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Musculoskeletal Asymmetries in Young Soccer Players: 8 Weeks of an Applied Individual Corrective Exercise Intervention Program

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Abstract: Introduction: In youth soccer, for examining injury prevention and exercise performance, most of the interventional studies concerning corrective postural asymmetries have applied general intervention programs, ignoring the specific individual corrective needs of each youth player separately. The aim, therefore, of the present study was to examine the effect of 8 weeks of an individualized corrective exercise intervention program on musculoskeletal asymmetries in young soccer players. Materials and Methods: Eighty young male soccer players (age: 14.4 ± 1.2 years; body height: 166.3 ± 9.6 cm; body mass: 59.1 ± 11.5 kg) participated in the current laboratory-based study. A battery of postural and musculoskeletal asymmetry evaluations were initially performed. After the completion of the initial assessment, each player was provided with an individual musculoskeletal asymmetry corrective exercise intervention program which lasted for 8-weeks, with the aim of restoring muscular asymmetries. Following the application of the intervention program, a re-evaluation of their musculoskeletal asymmetries was performed. Results: There was a significant improvement in the primary angle of trunk rotation ($r = -0.56$, $p < 0.001$), hamstring flexibility (right: $r = -0.55$, $p < 0.001$; left: $r = -0.48$, $p < 0.001$), hip external rotation (right: $r = -0.46$, $p < 0.001$; left: $r = -0.26$, $p = 0.020$), hip internal rotation (right: $r = -0.26$, $p = 0.021$; left: $r = -0.35$, $p = 0.002$), the opened-eyes Stork Test (right: $r = -0.33$, $p = 0.003$: left: $r = -0.33$, $p = 0.003$), the closed-eyes Stork Test (right: $r = -0.39$, $p < 0.001$; left: $r = -0.43$, $p < 0.001$), the Thomas test [right: ($\chi^2(3) = 52.281$, $p = 0.001$, $\hat{\gamma} = -0.751$; left: ($\chi^2(3) = 45.832$, $p = 0.001$, $\hat{\gamma} = -0.696$)] and of ankle prone passive dorsiflexion (flexed knees) ($\chi^2(2) = 13.019$, $p = 0.005$, V = 0.285). Conclusions: An 8-week individual corrective intervention exercise program may improve postural and musculoskeletal asymmetry status in young male soccer players.

Keywords: postural asymmetries evaluation; youth soccer; corrective exercise program

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1. Introduction

Several studies have previously observed that body posture asymmetry may cause muscle imbalance, musculoskeletal injuries, motor control impairment [1–6] and a reduction in exercise performance in young soccer players [7]. Postural asymmetry-induced injuries might be due to early specialization and/or to premature participation in sports [8–11]. Both early specialization and premature participation in sports may cause postural malalignment in young athletes since the development of their musculoskeletal system is not yet fully developed, predisposing young athletes to injury development [9–12]. It was also observed that the magnitude of asymmetry-induced injuries progressively increases in young soccer players over time, being higher in older adolescent players than in younger counterparts [13].

An additional factor that has been observed to be associated with asymmetrical adaptations in bone and muscle circumferences, as well as in lower limb flexibility and in muscular strength, is the presence of laterality in sports [2,14]. It was observed, for example, that the increased usage of the dominant leg in soccer may progressively negatively influence postural asymmetrical adaptations [15,16] and the asymmetry between the two legs due to the single-leg landing impact [17]. However, postural asymmetry-induced muscle imbalance, muscular injuries and motor control impairments [1–6], leading to a reduction in exercise performance [7], are potentially modifiable factors [16]. Zuk et al. (2019) pointed out that corrective exercises can be regularly applied for stabilizing the lumbar-pelvis complex, particularly in an attempt to protect spinal overload, during daily soccer training in young female soccer players [16]. However, apart from the study conducted by Zuk et al. (2019), according to the authors' knowledge, no other previous relevant study has applied any corrective individualized exercise intervention program in an attempt to correct the identified postural asymmetries of young female or male soccer players.

The only attempt that has been applied to potentially alleviate postural asymmetries as much as possible, and subsequently reduce injury incidences in young soccer players, is the FIFA 11 plus, which was proposed by the International Federation of Association Football (FIFA) in 2005. The FIFA 11 Plus is an injury prevention program aiming to provide a complete warm-up during training in an attempt to prevent injuries in amateur soccer players of 14 years of age and older [18]. Indeed, studies have shown that the 8-week implementation of the FIFA 11+ program was effective in reducing the injury rate [19–21] and in improving lower limb strength and body balance [22]. However, the FIFA 11+ Program effectively targets amateur players in general, since all players perform the same exercises, particularly during the warm-up. Nevertheless, each player has different corrective-exercise needs due to different body asymmetry cases and to the dissimilar levels and degrees of postural asymmetries. Consequently, the design of a specific individualized program for each soccer player is required for targeting the personal needs of each young athlete.

Although several studies have examined the relationship between body posture and injury development in young soccer players, no interventional studies incorporating individualized corrective-exercise programs (CEP) which target the correction of body asymmetries in young soccer players were located. Since postural asymmetries predispose young elite soccer players to injuries [2] and to a reduction in power performance and hamstring flexibility [7], specific corrective exercises that may be applied in an attempt to alleviate postural asymmetry incidences, and, therefore, to improve the overall musculoskeletal clinical and kinesiological health statuses of young athletes should be discovered. The current study, therefore, aimed to examine the effect of 8 weeks of individual CEP on postural and musculoskeletal asymmetries in young soccer players. It was hypothesized that the specific individual CEP, applied for 8 weeks to each player initially diagnosed with postural asymmetry, would induce significant reduction in the degree of postural asymmetry and subsequently may contribute to enhancing the overall musculoskeletal and kinesiological health statuses of young soccer players.

2. Materials and Methods

2.1. Participants

The participants (n = 80) of this clinical laboratory-based study were young male soccer players (age: 14.4 ± 1.2 years; body height: 166.3 ± 9.6 cm; body mass: 59.1 ± 11.5 kg), enrolled in professional soccer academies for at least 3 years and solely practicing soccer. Injured or sick players were excluded from the study. All parents were informed in writing regarding the purpose and the significance, as well as the experimental methods and procedures, of the study. Parental and participants' written informed consent was obtained prior to the initiation of any evaluation. All participants completed a medical history questionnaire. None of them were on any medication and/or had a history of any disease or evidence of musculoskeletal injury before or during the study period. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the National Bioethics Committee (EEBK/EP/2017/39). The coaches and parents were allowed to be present during all laboratory testing procedures.

