available on the provincial boards and the Veterans and Disabled Federation, the positions obtained by each athlete were considered as a criterion for sports performance. There was a significant relationship between the flexibility factor for men and women ($r = 0.123$, $p = 0.017$), neuroticism ($r = 0.114$, $p = 0.027$), adaptation ($r = 0.171$, $p = 0.001$), extraversion ($r = 0.157$, $p = 0.002$), duty orientation ($r = 0.104$, $p = 0.045$), and sports performance at a national level. There was a significant relationship between neuroticism ($r = 0.142$, $p = 0.006$), adaptation ($r = 0.133$, $p = 0.010$), extraversion ($r = 0.163$, $p = 0.002$), and duty orientation ($r = 0.130$, $p = 0.011$) with sports performance at a provincial level. There was a significant relationship between neuroticism ($r = 0.156$, $p = 0.002$), extraversion ($r = 0.168$, $p = 0.001$), duty orientation ($r = 0.182$, $p = 0.001$), and sports performance at international level. Disabled athletes seem to have above-average performance scores in most personality factors, which can improve their physical health and increase their success in sports.

1. Introduction

Although psychologists acknowledge "personality" as a general concept, its definition is open to debate, with more effort being expended in actually evaluating the concept of personality [1]. Factor analysis in explaining personality structure based on traits is one of the most important and effective methods used by psychologists [2]. Researchers consider the big five main dimensions of personality to include openness to experience, neuroticism, agreeableness, extraversion, and conscientiousness. These big five factors have been shown to have good convergent validity and good separation between instrument and observer [3]. Today, this model of five major personality factors is a popular approach in the study of personality traits. In this particular model, a human is identified as a rational being who has the justification for his/her personality [4]. The model states that "man" is a rational being who can justify his/her personality and behavior [5].

In the behavioral sciences, the relationship between personality and sports behaviors of individuals has been studied as part of research conducted in the sports sciences. The five-factor personality model underlies many studies in the field of sports and personality [6]; Safari et al. [7] examined the effect of five major personality factors on the motivation of students' sports participation and reported that the five factors had a significant effect on their motivation and in total 78% of the variable changes in the motivation of students' sports participation. Shams Ravandi et al. [2] presented a structural model based on the five major personality factors to predict the "burnout" of professional football referees; they reported that personality traits with burnout through the mediation of self-esteem had a significant indirect relationship [2]. Even the relationship between personality and the choice of sports has been discussed, as it has been shown that team athletes have more factors identified with extraversion [2, 8].

Such studies show that personality factors can be very important for athletic performance. Exercise can be considered as a "laboratory" in which the performance of athletes under high pressure and with strong emotions is evaluated [9], which creates unique conditions to examine the role of personality and individual differences in athletic performance [10]. Many athletes, despite having good performance in individual or group training, have poor performance in competition, and the cause of these problems, in addition to technical problems and weakness of coaches, can be attributed to environmental and stressors affecting the mental spirit of the athlete [11]. The personality of individuals can greatly affect this athletic performance, a topic that in certain groups such as veterans and the disabled can provide an attractive field for research.

Stefanovics et al. [12] showed that the five major personality factors have a significant relationship with the body mass index (BMI) of the disabled and mentioned these factors as important factors in preventing obesity in this group. However, knowledge of the psychological issues of different groups in society can help in the management and implementation of sports programs and thus improve their athletic performance. Similarly, knowing these issues in the field of sports for the disabled and veterans can improve their athletic performance at national and international levels of competition. To date, these five personality components on the sports performance of veterans and the disabled have not been studied; therefore, the present study is aimed at investigating the relationship between the big five personality traits and the sports performance of disabled athletes in team sports.

2. Materials and Methods

This descriptive-analytical research (correlational study) was conducted in 2021 in Iran.

2.1. Participants. All disabled athletes participating in provincial, national, and international competitions made up the statistical population of the present study, of which 376 team athletes participated in the present study. Criteria for entering the study included informed consent to participate, no mental illness, and a willingness to cooperate and complete a questionnaire. All ethical considerations regarding the confidentiality of the subjects' information were observed, and the present study received ethical approval with the code IR.JUMS.REC.1399.045 from the Ethics Committee of Jahrom University of Medical Sciences (Fars Province, Iran).

2.2. Procedure. After the approval of the plan by the Federation of Veterans and Disabled and coordination with the sports delegations of Veterans and Disabled of the provinces, all stages of work were sent in writing to the delegations through the federation. Before data collection, the five major personality factors, as well as how to implement the research plan, were fully explained to the participants. Each volunteer completed a questionnaire of the five major personality factors [13], and based on the information available on the provincial boards and the Veterans and Disabled Federation, the positions (position refer to whether the athlete competed at provincial, national, or international level) obtained by each athlete were considered as a criterion for sports performance.

2.3. Questionnaire of Big Five Personality Traits. The current questionnaire identifies the big five personality traits and consists of 21 questions. The 50-item questionnaire of the five major personality factors was first developed by Goldberg [14]. And its psychometric properties in Iran were studied by Khormaee and Khayer [15] with the permission of the main creator of the questionnaire in the form of a doctoral thesis. The results of the study by Khormaee and Khayer [15] showed the high validity and reliability of this questionnaire. In addition, Khormaee and Farmani [13] based on the results of Khormaee and Khayer [15] research, by selecting the items of the questionnaire, the five major factors of Goldberg personality [14] prepared a shorter form of this questionnaire, including 25 items. The results of the factor analysis of their research confirmed the independence of the five major personality factors. The revelation of these five factors in short form is consistent with the model of the five major personality factors of Goldberg [14] and McCrae and Costa Jr [5] regarding the 50-item questionnaire. In addition, the results of factor analysis showed that four items of the short form were removed due to insufficient factor loading on the desired factor and the number of items was reduced to 21 items. In addition, the results of the reliability measure showed that the short form of the questionnaire on the five major personality factors has high reliability (from 69% for openness to experience to 83% for neuroticism and agreeableness). The five major personality factors are divided into five subscales, and the questions are measured on a 5-point Likert scale: (a) openness to experience which includes questions 5-10-14-19, (b) neuroticism which includes questions 4-9-13-18, (c) agreeableness which includes questions 2-7-16-21, (d) extraversion which includes questions 1-6-11-15-20, and (e) conscientiousness which includes questions 3-8-12-17.

2.4. Sports Performance. Based on the information available in the provincial sports delegations and the Veterans and Disabled Federation, the positions obtained by each athlete were considered as a criterion for sports performance.

Table 1: Examining the five major personality factors (mean ± standard deviation) in team athletes.

Variable	Women	Men	Women+men	p
Openness to experience	12.51 ± 3.02	12.66 ± 1.96	12.60 ± 2.42	0.618
Neuroticism	12.85 ± 2.52	12.88 ± 2.00	12.87 ± 2.226	0.899
Agreeableness	12.31 ± 2.05	12.34 ± 1.35	12.33 ± 1.65	0.839
Extraversion	18.08 ± 3.20	18.22 ± 2.72	18.16 ± 2.91	0.681
Conscientiousness	12.72 ± 2.40	12.40 ± 2.14	12.52 ± 2.25	0.185

2.5. Information Analysis Method. Descriptive statistics were used to determine the mean and standard deviation, and a regression correlation test (Pearson product-moment correlation coefficient) was used to investigate the relationship between research variables in the inferential statistics section. Where the data was not normally distributed, a Mann-Whitney U test was used to compare men versus women.

3. Results

3.1. Examination of the Five Major Personality Factors of Team Athletes. The results of the five major personality factors in women and men in team disciplines are shown in Table 1. Between openness to experience, neuroticism, agreeableness, extroversion, and conscientiousness, there was no significant difference for women compared with men.

3.2. Investigating the Relationship between Flexibility Factors (Related to Personality) with Sports Performance at Different Levels: Provincial, National, and International. The results showed that there was a significant relationship between the flexibility factor related to personality and athletic performance of female team athletes in the province ($r = 0.166$, $p = 0.046$), but at the national level ($r = 0.123$, $p = 0.141$) and international level ($r = 0.041$, $p = 0.62$), no significant relationship was observed (Table 2). In addition, the results showed that there was a significant relationship between personality-related flexibility to mental health, quality of life, and athletic performance of male team athletes at the national level ($r = 0.136$, $p = 0.038$), but at the provincial level ($r = 0.045$, $p = 0.494$) and international level ($r = 0.072$, $p = 0.272$), no significant relationship was observed. Also, there was a significant relationship between the flexibility factor related to personality and athletic performance of athletes (total: men and women) in team disciplines at the national level ($r = 0.123$, $p = 0.017$), but at the provincial level ($r = 0.099$, $p = 0.055$) and international level ($r = 0.062$, $p = 0.233$), no significant relationship was observed.

3.3. Investigating the Relationship between Neuroticism Factors (Personality Related) with Sports Performance at Different Levels: Provincial, National, and International. The results showed that between the neuroticism factor related to the personality and athletic performance of female team athletes in the province ($r = 0.174$, $p = 0.037$) and internationally ($r = 0.215$, $p = 0.002$), there was a significant relationship, but at the national level ($r = 0.141$, $p = 0.092$), no significant relationship was observed (Table 3). Between the neuroticism factor related to personality to mental health, quality of life, and athletic performance of male athletes in team disciplines in the province ($r = 0.112$, $p = 0.087$) at national ($r = 0.091$, $p = 0.166$) and international level ($r = 0.092$, $p = 0.162$), no significant relationship was observed. Moreover, between the neuroticism factor related to personality to mental health, quality of life, and sports performance of athletes (total: men and women) in team disciplines in the province ($r = 0.142$, $p = 0.006$), national ($r = 0.114$, $p = 0.027$), and international level ($r = 0.156$, $p = 0.002$), a significant relationship was observed.

3.4. Investigating the Relationship between Adaptation Factors (Related to Personality) with Sports Performance at Different Levels: Provincial, National, and International. There was a significant relationship between personality adjustment factor and sports performance of female team athletes at the national level ($r = 0.267$, $p = 0.001$(, but at the province ($r = 0.30$, $p = 0.20$) and international level ($r = 0.136$, $p = 0.103$), no significant relationship was observed (Table 4). The results showed that there was a significant relationship between personality adjustment factor related to mental health, quality of life, and athletic performance of male team athletes at the province level ($r = 0.145$, $p = 0.027$), but at the national ($r = 0.094$, $p = 0.151$) and international level ($r = 0.057$, $p = 0.382$), no significant relationship was observed. Furthermore, between personality adjustment factors related to mental health, quality of life, and sports performance of athletes (total: men and women) in team disciplines in the province ($r = 0.133$, $p = 0.010$) at the national level ($r = 0.171$, $p = 0.001$), there was a significant relationship, but at the international level ($r = 0.097$, $p = 0.060$), no significant relationship was observed.

3.5. Investigating the Relationship between Extraversion Factor (Personality Related) with Sports Performance at Different Levels: Provincial, National, and International. Between the extraversion factor related to personality and sports performance of female team athletes in the province ($r = 0.226$, $p = 0.006$) at the national ($r = 0.358$, $p = 0.001$) and international level ($r = 0.235$, $p = 0.005$), significant relationships were observed (Table 5). The results showed that between the factor of extraversion related to personality with mental health, quality of life, and athletic performance of male team athletes in the province ($r = 0.117$, $p = 0.074$) at

Table 2: Investigating the relationship between flexibility factor and sports performance at different levels: provincial, national, and international.