2.2. Experimental Design

All anthropometric, postural and musculoskeletal asymmetry evaluations were performed in the laboratory during afternoon hours (3 pm–6 pm). The participants arrived in the lab in groups of four players. The baseline data were collected after the completion of the competitive season 2016–2017 and prior to the beginning of the preparation training for the next season 2017–2018. According to the individual evaluation results, participants with any postural asymmetries and/or musculoskeletal dysfunctions received a booklet with the necessary and specific CEP. Each booklet consisted of the appropriated CEP, where each CEP was designed to correct a postural or musculoskeletal asymmetry. The order of the CEP implementation was chosen due to the restoration nature of the exercise program and the musculoskeletal asymmetry corrective goal of each exercise program. Between the two corrective training sessions, a gap at least 72 h was applied. The implementation period of the intervention CEP lasted for 8 weeks. Thereafter, the participants were re-evaluated following the completion of the interventional program. Table 1 presents the timeline of the study.

Table 1. Intervention timeline.

Period	Baseline	1st Week	4th Week	8th Week	9th Week
Soccer Season	End of season 2016–2017	Beginning of Pre-season 2017–2018	End of Pre-season 2017–2018	In season 2017–2018	In season 2017–2018
Assessments and Intervention	Initial assessment		Intervention period (CEPs)		Reassessment

CEPs = Corrective exercise programs.

2.3. Anthropometric Characteristics Evaluation

Standing and sitting height as well as body mass were all measured with a stadiometer and calibrated scale (Tanita Digital Scale, BC-545n, Southampton, UK) without shoes to the nearest 0.1 cm and 0.1 kg, respectively.

2.4. Postural and Muscular Asymmetry Evaluation

Thoracic kyphosis and lumbar lordosis were evaluated using an inclinometer (AcuAngle® Inclinometer, Baseline Evaluation Instruments, White Plains, NY, USA) [23]. The angle of trunk rotation (ATR) was evaluated with a scoliometer (Mizuho Osi®, Mizuho OSI Inc., Tokyo, Japan) [24]. Furthermore, the pelvic tilt [25], the hamstring tightness (90–90 test), the hip abductor and hip adductor length, and the hip rotation (internal and external) [26] were evaluated with a goniometer (Baseline Evaluation Instruments, HiRes®12-100HR). The leg length discrepancy was measured with meter and the Stork test with a stopwatch [25]. The ankle prone passive dorsiflexion with extended and flexed knees were assessed and scored [26]. A Thomas test was implemented and scored as described by Magee (2014) [25]. The two functional movement screening tests, a deep squat and a hurdle test, were applied and scored as previously described [27].

2.5. Categorization

The participants were divided into two groups, normal and asymmetry groups, based on the cut-off values of each measured musculoskeletal variable [23,25,28] as indicated below. Based on kyphotic posture: asymmetry1 (lower value—35°), normal (36°–40°), and asymmetry2 (41°—through highest value) [23]; based on lordotic posture: asymmetry1 (lower value—25°), normal (26°–29°), and asymmetry2 (30°—through highest value) [23]; based on ATR: normal (0–4°) and asymmetry (5°—through highest value) [28]; based on pelvic tilt: normal (lower value—20°, used) and asymmetry (21°—through highest value) [25]; based on hamstring tightness (knee extension with flexed hip): normal (lower value—20°) and asymmetry (21°—through highest value) [29]; based on hip abduction (hip adductors length): normal and asymmetry [29]; based on hip external rotation: normal and asymmetry [29]; and based on hip internal rotation: normal and asymmetry [29]. Based on the cut-off values, the CEPs were designed to target the postural asymmetries.

2.6. Implementation of Intervention and CEPs

Each CEP was coded with a number and assigned for a condition. Seventeen different programs were designed for thoracic kyphosis (1), lumbar lordosis (2), right thoracic scoliosis (3), left thoracic scoliosis (4), right lumbar scoliosis (5), left lumbar scoliosis (6), anterior pelvic tilt (7), posterior pelvic tilt (8), hamstring stretching (9), hip adductor muscle length—stretching (10), iliopsoas stretching (11), rectus femoris stretching (12), tensor fasciae latae stretching (13), hip external rotator stretching (14), hip internal rotator stretching (15), soleus stretching (16) and gastrocnemius stretching (17) (see Supplementary Materials). In addition, for convenience, the program code was referred to the participants by the researchers during the programs' demonstration. Each participant was also coded, and instead of their names, their code was used in each program. Each CEP targeted one condition, assigned a frequency of twice per week, with an illustration of each exercise and the assigned sets and repetitions. In stretching exercises, holding time was assigned in seconds (see below). Prior to the demonstration, the researcher verbally explained the general instructions, all of which also could be found printed behind each program. In scoliosis programs some exercises should be performed unilaterally. Therefore, the letter R was used for right and the L for left side.

For maximizing muscle flexibility, the static stretching technique was used in the stretching CEPs [30]. The stretching programs were performed at the end of the regular daily training session for improving joint flexibility and range of motion (ROM) [30]. The duration of a static stretch should be less than 60 s to avoid it negatively influencing performance [31]. The static stretching protocol was designed based on Hadjicharalambous (2016) and Takeuchi and Nakamura (2020) [32,33]. The start-of-hold duration was 5 s for the first two weeks and progressively increased with 10 s during the third to fifth week and an additional 10 s during the sixth to eighth week. Each player alongside his CEPs also received written relevant general instructions. All the programs were designed to target the muscles influenced by each asymmetry, either with stretching or strengthening exercises or both [25]. The illustrations used for each program were derived from the Exercise Pro Version 5.0 developed by BioEx Systems, Inc.©, Smithville, TX, USA [34].

2.7. Statistical Analysis

All data are expressed as the mean ± standard deviation (SD) following a test for normality of distribution (Kolmogorov–Smirnov). For data that violated the assumptions of parametric analysis (i.e., equality of variance and normality of distribution) non-parametric examination was carried out, and these data were expressed as the median (interquartile range: IQR). For comparing the differences in the measured variables before and after the intervention, the non-parametric Wilcoxon test and parametric paired-samples t-test were performed. The effect sizes (ESs) for the Wilcoxon test were estimated according to Rosenthal's (1991) equation ($r = Z/\sqrt{N}$) [35]. The ESs for the paired t-test were estimated according to Rosenthal (1991) and Rosnow and Rosenthal's (2005) equation ($r = \sqrt{(t2/(t2 + df))}$) [35]. Nominal and ordinal data were analyzed by the Chi-square test (χ^2). The ESs were estimated and reported with the Cramer's V value for nominal and the Gamma value for ordinal data. The ESs were interpreted according to Cohen's criteria. A value of r = 0.1 was considered a small effect size, 0.3 represented a medium effect size, and 0.5 represented a large effect size [36]. A value of Cramer's V = 0.1 was considered a small effect size, 0.3 represented a medium effect size and 0.5 represented a large effect size [36]. The Gamma value ($\hat{\gamma}$) is used to test whether there is an association between ordinal variables [37]. The Gamma value ranges from −1.00 to 1.00, where a Gamma value of 0.00 represents no association; a Gamma value of 1.00 represents a perfect positive relationship between variables; and a Gamma value of −1.00 represents a perfect negative relationship between the ordinal variables [37].