Variable	Group	Sports performance at the provincial level		Sports performance at the national level		Sports performance at the international level	
		r	p	r	p	r	p
Flexibility	Women	0.166	0.046*	0.123	0.141	0.041	0.628
	Men	0.045	0.494	0.136	0.038*	0.072	0.22
	Women+men	0.099	0.055	0.123	0.017*	0.062	0.232

*Indicates a significant relationship between the two variables.

Table 3: Investigating the relationship between neuroticism factors and sports performance at different levels: provincial, national, and international.

Variable	Group	Sports performance at the provincial level		Sports performance at the national level		Sports performance internationally	
		r	p	r	p	r	p
Neuroticism	Women	0.174	0.037*	0.141	0.092	0.251	0.002*
	Men	0.112	0.087	0.091	0.166	0.092	0.162
	Women+men	0.142	0.006*	0.114	0.027*	0.156	0.002*

*Indicates a significant relationship between the two variables.

Table 4: Investigating the relationship between adaptation factors and sports performance at different levels: provincial, national, and international.

Variable	Group	Sports performance at the provincial level		Sports performance at the national level		Sports performance at the international level	
		r	p	r	p	r	p
Adaptation	Women	0.130	0.120	0.267	0.001*	0.136	0.130
	Men	0.145	0.027*	0.094	0.151	0.057	0.382
	Women+men	0.133	0.010*	0.171	0.001*	0.097	0.060

*Indicates a significant relationship between the two variables.

Table 5: Investigating the relationship between extraversion factor and sports performance at different levels: provincial, national, and international.

Variable	Group	Sports performance at the provincial level		Sports performance at the national level		Sports performance at the international level	
		r	p	r	p	r	p
Extraversion	Women	0.226	0.006*	0.385	0.001*	0.235	0.005*
	Men	0.117	0.074	0.016	0.814	0.117	0.075
	Women+men	0.163	0.002*	0.157	0.002*	0.168	0.001*

*Indicates a significant relationship between the two variables.

national ($r = 0.016$, $p = 0.814$) and international level ($r = 0.117$, $p = 0.075$), no significant relationship was observed. Also, between the extroversion factor related to personality to mental health, quality of life, and sports performance of athletes (total: men and women) in team disciplines at the provincial ($r = 0.163$, $p = 0.002$), national ($r = 0.157$, $p = 0.002$), and international level ($r = 0.168$, $p = 0.001$), significant relationships were observed.

3.6. Investigating the Relationship between Duty-Oriented Factors (Personality Related) with Sports Performance at Different Levels: Provincial, National, and International. The results showed that between the duty-oriented factor related to personality and athletic performance of female team athletes in the province ($r = 0.246$, $p = 0.003$) at the national ($r = 0.251$, $p = 0.002$) and international level ($r = 0.138$, $p = 0.001$), significant relationships were observed

Table 6: Investigating the relationship between the duty-oriented factor and sports performance at levels: provincial, national, and international.

Variable	Group	Sports performance at the provincial level		Sports performance at the national level		Sports performance at the international level	
		r	p	r	p	r	p
Duty-oriented	Women	0.246	0.003*	0.251	0.002*	0.138	0.001*
	Men	0.044	0.502	0.000	0.998	0.211	0.001*
	Women+men	0.130	0.011*	0.104	0.045*	0.182	0.001*

*Indicates a significant relationship between the two variables.

(Table 6). The results showed that between the duty-oriented factor related to personality to mental health, quality of life, and athletic performance of male team athletes in the province ($r = 0.044$, $p = 0.502$) at the national level ($r = 0.00$, $p = 0.998$), no significant relationship was observed, but at the international level ($r = 0.211$, $p = 0.001$), a significant relationship was observed (Table 6). The results showed that between the factor of duty orientation related to personality and sports performance of athletes (total: men and women) in team disciplines in the province ($r = 0.30$, $p = 0.011$) at the national ($r = 0.104$, $p = 0.045$) and international level ($r = 0.182$, $p = 0.001$), significant relationships were observed (Table 6).

4. Discussion

In the present study, the relationship between the big five major personality factors and sports performance of veterans and athletes with a disability was investigated. The results of the present study showed a significant relationship between the openness and athletic performance of the athlete's team (total: men and women) at the national level. But there was a significant difference between the three factors of neuroticism, extraversion, and conscientiousness with the sports performance of athletes (total: men and women) in all three levels of competition, and there was a significant relationship in the factor of agreeableness at both province and national level.

In a research by Safari et al. [7], it was shown that these five factors have a significant effect on the motivation of students' sports participation. In the study of Keshavarz et al. [16], there was a significant difference in neuroticism of Iranian and non-Iranian athletes, but there was no significant difference in this characteristic in Iranian student-athletes. According to McCrae and Costa [3], people who score higher on neuroticism are anxious, timid, and prone to panic and anxiety. They also cannot cope well with everyday stress, helplessness, and embarrassment. According to the findings of the present study, it seems that elite veteran male and female athletes are of "high quality," which can pave the way for their success.

Fazel [1] compared these five major personality factors between male and female athletes and reported that, except for the personality factor of openness, there was a significant difference between athletes and nonathletes in four other factors. Jackson et al. [17] also showed that there was a significant difference between the personality factor of openness in athlete and nonathlete groups. However, these findings are inconsistent with the results of Kajtna et al. [18] and Reiter et al. [19]. Nevertheless, the nature of sports and physical activity seems to satisfy people's inner emotions through more openness, an increase in the desire for more experiences and learned techniques, and increased motivation to participate in social arenas such as sports that this issue in veteran and disabled athletes can have a positive effect on their athletic performance.

In the study of Lewis and Sutton [20] and also Ghaderi and Ghaderi [6] in line with the present study, it was shown that personality factors such as extraversion are higher in athletes, and it links with greater sports participation. Extroverts gain extra energy from connecting with the outside world and exposing themselves to social activities. Therefore, it seems that veterans and the disabled, due to having a higher score in this personality trait, have good sports performance and can achieve high levels at the national and international levels in the field of sports. Brinkman [21] also reported a significantly higher conscientiousness personality factor in athletes. Conscientious people have a great desire to control their emotions and focus on their goals and thus have a higher sense of responsibility and try to perform in the best possible way in their assigned tasks [7]. It seems that the highest score of this personality trait in veterans and athletes with disabilities can have a positive effect on their performance and help them to be more successful in the field of sport. Agreeableness was also mentioned in line with this research by Ghaderi and Ghaderi [6] as a personality trait that affects athletic performance. Agreeableness shows the level of cooperation and friendly attitude, and people with higher agreeableness have a high tendency to participate in team sports, which can have a positive effect on their performance. This finding was also shown in the present study of veteran and disabled athletes.

As mentioned, this questionnaire examined the five major personality factors (openness to experience, neuroticism, agreeableness, extraversion, and conscientiousness) among disabled athletes. It seems that the high score obtained in this questionnaire for some factors, such as openness to experience, reflects disabled athletes' physical and motivational limitations, which in turn may cause them frustration within society. These findings highlight the need to help these people to show their innate ability by experiencing new sports environments and gain the respect and admiration of people in the community. In addition, it has been observed that, in general, the factor of extraversion is higher in athletes than nonathletes, and disabled athletes are more inclined to participate in sports activities [1, 17–19]. Therefore, it seems that disabled athletes with a higher score in this factor have a high motivation to participate in sports activities and be able to achieve high success by participating in national and international competitions. In addition, people with disabilities have a high sense of duty and try to be able to best fulfill the responsibilities assigned to them, and this feature can have a significant impact on the national and international success of these athletes [7]. In people with disabilities, due to their disabilities, the spirit of cooperation is very high, so these people have a high score in agreement, and this high score affects their success in national and international competitions [6].

Based on the findings of the present study, it seems that disabled athletes have above-average performance scores in most personality factors, which indicates that sport and physical activity in this group of society can not only improve their level of physical and mental health but also increase their success in domestic and international sports participation. This finding should be given special attention in the planning of a country's sports officials and plans for the competition.

Data Availability

Data will be available from the corresponding author if required.

Ethical Approval

Approval was taken from the Ethics Committee of Jahrom University of Medical Sciences (Fars Province, Iran).

Consent

Written informed consent was obtained from all participants.

Conflicts of Interest

The authors report no conflict of interest.

Authors' Contributions

All authors read and approved the final manuscript.

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Research Article

Impact of the COVID-19 Pandemic on the Motor Development of Schoolchildren in Rural and Urban Environments

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Social and school closures during the COVID-19 pandemic may have led to significant stagnation in children's motor development, but precise data on this are lacking. We aimed to examine the impact of the pandemic and society closure on motor development of school children and to find differences between rural and urban environments. From the SLOfit database, we obtained anonymous results from 756 6^{th} grade children before the pandemic (11.3 ± 0.5 years, 52.5% boys) who performed physical fitness measurements in 2017 and 2019 in 8th grade and from 853 6^{th} grade children (11.4 ± 0.5 years, 51% boys) who performed measurements in 2019 and 2021, after 3 pandemic waves. The results of eight physical activity tests and the overall physical fitness index were compared between the prepandemic and the pandemic generation. We divided the sample into four groups (rural and urban prepandemic group and rural and urban pandemic group) and compared the changes in test scores between 6th and 8th grade. We found a statistically significant decrease in the physical fitness index of the pandemic generation (from 51.6 ± 29.6 to 45.8 ± 30.3) compared to the prepandemic generation (from 50.4 ± 30.5 to 50.5 ± 29.7), $p < 0.001$. The greatest effects of pandemic closure were found in the 600-meter run, in polygon course backwards test, in the number of sit-ups in 60 seconds, and in the 60-meter sprint. Children from rural areas showed worse decrement in physical fitness index compared to urban areas, except for 600-meter run. We conclude that the pandemic closure has had a significant inhibitory effect on the motor development of schoolchildren and has reduced their overall physical fitness with worse decline in rural areas. The pandemic generation of children needs more physical education in schools and other systemic interventions to mitigate these consequences.

1. Introduction

In the Republic of Slovenia, the COVID-19 pandemic was declared on March 12, 2020 [1]. Since the beginning of the pandemic, we have been hearing warnings from experts that the pandemic-related closure of schools and sports facilities, as well as the restriction of outdoor exercise, will have a negative impact on the physical (and mental) condition of the population, including children [2, 3]. Pandemic measures, including the closure of schools and kindergartens, have eliminated regular physical education, which accounts for a large part of planned physical activity of schoolchildren [4]. Accordingly, the first reports on the impact of the pandemic closure showed a decline in children's physical fitness after the first wave of the pandemic in 2020 [5]. The first wave was followed by subsequent waves, and therefore there is a need for reliable data on the impact of the protracted pandemic course on the motor development of children in Slovenia.

The Sports Educational Chart (Slovenian: »športno-vzgojni karton«) and its upgrade, the SLOfit project, is the main system used in Slovenia to monitor and assess the physical and motor development of school children [6]. In this system, motor development has been assessed in all Slovenian primary and secondary schools since 1987. The results are evaluated by the Faculty of Sport at the University of Ljubljana, Laboratory for Diagnostics of Physical and Motor Development [7]. Before the pandemic, from 2010 to 2019, a trend of gradual improvement in physical fitness indicators of schoolchildren was observed in Slovenia [1]. In the first pandemic year 2020, lower, moderate, and high-intensity physical activity as measured by School Health Action, Planning, and Evaluation System (SHAPES) questionnaire was found in a relatively small sample of 62 schoolchildren, but no significant effect on fitness indicators as captured by Sports Educational Chart was found compared with the prepandemic control sample [8].