3. Results

Anthropometric Characteristics

The anthropometric characteristics of the participants, before and after the application of the intervention programs, are presented in Table 2.

Table 2. Anthropometric characteristics.

Variable	Before Intervention	After Intervention
	Participants (n = 80, Median, [IQR])	
Age (years)	14.36 [1.24]	14.36 [1.24]
Body standing height (cm)	166.30 [9.57]	168.16 [9.14]
Right leg length (cm)	92.21 [5.76]	92.26 [5.76]
Left leg length (cm)	92.34 [5.73]	92.46 [5.79]
Variable	**Before Intervention**	**After Intervention**
	Participants (n = 80, Mean ± SD)	
Body sitting height (cm)	83.34 ± 6.13	84.19 ± 5.85
Body mass (kg)	59.13 ± 11.54	62 ± 11.12

The descriptive data of postural and muscular asymmetries before and after the intervention programs are presented in Table 3.

There was a statistically significance difference in sitting height ((pre = 83.3 cm, post = 84.2 cm), t(79) = −8.09, $p < 0.001$) and in body mass ((pre = 59.1 kg, post = 62.0 kg), t(79) = −8.78, $p < 0.001$) (Table 3), both being higher by the end of the intervention programs.

Thomas test score results demonstrated a statistically significant improvement, $\chi^2(3) = 52.281$, $p = 0.001$, $\hat{\gamma} = -0.751$, for the right side, and, $\chi^2(3) = 45.832$, $p = 0.001$, $\hat{\gamma} = -0.696$, for the left side (Figure 1) following the implementation of the intervention program.

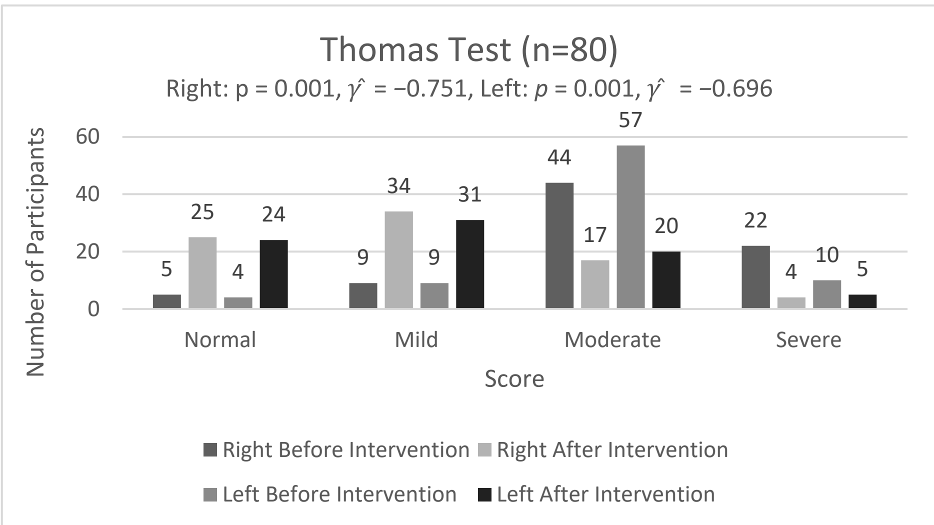

Figure 1. Thomas Test: pre- and post-intervention results, $\hat{\gamma}$ = effect size.

Table 3. Descriptive data and Wilcoxon Test.

Postural and Muscular Asymmetries	Before Intervention Median [IQR]	After Intervention Median [IQR]	Z Score	*p*	ES
Standing height (cm)	166.30 [9.57]	168.16 [9.14]	−7.153	0.001	−0.80
Thoracic kyphosis (°)	43.25 [8.87]	42.68 [6.73]	−0.808	0.419	−0.09
Lumbar lordosis (°)	31.39 [7.17]	29.76 [7.16]	−1.927	0.054	−0.22
Spinal rotation (A) (°)	2.33 [2.29]	1.25 [1.87]	−4.987	0.001	−0.56
Spinal rotation (B) (°)	0.19 [0.73]	0.05 [0.35]	−1.444	0.149	−0.16
Pelvic tilt (°)	19.84 [3.71]	19.88 [2.97]	0.000	1	0
Right hamstring (90-90 test) (°)	30.69 [12.60]	23.75 [11.62]	−4.957	0.001	−0.55
Left hamstring (90-90 test) (°)	33.44 [12.94]	27.19 [13.36]	−4.306	0.001	−0.48
Right hip abduction (°)	45.75 [6.76]	45.88 [5.67]	−0.151	0.880	−0.02
Left hip abduction (°)	46.41 [5.34]	47.06 [5.44]	−0.923	0.356	−0.10
Right hip external rotation (°)	29.13 [4.27]	32.31 [4.35]	−4.137	0.001	−0.46
Right hip internal rotation (°)	25.94 [5.16]	28.00 [6.68]	−2.304	0.021	−0.26
Left hip external rotation (°)	25.63 [6.43]	27.50 [5.63]	−2.325	0.020	−0.26
Left hip internal rotation (°)	28.13 [4.99]	30.44 [4.22]	−3.168	0.002	−0.35
Right leg length (cm)	92.21 [5.76]	92.26 [5.76]	−0.905	0.366	−0.10
Left leg length (cm)	92.34 [5.73]	92.46 [5.79]	−2.460	0.014	−0.28
Stork Test—opened eyes right leg (s)	26.72 [6.95]	28.33 [5.79]	−2.940	0.003	−0.33
Stork Test—opened eyes left leg (s)	26.46 [6.99]	28.24 [5.65]	−2.986	0.003	−0.33
Stork Test—closed eyes right leg (s)	10.69 [8.74]	14.28 [10.31]	−3.515	0.001	−0.39
Stork Test—closed eyes left leg (s)	9.69 [9.19]	13.24 [10.30]	−3.833	0.001	−0.43

ES: Effect Size estimate.