There are some hereditary and maternal factors associated with early motor development of children [9]. Later in development, parental beliefs and behaviours but also some school and sports environment features such as peer relations, classroom age range, in-class interaction, and teacher education relate to better motor performance as well [10]. Although it is known that physical inactivity associates with obesity and poorer motor abilities [11], there is lack of information on the impact of population-level physical activity on motor development in children. After three pandemic waves, regular measurements of physical fitness were conducted in schools from April 12, 2021, as part of the SLOfit project. This gave us a unique opportunity to analyze the impact of the protracted course of the pandemic in several waves and subsequent society closures with reduction of physical activity on children's motor development.

We designed this research with the main aim to determine the impact of the COVID-19 pandemic on physical fitness and motor development of primary school children. Our secondary aim was to find possible differences between rural and urban areas. On the basis of previous findings of declines in aerobic fitness in a sample of healthy American children during the first pandemic wave [5] and the reported decline in physical activity in Slovenia [8], we expect to find a statistically significantly lower progress of physical performance of the children in pandemic generation (first hypothesis). The pandemic measures are unlikely to have affected people equally in all regions. In densely populated urban areas, children had fewer opportunities to unrestrictedly play outdoors, because of the mandated wearing of masks when interpersonal distance was less than 2 meters and a ban on the use of children's playgrounds. Children in less populated rural communities had an easier access to outdoor places where they could be physically active without restriction. Therefore, we hypothesized that the motor progress of children from urban, densely populated areas in physical performance would be statistically significantly lower than the progress of children from rural, sparsely populated areas (second hypothesis).

2. Materials and Methods

We designed this research as a prospective observational study, where we analyzed the results of physical fitness of two generations of schoolchildren: prepandemic generation, which was measured in 2017 in the 6th grade of primary school and in 2019 in the 8th grade, and pandemic generation, which was measured in 2019 in 6th grade and in 2021 in 8th grade of elementary school. In its motor development, the pandemic generation has been exposed to a risk factor—the impact of the pandemic with all its social and health consequences. A brief summary of the key effects of the pandemic and the social distancing and closure measures taken is shown in Table 1. The prepandemic generation was not exposed to these measures and had 3 hours of physical education per week in the 6th grade and 2 hours of physical education per week in the 7th and 8th grade of elementary school. Youth club sports and recreational activities during this period were normal, but during the pandemic period, they were subjected to restrictions and closures.

Since the measurements of physical fitness are performed in the vast majority of Slovenian schools (more than 94% of children in Slovenian public schools), we were able to evaluate possible regional differences in addition to the general impact on motor development. To compare the impact of the COVID-19 pandemic on children from urban and rural areas, we selected participants from the municipalities with the highest and lowest population density in the Republic of Slovenia. Data on population density were taken from the publicly available SiStat database of the Statistical Office of the Republic of Slovenia as of December 21, 2021. We used the table "Population Density and Femininity Index, Municipalities, Slovenia, Semiannual" (Table ID: 05C4010S), which is publicly available. We included schools from the municipalities with the highest and lowest population density and evenly geographically distributed across the Slovenian regions. About 800 children were included in each group. In this way, we included 11 schools from the 18 most densely populated municipalities and, on the other hand, 18 schools from the 27 least populated municipalities (Supplement Table S1 shows all the included municipalities and schools).

All children who participated in the SLOfit measurements in the selected schools and whose parents gave informed consent to participate in the The Sports Educational Chart (the part of SLOfit system that measures schoolchildren in schools) were included in the study sample. Affirmative verbal consent was obtained from all children before each measurement and data collection. Participation was completely voluntary. Data were collected and analyzed anonymously. The collection and anonymous use of data in the SLofit system was approved by the Medical Ethics Committee of the Republic of Slovenia (document ID 102/03/15).

In our study we used the results of SLOfit physical fitness measurements, which were measured every year in April at public elementary schools. The measurement system is described in detail elsewhere [7] and, in addition to measuring height, weight, and triceps skinfolds, includes a battery of fitness tests. This consists of the performance of eight tasks in four groups: (i) 60 second sit-ups, bent arm hang (indicators of muscular fitness), (ii) stand and reach (indicator of flexibility), (iii) standing long jump, polygon course backwards, 20 seconds arm plate tapping, 60 m sprint run (indicators of skills related fitness), and (iv) 600 m run (indicator of cardiorespiratory endurance). The exact description and measurement properties of these tests are given in ref. [6] and ref. [7].

The physical fitness index (XT) was also calculated to represent the average performance at abovementioned 8 motor tests. It is an average value of eight T-scores. The T-score is a value that tells us where within the population of children of the same sex the individual's score lies. The T-score is calculated by converting the individual's test

Table 1: Key societal actions during the pandemic and before the last pandemic generation testing [12].

Pandemic wave (year)	Time frame	Measures taken
The first (spring 2020)	4th March–14th May 2020	Restrictions on gathering in public places and movement in public areas (individual movement allowed) Closure of schools and other educational institutions∗ Closure of public transportation Closure of stores and services, including sports clubs (with exceptions, e.g., grocery stores, pharmacies, and gas stations) Prohibition of movement outside the residential community Mandatory use of a protective mask in enclosed public spaces
The second (autumn 2020 and winter 2020/21)	4th September–8th February 2021	Mandatory wearing of masks in addition to public enclosed spaces (including schools) in open public areas. Closure of restaurants after 10 p.m. and complete closure of restaurants in red regions Prohibition of the use of sports facilities Prohibition of gatherings in groups of more than 10 people and, from November 13, a ban on all socializing except for families Closure of gyms and sports clubs From October 17, schools were closed and distance learning was organized for primary and secondary school students Only sport activities of top athletes, individual athletes and sports with a maximum of 6 participants at a distance of 3 m were permitted Introduction of a curfew between 9 p.m. and 6 a.m. Restriction of movement to the municipality of residence
The third wave (spring 2021)	1st April–12th May 2021	Continuation of distance learning Shortening the curfew between 10 p.m. and 5 a.m. Opening of schools on April 12, 2021

∗School took place through remote (on-line) learning.

result to the Z-score, multiplying by 10 and adding 50 (quantile normalization) [6].

Descriptive statistics were obtained by calculating averages and standard deviations as all variables were normally distributed. Differences between generations were tested by repeated measures ANOVA. The effect size was calculated in the analysis of variance using the eta squared parameter (η^2). The difference between the 2 generations in 8th grade was calculated as an adjusted difference that included the baseline scores in 6th grade as a covariate (analysis of covariance). The difference between the generations was also expressed in a standardized form by standardizing the calculated adjusted difference between the generations to the overall standard deviation (Cohen's d). Calculated differences in results from 8th and 6th grade were used compared in four groups of children (prepandemic and pandemic urban and rural group) using a test of variance between these four different groups. IBM SPSS Statistics 22 and 27 (IBM corp., NY, USA) were used for the analyses. The limit of statistical significance was always $p < 0.050$.

3. Results

3.1. Sample Description. The study included 1609 male and female students, 756 of whom belonged to the prepandemic generation, attending 6th grade of elementary school in 2016/2017. The pandemic generation in our sample includes 853 children who entered 6th grade in the 2018/2019 school year and were then exposed to SARS-CoV-2 virus containment measures in 7th and 8th grade. Baseline demographic and anthropometric data for the included children are shown in Table 2.

The same children were included in 6th and 8th grade. Data are given as mean ± SD.

3.2. Differences between Prepandemic and Pandemic Generation. The absolute values of the SLOfit fitness test results are shown in Table 3. Columns 3 and 4 show the absolute results for the two generations in 6th and 8th grade, and the p value in column 5 was calculated using repeated measures ANOVA for time x group interaction. There was a statistically significant difference between the two generations over time at all tests except for the 20 s arm plate tapping. The adjusted mean difference between the generations in the 8th grade showed similar results—significant differences with poorer results for pandemic generation at all tests except for one. The effect size of time x generation differences, expressed by partial eta squared, was the greatest in the physical fitness index, 600 m run, polygon course backwards, bent arm hang, and 60 m sprint.

Figure 1 shows the magnitude of the standardized difference in test scores between the prepandemic generation and the postpandemic generation in eighth grade. Standardized differences were determined by dividing the adjusted difference between generations in 8th grade (Table 3, column 6) by the total standard deviation in each test. The results allow for comparison across tests. When we compare these standardized differences, we see that the largest adjusted

Table 2: Baseline demographic and anthropometric characteristics of the sample.

Grade	Generation (N)	Age (years)	Male sex (%)	Height (cm)	Weight (kg)	BMI (kg/m^2)
6th grade	Prepandemic ($N = 756$)	11.3 ± 0.5	52.5	154.5 ± 7.5	48.6 ± 12	20.2 ± 3.9
	Pandemic ($N = 853$)	11.4 ± 0.5	51	154.2 ± 7.8	47.6 ± 11.8	19.9 ± 3.9
8th grade	Prepandemic ($N = 756$)	13.3 ± 0.5	52.4	166.4 ± 7.8	59.8 ± 13.1	21.6 ± 4
	Pandemic ($N = 853$)	13.4 ± 0.5	51	166.6 ± 8.3	60.3 ± 14.1	21.6 ± 4.3

Table 3: Absolute values of tests, analysis of variance, and difference between generations.

Test	Generation	6th grade	8th grade	p	Difference in 8th grade (95% CI)∗	Effect size (η^2)
Tapping (n)	Prepandemic	37.8 ± 4.5	42.3 ± 4.8	0.619	0.2 (-0.6 to 0.1)	0.001
	Pandemic	37.4 ± 4.2	41.7 ± 4.8			
Standing long jump (cm)	Prepandemic	160.3 ± 24.2	179.9 ± 28.3	0.007	2.4 (0.6 to 4.2)	0.005
	Pandemic	162.3 ± 23.7	179.4 ± 29.9			
Polygon backwards (0.1 s)∗∗	Prepandemic	139.8 ± 42.5	122.8 ± 36.2	<0.001	7.2 (3.9 to 10.5)	0.013
	Pandemic	134.3 ± 40.0	126.4 ± 46.1			
Sit-ups (n)	Prepandemic	42.9 ± 9.4	46.9 ± 9.9	0.001	1.5 (0.7 to 2.3)	0.01
	Pandemic	42.5 ± 9.9	45.1 ± 10.5			
Stand and reach (cm)	Prepandemic	44.3 ± 8.4	47.2 ± 29.1	0.030	1.9 (-0.1 to 3.9)	0.002
	Pandemic	43.8 ± 8.4	44.1 ± 30.1			
Bent arm hang (s)	Prepandemic	46.8 ± 29.6	47.6 ± 29.7	0.006	1.8 (0.01 to 3.7)	0.003
	Pandemic	49.1 ± 29.8	46.9 ± 30.7			
60 m sprint (0.1 s)∗∗	Prepandemic	106.6 ± 11.5	99.3 ± 11.3	0.001	1.6 (0.7 to 2.5)	0.009
	Pandemic	106.6 ± 11.2	100.9 ± 12.6			
600 m run (s)	Prepandemic	163.1 ± 28.6	157.1 ± 30.7	<0.001	7.7 (5.0 to 10.4)	0.023
	Pandemic	162.7 ± 27.6	164.5 ± 34.8			
Physical fitness index	Prepandemic	50.4 ± 30.5	50.5 ± 29.7	<0.001	5.7 (3.8 to 7.6)	0.028
	Pandemic	51.6 ± 29.6	45.8 ± 30.3			

∗The adjusted average difference between generations in 8th grade is adjusted according to the baseline in 6th grade. ∗∗The result in polygon course backwards and in the 60 m sprint is measured in tenths of a second.
Abbreviations: ANOVA: Analysis of variance; CI: Confidence interval; η^2: Partial eta squared.

differences are visible in the 600-meter run, the physical fitness index, the polygon course backwards, the sit ups, and the 60-m sprint. For these tests, we also analyzed the differences between students from urban and rural areas.