The ankle prone passive dorsiflexion with flexed knees demonstrated a statistically significant improvement, $\chi^2(2) = 13.019$, $p = 0.005$, V = 0.285, following the implementation of the intervention programs (Figure 2). However, there was no statistically significant improvement in the ankle prone passive dorsiflexion with extended knee, although the number of the participants/players who turned to normal cases increased from 57 to 67 following the implementation of the intervention programs, $\chi^2(3) = 5.789$, $p = 0.122$, V = 0.190 (Figure 2).

The Deep Squat variable did not demonstrate a statistically significant improvement ($\chi^2(2) = 5.381$, $p = 0.068$, $\hat{\gamma} = 0.420$) following the application of the intervention programs, despite the fact that the number of participants who reached normal cases increased from 57 to 69 after the intervention (Figure 3).

Following the implementation of the intervention programs, the Hurdle Test results demonstrated no statistically significant improvement, for the right side, $\chi^2(2) = 0.432$, $p = 0.806$, $\hat{\gamma} = -0.092$, or for the left side, $\chi^2(2) = 1.927$, $p = 0.382$, $\hat{\gamma} = 0.113$ (Figure 4).

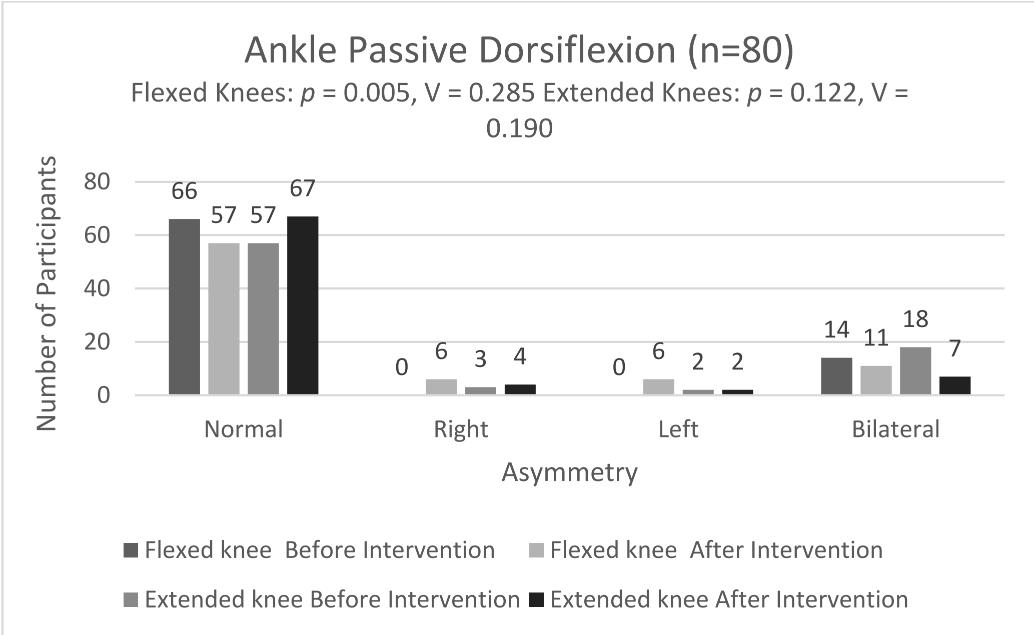

Figure 2. Ankle passive dorsiflexion: pre- and post-intervention results, V = effect size.

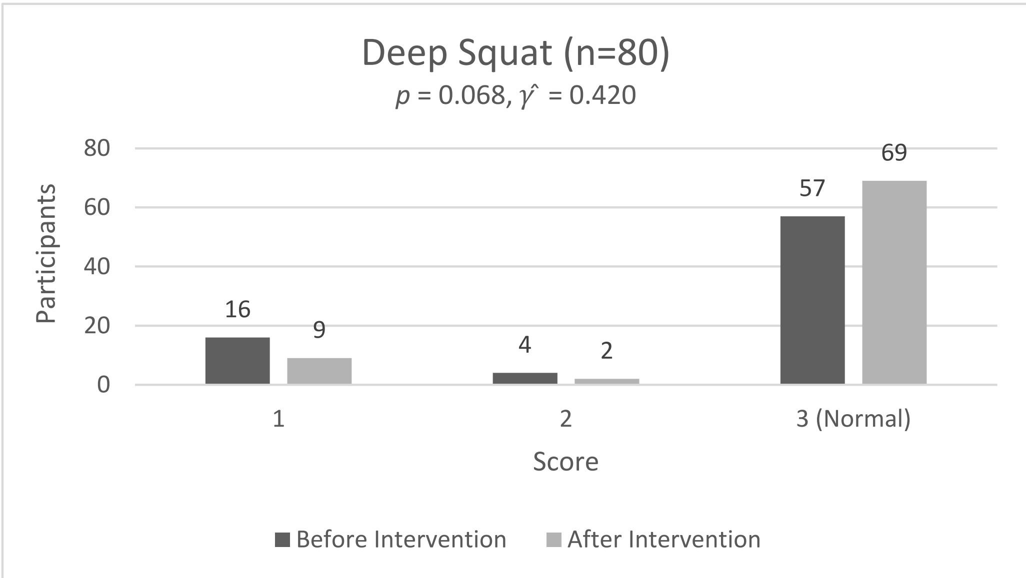

Figure 3. Deep squat: pre- and post-intervention results, $\hat{\gamma}$ = effect size.

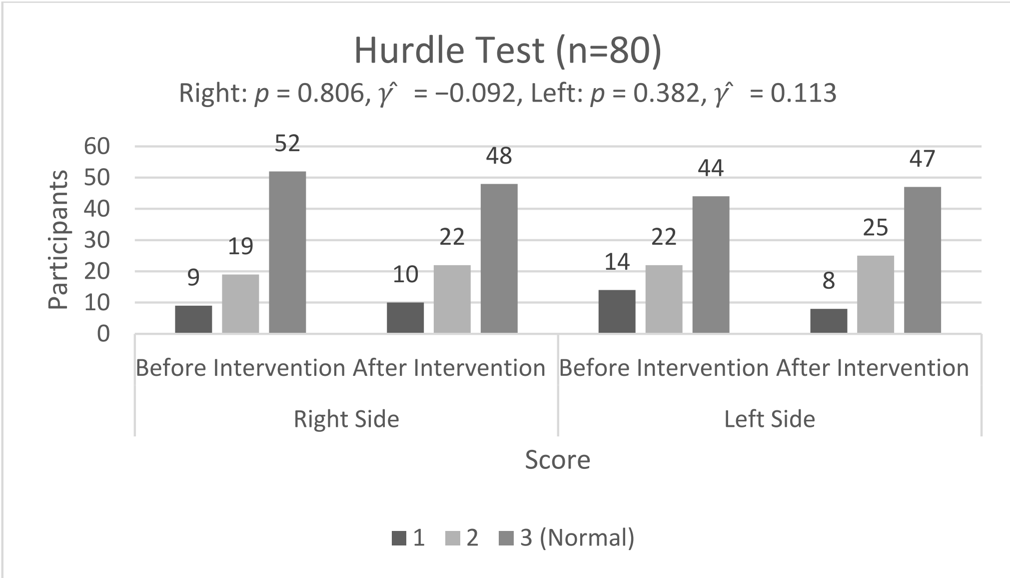

Figure 4. Hurdle Test: pre- and post-intervention results, $\hat{\gamma}$ = effect size.