3.3. Differences between Rural and Urban Areas. Students were divided into four groups according to generation (prepandemic and pandemic) and whether the school was located in an urban or rural setting. Their demographic composition and baseline physical characteristics in 8th grade are shown in Table 4.

BMI: Body mass index.

We can see that the composition by sex and physical characteristics was very similar between the groups. The differences in physical characteristics between groups within each sex were not statistically significant.

The physical fitness index as a composite measure of physical fitness shows the largest decrement in rural areas (Figure 2). Stars in Figure 2 designate the significant intragroup differences. The differences between the groups in Figure 2 are statistically significant ($p < 0.001$). The urban pandemic group is significantly different from the urban prepandemic group and the rural pandemic group ($p \leq 0.050$). The rural pandemic group is significantly different from all other groups ($p < 0.001$ for the comparison with the prepandemic groups and $p \leq 0.050$ for the comparison with the urban pandemic group).

The urban pandemic group showed the largest deficit in 600 m run with 8th grade results actually being worse than in the 6th grade (Figure 3). In other tests, rural pandemic group was inferior. Differences between the groups for 600 m run in Figure 3 are statistically significant ($p < 0.001$), all differences between urban pandemic and other groups are also significant ($p < 0.001$). The differences between rural pandemic and prepandemic groups are not significant. Stars designate the significant intragroup differences.

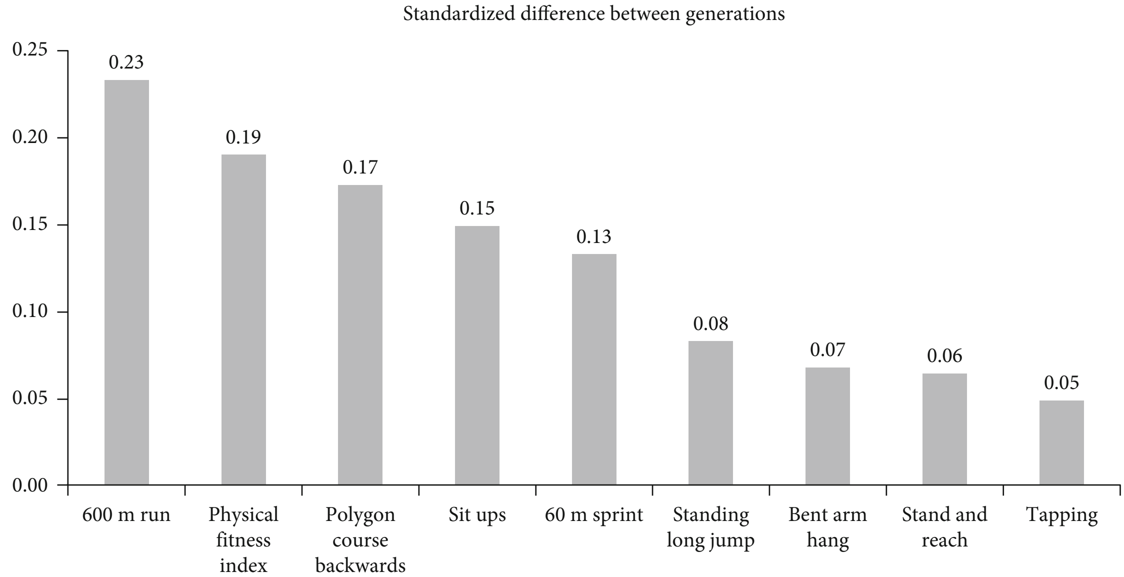

Figure 1: Standardized difference between the generations in 8th grade.

Table 4: Demographic composition of 4 groups of students and body composition in 8th grade.

Generation	Municipality (N)	Male/female N (%)	Height (cm, male/female)	Weight (kg, male/female)	BMI (kg/m^2, male/female)
Prepandemic	Urban (381)	200 (53.5)/181 (47.5)	168/164	61/58	21.4/21.5
	Rural (375)	197 (52.5)/178 (47.5)	167/164	61/59	21.5/21.8
Pandemic	Urban (430)	229 (53.3)/201 (46.7)	169/164	62/59	21.5/21.7
	Rural (423)	206 (48.7)/217 (51.3)	169/163	61/58	21.7/21.5

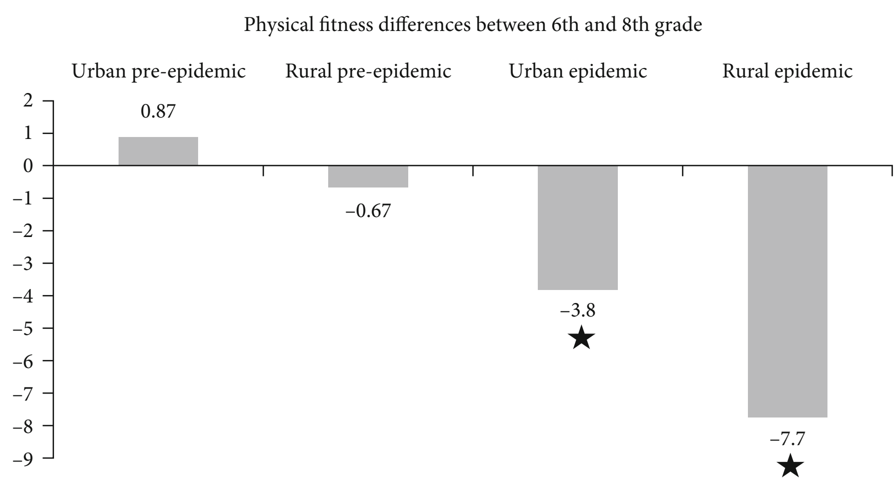

Figure 2: Physical fitness index changes (average) in the four groups.

4. Discussion

Our results show a large and statistically significant impact of the COVID-19 pandemic on the motor development of schoolchildren. When we look at the differences in motor development between the prepandemic generation and the pandemic generation, we find that the pandemic generation had statistically significant lower progress in motor abilities as measured in all fitness tests except for the 20 second arm plate tapping. The effects of the pandemic were the greatest in the 600-meter run, polygon course backward, sit ups, and the 60-meter sprint. The greatest negative effects were seen in the endurance (600-meter run) and skill-related motor tests (60-meter sprint, polygon course backwards),

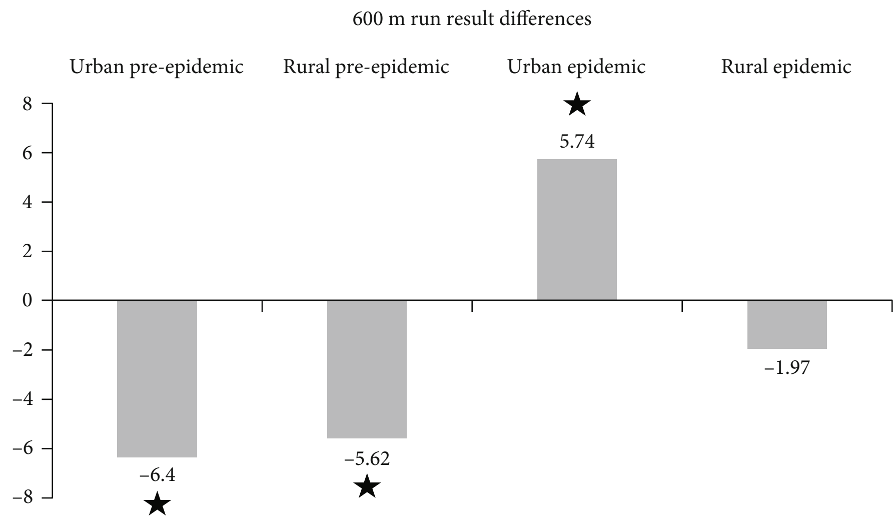

Figure 3: Average difference between the 8th and 6th grade 600 m run time (in seconds).

and upper-body muscle fitness (60 second sit-ups). As a result, there was also a large effect on the physical fitness index, which is a composite measure of physical fitness. Based on these results, we can confirm the first hypothesis and conclude that the measured age progress in physical fitness of children exposed to pandemic measures is statistically significantly lower than the progress of children of the same age in the generation before the pandemic.

We could not confirm the second hypothesis that the progress of children from urban, densely populated areas in terms of physical performance would be statistically significantly lower than the progress of children from rural, sparsely populated areas. Conversely, the physical fitness index deteriorated more in the rural pandemic group than in the urban pandemic group, which is the opposite of what we expected. The only fitness test in which children from the urban pandemic group performed largely worse than the others was the 600-meter run, in which scores actually deteriorated significantly between 6th and 8th grade, and the expected progress with age did not occur at all. This confirms the significant effect of the difference in access to the external environment between the urban and rural environments on the maintenance of cardiorespiratory endurance, which was the basis for our second hypothesis. However, the greater decline in the overall index of physical fitness in the rural group of children suggests that overall physical incentives declined more in rural areas than in urban areas at the time of the pandemic.

Comparing our results with recent reports by other investigators, we note that both French [13] and Austrian authors [14] found a decline in fitness in schoolchildren after the first pandemic wave. To our knowledge, our study is the first to report the effects of pandemic over the prolonged duration of three waves and to include a (historical) control group. Chambonniere et al. measured 106 3rd- and 4th-grade elementary school children (aged 9 and 10 years) in February 2020 and 100 additional children at the same grade level in January 2021. They described significant deteriorations in cardiorespiratory endurance, standing long jump, ball throw, and cognitive function [13]. In contrast to our study, they compared the results of different children without a control group. However, Jarnig et al. reported a significant decrease in distance in a 6-minute running test in 764 Austrian children aged 7-10 years and a significant increase in the proportion of overweight and obese children [14]. This study also had no control group. In contrast to the Austrian researchers, we found no significant differences in body mass index between eighth graders from the prepandemic and pandemic generations.

Limitations of our study include the possibility of bias in the selection of schools in the municipalities, since we followed the principle of even geographical representation in selecting municipalities at the high and low ends of the settlement density scale and did not select them randomly. Another limitation is not including the schools from municipalities with a medium settlement density in the Republic of Slovenia. Sensitivity analysis should also be performed with a separate analysis of the results by gender.

5. Conclusions

In our study, we showed that COVID-19 pandemic significantly affected the motor development of schoolchildren with major deficits in domains of cardiorespiratory endurance (600 m run), skill-related fitness (polygon course backwards, 60-m run), and core strength (sit-ups). In general, the effects of the pandemic were larger in rural areas. Our research will help physical education teachers and coaches in sports clubs to plan physical activity programs for children. Given the characteristic negative changes in children's motor development, our results justify the need to closely monitor the development of the pandemic generation and take systematic corrective measures. First and obvious corrective measure would be to increase the number of physical education hours for the pandemic-affected generation of children.

Data Availability

The raw data including the anonymized test results is available from the authors upon request.

Conflicts of Interest

The author declares no conflict of interest.

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Supplementary Materials

Supplementary Table 1: selected schools and municipalities. *(Supplementary Materials)*

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