4. Discussion

The aim of the current clinical laboratory-based study was to examine the effect of 8 weeks of individualized CEP on postural and musculoskeletal asymmetries in young soccer players. According to the authors' knowledge, this is the first study that has examined the effect of individual specific intervention programs in an attempt to improve the overall musculoskeletal health of young soccer players by individually correcting their postural asymmetries. The main findings of the current study were the significant corrections in several of the tested asymmetries (such as the ATR (A), the 90-90 test for hamstring flexibility, the external and internal hip rotation, the Stork Test, the Thomas test, and the ankle prone passive dorsiflexion) following the application of the intervention programs. These results suggest that 8 weeks of an individual CEP program may improve postural and musculoskeletal asymmetry statuses in young male soccer players. Considering that postural asymmetries may induce injury development [1–6] and a reduction in exercise performance in young soccer players [7], they should be regularly screened for postural and musculoskeletal asymmetries for an early diagnosis and a primary correction purpose.

In the current study, the ATR (A) results demonstrated a statistically significant improvement with a large effect size, following the application of the intervention programs. In mild scoliosis, the main goal of exercise intervention applications is to decrease the progression of the scoliosis curvature [38], while the same intervention has been used as the only treatment for severe adolescent idiopathic scoliosis as well [39]. In our study, most of the participants observed were in the functional scoliosis range, and individualized CEP interventions were able to improve their functional scoliosis curvature. Our results support a previous study suggesting that scoliotic posture and/or non-structural scoliosis are impermanent and reversible [40]. There was also improvement in the co-existing spine asymmetries, such as thoracic kyphosis or lumbar lordosis, results that are in agreement with a previous report [41], although in this previous study the frequency was everyday treatment under direct supervision, for 30 to 60 min, and lasted for three months in junior soccer players. However, only 8 weeks of CEP intervention may induce similar results in young soccer players.

Interestingly, no significant improvement was found in the results of thoracic kyphosis or lumbar lordosis following the intervention program, which is not in agreement with the study of Mahrová et al. (2014). In our study, the suggested frequency of the intervention program was twice a week and lasted for 8 weeks. However, in the study of Mahrová et al. (2014), the intervention period lasted for six months and the hold during stretching and rest periods between sets was not more than 5 s. Thus, the total time of the stretching sessions in both groups was 10–15 min, resulting in 40–65 min per week [3]. Similar to our study, holding during the stretching exercises started with 5 s, but progressively increased, resulting in 7–12 min per stretching program and a total of 14–24 min per week per program, a frequency much less than one used in the study of Mahrová et al. (2014). Likewise, stretching exercises were used for lower body muscle tightness which decreased involved joints' ROM, and combined with strengthening exercises targeting the weak muscles, resulted in an improved muscle balance and postural asymmetries [3]. Consequently, a greater training frequency when combined with a longer-training intervention period, such as the one used in a previous study (Mahrová et al. 2014), might possibly contribute to further improving thoracic kyphosis and lumbar lordosis.

During the 8-week intervention program, there was a statistically significant increase in standing and sitting height and in body mass results as well. According to the World Health Organization growth charts, z-scores for boys aged 5 to 19 years old show that the height and mass norms change every three months [10]. In our study, significant changes occurred within 8 weeks. Height is the simplest parameter for growth and affects almost all orthopedic conditions during a child's growth [42]. An increase in body height was found to increase trunk asymmetry [43]. Consequently, in the current study, the significant increase in standing and sitting height observed within 8 weeks might have negatively affected the programs' effectiveness in correcting thoracic kyphosis and lumbar lordosis. An alternative reason could be that the frequency of the intervention program application and the 8-week duration of the training intervention was not adequate to contribute to significantly improving thoracic kyphosis and lumbar lordosis. A combination of both above mentioned reasons could have caused the lack of improvement in thoracic kyphosis and lumbar lordosis following the intervention program.

Hamstring flexibility was significantly improved bilaterally, with a large effect size, following the application of CEP, a result which is supported by several previous studies [32,44]. The frequency of our proposed hamstring stretching program was twice a week, 2.5 to 12.5 min, for 8 weeks. It is essential to preserve flexibility in young athletes, through stretching programs from an early age [12]. It was found that the inclusion of stretching programs on tight hamstrings in 6- to 11-year-old school children can improve their performances in straight-leg-raise and sit-and-reach tests. In order for such a program to be effective, it was suggested that stretching exercises should be included during both the warm-up and cool-down periods [44]. It was also found that studies with two to four sessions per week, 4 to 7 min per session, 20 s holding per stretching, and between 8 and 32 weeks duration, may effectively improve hamstring flexibility [44]. Hill and Najera (2020) tested the efficacy of the hamstring stretching program in 13–15-year-old students. They found significant improvements in the intervention group who performed a 3 min stretching program, holding each stretch for 20 s, twice a week for nine weeks [45]. Consequently, the results of the current study are in line with these previous reports and further support the significance and inclusion of stretching exercises in the individual CEPs of young soccer players.

Both hip external and internal rotation ROM demonstrated statistically significant improvements following the application of the current individual intervention exercise programs. Similarly to our study, a previous study showed that stretching exercises used for lower-body muscle tightness and decreased ROM, combined with strengthening exercises targeting weak muscles, results in an improved muscle balance and postural asymmetries [3]. Mahrová et al. (2014) found that the combined program, which included joint mobilization exercises, elicited improvement in the left hip flexion ROM. Improvements in the rectus femoris, tensor fasciae latae, knee flexors, and triceps surae bilateral muscles shortening were also found. Additionally, improvements in the left iliopsoas, right rectus femoris, bilateral tensor fasciae latae, bilateral knee flexors, and right triceps surae were found [3].

In our study, the Thomas test score included testing iliopsoas, rectus femoris, and tensor fasciae latae muscle tightness. Similar to the study of Mahrová et al. (2014), the results from our study showed that both sides demonstrated statistically significant bilateral improvements in the Thomas test score, with a strong association of the Gamma value. Regarding ankle dorsiflexion, Mahrová et al. (2014) found no modification in the ROM; only ankle plantar flexion ROM was improved [3]. In our study, the ankle prone passive dorsiflexion was passively assessed in positions with extended and flexed knees in order to test gastrocnemius and soleus shortening, respectively. Soleus shortening was significantly improved with a medium effect size. However, in the study of Mahrová et al. (2014), the evaluation of joint mobility was performed with 2D video-graphic kinematic analysis [46], which is a more accurate test that the one used in our study. Additionally, in the study of Mahrová et al. (2014), the intervention program lasted longer (six months) compared to our study. However, although these differences exist, 8 weeks of CEP may also induce significant increases in soleus shortening in young soccer players.

The current study did not evaluate the effect of postural asymmetry corrective exercise programs on exercise performance parameters, which would be the ideal research methodology scenario of the study. Considering, however, the absence of a control group, by using this particular methodology, we wanted the participants of the current study to maintain as much focus as possible toward performing their intervention programs properly and with high motivation without being disturbed by fitness evaluations. Future studies, however, using elite and preferably young soccer players, may examine the effect of individualized exercise corrective programs not only on postural asymmetries but simultaneously also on exercise performance parameters. A previous study from our laboratory, for example, examined the effect of postural asymmetries on some exercise performance parameters, and suggested that kyphotic and scoliotic postural asymmetries deteriorate neuromuscular explosiveness performance and diminish lower limb flexibility in young international-level soccer players [7]. Other recent studies suggested that the presence of inter-limb asymmetries may negatively affect dynamic task performance and represent an injury risk factor in male soccer players [47], and that the magnitude and direction of within-limb strength imbalances were inconsistent when compared within the same assessment under different-resistance load conditions in youth elite soccer players [48]. Using also Y-Balance-Test scores, González-Fernández et al. (2022) [49] examined postural stability and inter-limb asymmetry in the anterior, posteromedial and posterolateral directions in youth and mature semi-professional soccer players with different competitive levels and playing positions, revealing that inter-limb asymmetry showed higher values in lower age categories, and center-backs were worse than wingers and forwards. Based on the results of the current study, in combination with the results derived from the aforementioned discussed studies, we could hypothesize that correcting postural asymmetries in lower age categories with specific individualized exercise intervention programs, whilst also taking into consideration the playing position of the children, will contribute significantly in improving exercise performance parameters and eliminating injury risk factors in youth soccer players.

From a methodological point of view, recent advances have suggested the importance of using countermovement jumps as a tool for detecting bilateral asymmetries in hip and knee strength in elite young soccer players [50]. However, others have not supported the use of functional tests, such as the isometric hip torque, which, as they are resembling sports, could be used for movement analysis and as injury-minimizing factors in soccer players [51]. Consequently, using the methodological techniques for detecting postural asymmetries employed in the current study may be considered an easy, reliable and safe methodological approach for regularly evaluating postural and muscular asymmetries in youth athletes.

4.1. Limitations and Strengths

A limitation of the current study was the absence of a control group. This, however, was inevitable for ethical reasons, since it would be inappropriate to exclude a young athlete from an individual CEP which could improve his soccer performance and health.

In addition, direct supervision was not always feasible since the three soccer academies which participated in the study were in three different cities. However, coaches were able to monitor the training intervention and supervise the young soccer players during the training period.

4.2. Practical Application

From the point of view of practical application and for a better translation of laboratory knowledge to daily practice in youth soccer, the medical teams of soccer academies should regularly perform clinical evaluations of postural asymmetry identification in young athletes. This early diagnosis may contribute in reducing spinal asymmetry incidences in young soccer players through specific individual corrective exercise intervention programs. The primary purpose of these corrective programs is to progressively improve the physiological adaptations of the spine through specific training intervention exercises in an attempt to reduce and/or eliminate postural asymmetries during the developmental stages of young soccer players, and, therefore, to support their musculoskeletal health and their long-term training development.

5. Conclusions

An 8-week individual interventional corrective exercise program may improve postural asymmetries in young male soccer players between the ages of 12 and 17. The inclusion, therefore, of both strengthening exercises targeting weak muscles and stretching exercises targeting tight muscles have effectively improved several postural and musculoskeletal asymmetries and, therefore, the overall musculoskeletal health statuses of young soccer players. Young soccer players should be regularly screened for postural and musculoskeletal asymmetries for early correction purposes. Further research is required to test whether a direct and firm supervised intervention and a more prolonged exposure to CEPs would better-improve postural and musculoskeletal asymmetries in young soccer players.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13116445/s1, Corrective Exercise Programs.

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References

1. Arede, J.; Fernandes, J.; Moran, J.; Leite, N.; Romero-Rodriguez, D.; Madruga-Parera, M. Effects of an Integrative Neuromuscular Training Protocol vs. FIFA 11+ on Sprint, Change of Direction Performance and Inter-Limb Asymmetries in Young Soccer Players. *Int. J. Sports Sci. Coach.* **2022**, *17*, 54–62. [CrossRef]
2. Bernardes Marques, V.; Menezes Medeiros, T.; de Souza Stigger, F.; Yuzo Nakamura, F.; Manfredini Baroni, B. The Functional Movement Screen (FMS^{TM}) in elite young soccer players between 14 and 20 years: Composite score, individual-test scores and asymmetries. *Int. J. Sports Phys. Ther.* **2017**, *12*, 977. [CrossRef]
3. Mahrová, A.; Hráský, P.; Zahálka, F.; Požárek, P. The Effect of Two Types of Stretching on Flexibility in Selected Joints in Youth Soccer Players. *Acta Gymnica* **2014**, *44*, 23–32. [CrossRef]
4. Mandorino, M.; Figueiredo, A.J.; Cima, G.; Tessitore, A. A Data Mining Approach to Predict Non-Contact Injuries in Young Soccer Players. *Int. J. Comput. Sci. Sport* **2021**, *20*, 147–163. [CrossRef]
5. Schwank, A.; Blazey, P.; Asker, M.; Møller, M.; Hägglund, M.; Gard, S.; Skazalski, C.; Andersson, S.H.; Horsley, I.; Whiteley, R. 2022 Bern Consensus Statement on Shoulder Injury Prevention, Rehabilitation, and Return to Sport for Athletes at All Participation Levels. *J. Orthop. Sports Phys. Ther.* **2022**, *52*, 11–28. [CrossRef]
6. Towlson, C.; Salter, J.; Ade, J.D.; Enright, K.; Harper, L.D.; Page, R.M.; Malone, J.J. Maturity-Associated Considerations for Training Load, Injury Risk, and Physical Performance in Youth Soccer: One Size Does Not Fit All. *J. Sport Health Sci.* **2021**, *10*, 403–412. [CrossRef]
7. Theodorou, E.; Christou, M.; Apostolidis, A.; Tryfonidis, M.; Zaras, N.; Hadjicharalambous, M. The Effect of Spinal Asymmetries on Physical Fitness Parameters in Young Elite Soccer Players. *Symmetry* **2022**, *14*, 2497. [CrossRef]
8. Asadi, M.; Nourasteh, A.; Daneshmandi, H. Comparison of Spinal Column Curvatures between Master Football Players and Their Non-Athletes Peers. *IJSS* **2014**, *5*, 338–342.
9. Puzzitiello, R.N.; Rizzo, C.F.; Garvey, K.D.; Matzkin, E.G.; Salzler, M.J. Early Sports Specialisation and the Incidence of Lower Extremity Injuries in Youth Athletes: Current Concepts. *J. ISAKOS* **2021**, *6*, 339–343. [CrossRef]
10. Mosher, A.; Till, K.; Fraser-Thomas, J.; Baker, J. Revisiting Early Sport Specialization: What's the Problem? *Sports Health Multidiscip. Approach* **2022**, *14*, 13–19. [CrossRef]
11. AMSSM Collaborative Research Network Youth Early Sport Specialization Summit; Tenforde, A.S.; Montalvo, A.M.; Nelson, V.R.; Myer, G.D.; Brenner, J.S.; DiFiori, J.P.; Jayanthi, N.A.; Marshall, S.W.; Kliethermes, S.A.; et al. Current Sport Organization Guidelines From the AMSSM 2019 Youth Early Sport Specialization Research Summit. *Sports Health Multidiscip. Approach* **2022**, *14*, 135–141. [CrossRef]
12. Daga, F.A.; Panzolini, M.; Allois, R.; Baseggio, L.; Agostino, S. Age-Related Differences in Hamstring Flexibility in Prepubertal Soccer Players: An Exploratory Cross-Sectional Study. *Front. Psychol.* **2021**, *12*, 5002.
13. Forte, P.; Morais, J.E.; Barbosa, T.M.; Reis, A. Análise Da Magnitude Das Assimetrias Posturais Em Crianças e Jovens Futebolistas. *Rev. Bras. Futeb. Braz. J. Soccer Sci.* **2021**, *13*, 3–16.
14. Taketomi, S.; Kawaguchi, K.; Mizutani, Y.; Yamagami, R.; Sameshima, S.; Takei, S.; Kage, T.; Kono, K.; Inui, H.; Fujiwara, S.; et al. Musculoskeletal Asymmetry in Young Soccer Players: Differences between the Dominant and Nondominant Leg. *Int. J. Hum. Mov. Sports Sci.* **2022**, *10*, 294–302. [CrossRef]
15. DeLang, M.D.; Kondratek, M.; DiPace, L.J.; Hew-Butler, T. Collegiate male soccer players exhibit between-limb symmetry in body composition, muscle strength, and range of motion. *Int. J. Sports Phys. Ther.* **2017**, *12*, 1087–1094. [CrossRef] [PubMed]
16. Żuk, B.; Sutkowski, M.; Paśko, S.; Grudniewski, T. Posture Correctness of Young Female Soccer Players. *Sci. Rep.* **2019**, *9*, 11179. [CrossRef]
17. Wang, J.; Fu, W. Asymmetry between the Dominant and Non-Dominant Legs in the Lower Limb Biomechanics during Single-Leg Landings in Females. *Adv. Mech. Eng.* **2019**, *11*, 168781401984979. [CrossRef]
18. Dvorak, J.; Junge, A.; Grimm, K. *Football Medicine Manual*, 2nd ed.; F-MARC: Zurich, Switzerland, 2009; pp. 83–90.
19. Zein, M.; Kurniarobbi, J.; Agung, N. The effect of FIFA 11+ as an injury prevention program in youth futsal players. *Br. J. Sports Med.* **2014**, *48*, 673.2–674. [CrossRef]
20. Owoeye, O.B.; Akinbo, S.R.; Tella, B.A.; Olawale, O.A. Efficacy of the FIFA 11+ Warm-up Programme in Male Youth Football: A Cluster Randomised Controlled Trial. *J. Sports Sci. Med.* **2014**, *13*, 321.
21. Sadigursky, D.; Braid, J.A.; De Lira, D.N.L.; Machado, B.A.B.; Carneiro, R.J.F.; Colavolpe, P.O. The FIFA 11+ Injury Prevention Program for Soccer Players: A Systematic Review. *BMC Sports Sci. Med. Rehabil.* **2017**, *9*, 18. [CrossRef]
22. Arsenis, S.; Gioftsidou, A.; Ispyrlidis, I.; Kyranoudis, A.; Pafis, G.; Malliou, P.; Beneka, A. Effects of the FIFA 11+ Injury Prevention Program on Lower Limb Strength and Balance. *J. Phys. Educ. Sport* **2020**, *20*, 592–598.
23. Van Blommestein, A.S. Reliability of Measuring Thoracic Kyphosis Angle, Lumbar Lordosis Angle and Straight Leg Raise with an Inclinometer. *Open Spine J.* **2012**, *4*, 10–15. [CrossRef]
24. Members of the international Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT); Kotwicki, T.; Negrini, S.; Grivas, T.B.; Rigo, M.; Maruyama, T.; Durmala, J.; Zaina, F. Methodology of Evaluation of Morphology of the Spine and the Trunk in Idiopathic Scoliosis and Other Spinal Deformities—6th SOSORT Consensus Paper. *Scoliosis* **2009**, *4*, 26. [CrossRef] [PubMed]
25. Magee, D.J. *Orthopedic Physical Assessment*, 6th ed.; Saunders, an imprint of Elservier Inc.: North York, ON, Canada, 2014.
26. Clarkson, H.M. *Musculoskeletal Assessment: Joint Motion and Muscle Testing*, 3rd ed.; Wolters Kluwer/Lippincott Williams & Wilkins Health: Philadelphia, PA, USA, 2013.

27. Cook, G. Movement: Functional Movement Systems: Screening, Assessment. In *Corrective Strategies*, 1st ed.; On Target Publications: Aptos, CA, USA, 2020; pp. 73–106.
28. Negrini, S.; Aulisa, A.G.; Aulisa, L.; Circo, A.B.; de Mauroy, J.C.; Durmala, J.; Grivas, T.B.; Knott, P.; Kotwicki, T.; Maruyama, T.; et al. 2011 SOSORT Guidelines: Orthopaedic and Rehabilitation Treatment of Idiopathic Scoliosis during Growth. *Scoliosis* **2012**, *7*, 3. [CrossRef]
29. Clark, M.; Lucett, S. *NASM Essentials of Corrective Exercise Training*; Lippincott Williams & Wilkins: Philadelphia, PA, USA, 2010.
30. Judge, L.W.; Avedesian, J.M.; Bellar, D.M.; Craig, B.W.; Langley, J.; Nordmann, N.; Dickin, C. Pre- and Post-Activity Stretching Practices of Collegiate Soccer Coaches in the United State. *Int. J. Exerc. Sci.* **2020**, *13*, 260.
31. Konrad, A.; Nakamura, M.; Bernsteiner, D.; Tilp, M.T. The Accumulated Effects of Foam Rolling Combined with Stretching on Range of Motion and Physical Performance: A Systematic Review and Meta-Analysis. *J. Sports Sci. Med.* **2021**, *20*, 535–545. [CrossRef]
32. Hadjicharalambous, M. The Effects of Regular Supplementary Flexibility Training on Physical Fitness Performance of Young High-Level Soccer Players. *J. Sports Med. Phys. Fitness* **2015**, *56*, 699–708.
33. Takeuchi, K.; Nakamura, M. The Optimal Duration of High-Intensity Static Stretching in Hamstrings. *PLoS ONE* **2020**, *15*, e0240181. [CrossRef]
34. BioEx Systems, Inc. ©. Available online: https://Exercise-pro.Software.Informer.Com/5.0/ (accessed on 12 June 2017).
35. Rosenthal, R. *Meta-Analytic Procedures for Social Research*, 2nd ed.; Sage: Newbury Park, CA, USA, 1991.
36. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*; Lawrence Erlbaum.: Hillsdale, NJ, USA, 1988.
37. Agresti, A. *Analysis of Ordinal Categorical Data*; John Wiley & Sons: Hoboken, NJ, USA, 2010; Volume 656.
38. Balne, N.K.; Jabeen, S.A.; Mathukumalli, N. Classifications of Adolescent Idiopathic Scoliosis in Relation to Physiotherapy. *Indian J. Physiother. Occup. Ther.* **2020**, *14*, 91–96.
39. Park, J.; So, W.-Y. The Effect of the Schroth Rehabilitation Exercise Program on Spinal and Feet Alignment in Adolescent Patients with Idiopathic Scoliosis: A Pilot Study. *Healthcare* **2022**, *10*, 398. [CrossRef]
40. Li, X.; Zhang, L. Sports Rehabilitation of Patients with Scoliosis Based on Intelligent Data Collection Technology under the Background of Artificial Intelligence. In *2021 3rd International Conference on Artificial Intelligence and Advanced Manufacture*; ACM: Manchester, UK, 2021; pp. 1131–1136. [CrossRef]
41. Kese, A.; Dragomir, M.; Daniel, C.; Ionescu, G.; Brabiescu-Calinescu, L. The benefits of kinetotherapy to the reductive idiopathic scoliosis at junior football players. In Proceedings of the 5th International Multidisciplinary Scientific Conference on Social Sciences and Arts Sgem, Vienna, Austria, 19–21 March 2018; pp. 889–896.
42. Hefti, F. *Pediatric Orthopedics in Practice*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2007.
43. Adamczewska, K.; Wiernicka, M.; Kamińska, E.; Małecka, J.; Dąbrowska, A.; Malchrowicz-Mośko, E. Annual Observation of Changes in the Angle of Trunk Rotation. Trunk Asymmetry Predictors. A Study from a Scoliosis Screening in School Adolescents. *Int. J. Environ. Res. Public. Health* **2020**, *17*, 1899. [CrossRef] [PubMed]
44. Becerra Fernandez, C.-A.; Merino-Marban, R. Efficacy of Hamstring Stretching Programs in Schoolchildren. A Systematic Review. *Timisoara Phys. Educ. Rehabil. J.* **2015**, *8*, 36–43. [CrossRef]
45. Hill, G.; Najera, W. Effect of a Two-Sessions-Per-Week Stretching Program on Hamstring Extensibility in Latino High School Students. *Phys. Educ.* **2020**, *77*, 455–464. [CrossRef]
46. Janura, M.; Zahálka, F. *Kinematická Analýza Pohybu Člověka*; Univerzita Palackého: Olomouc, Czech Republic, 2004.
47. Buoite Stella, A.; Galimi, A.; Martini, M.; Di Lenarda, L.; Murena, L.; Deodato, M. Muscle Asymmetries in the Lower Limbs of Male Soccer Players: Preliminary Findings on the Association between Countermovement Jump and Tensiomyography. *Sports* **2022**, *10*, 177. [CrossRef]
48. Ascenzi, G.; Filetti, C.; Di Salvo, V.; Nuñez, F.J.; Suarez-Arrones, L.; Ruscello, B.; Francioni, F.M.; Villanueva, A.M. Inter-Limb Asymmetry in Youth Elite Soccer Players: Effect of Loading Conditions. *PLoS ONE* **2022**, *17*, e0269695. [CrossRef]
49. González-Fernández, F.T.; Martínez-Aranda, L.M.; Falces-Prieto, M.; Nobari, H.; Clemente, F.M. Exploring the Y-Balance-Test Scores and Inter-Limb Asymmetry in Soccer Players: Differences between Competitive Level and Field Positions. *BMC Sports Sci. Med. Rehabil.* **2022**, *14*, 1–13. [CrossRef]
50. Wrona, H.L.; Zerega, R.; King, V.G.; Reiter, C.R.; Odum, S.; Manifold, D.; Latorre, K.; Sell, T.C. Ability of Countermovement Jumps to Detect Bilateral Asymmetry in Hip and Knee Strength in Elite Youth Soccer Players. *Sports* **2023**, *11*, 77. [CrossRef]
51. Rodrigues, G.; Dias, A.; Ribeiro, D.; Bertoncello, D. Relationship between Isometric Hip Torque with Three Kinematic Tests in Soccer Players. *Phys. Act. Health* **2020**, *4*, 142–149. [CrossRef]