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The Effect of Corrective Training with Varying Loads on Several Kinematic Indicators and Long Jump Performance in Young Athletes

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Abstract

Masalah utama dalam lompat jauh junior di Irak adalah stagnasi prestasi akibat kurangnya pemanfaatan analisis biomekanika dan latihan korektif berbasis indikator kinematik. Penelitian ini bertujuan untuk: (1) menyusun program latihan korektif dengan beban bervariasi (3%, 4%, dan 5% dari massa tubuh), (2) mengidentifikasi pengaruhnya terhadap tujuh indikator kinematik (sudut tolakan, sudut awal lepas landas, tinggi pusat gravitasi saat kontak pertama dan terakhir, sudut absolut tungkai tumpu, sudut absolut paha tungkai tumpu, serta sudut lutut tungkai ayun), dan (3) mengidentifikasi pengaruhnya terhadap prestasi lompat jauh. Metode penelitian menggunakan desain kuasi-eksperimental dengan pretest-posttest kontrol grup. Sampel berjumlah 16 atlet putra usia 17–19 tahun yang dibagi menjadi kelompok eksperimen (n=8) dan kontrol (n=8). Kelompok eksperimen menjalani latihan korektif berbeban selama 8 minggu (3 kali/minggu), sementara kelompok kontrol mengikuti latihan rutin klub. Pengukuran kinematik menggunakan perangkat lunak KINOVEA. Hasil menunjukkan peningkatan signifikan pada seluruh variabel kinematik dan prestasi lompatan pada kelompok eksperimen ($p<0,05$), dengan effect size besar hingga sangat besar (Cohen's $d=1,14–2,80$). Kelompok eksperimen juga secara signifikan lebih unggul dibanding kontrol pada seluruh variabel posttest. Simpulannya, latihan korektif dengan beban bervariasi 3–5% massa tubuh efektif meningkatkan indikator kinematik dan prestasi lompat jauh atlet muda, sehingga direkomendasikan sebagai metode pelatihan berbasis bukti ilmiah.

Keywords: Corrective exercises; varying weights; kinematic indicators; long jump; young athletes; biomechanics; takeoff angle; jump performance

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Introduction

Long jump is one of the most prestigious and technically demanding events in athletics. It has received considerable global attention, manifested in the continuous breaking of world records through the progressive development of performance levels resulting from scientific research and studies related to this event. The long jump depends on a systematic interaction between physical abilities, motor coordination, various biomechanical variables, and accuracy in executing the different technical phases approach run, takeoff, flight, and landing (Fouad, 2024). (Hay, 1993; Luhtanen & Komi, 1979). Achieving success in these phases is not limited to possessing high physical abilities such as speed and strength alone.

Rather, it is largely related to the efficiency of motor performance based on precise scientific foundations, especially those related to kinematic indicators. Kinematic indicators explain the nature of movement in terms of speed, angles, distances, and performance time (Hughes & Bartlett, 2002). These indicators provide coaches and researchers with objective data to evaluate and improve technique (Fernandez-Echeverria et al., 2017). The importance of employing motion analysis in studying technical and kinetic performance has contributed to a qualitative shift in understanding the motor performance of various activities, including the long jump. Through biomechanical analysis, strengths and weaknesses in an athlete's technique can be revealed, and training programs can be directed toward specific improvements.

Kinematic indicators have become one of the most important determinants that directly affect jump distance. Any slight defect in these indicators even at the level of a few degrees or centimeters may lead to a significant decrease in achievement, even if the player has high physical abilities (Schexnayder, 2006). Focusing on correcting the motor path through training programs based on scientific principles is essential to reach optimal performance. Among modern training methods that have received widespread attention in recent decades, corrective exercises come as an effective means of addressing motor errors and improving performance efficiency (Pârvu 2024).

Corrective exercises aim to redirect movement along the correct path by repeating the performance in a deliberate manner, focusing on the technical aspects that need development (Bompa & Haff, 2009). When these corrective exercises are combined with the use of various weights such as free weights, added weights on limbs, weighted jackets, or auxiliary tools like medicine balls they contribute to the development of specific muscle strength and the improvement of neuromuscular coordination (McHenry & Myers, 2025). This combination is particularly beneficial for young athletes because it enhances proprioception, teaches proper movement patterns under load, and transfers training effects directly to competition performance (Young, 2006)

The importance of studying the effect of corrective exercises with various weights on kinematic indicators and performance in the long jump event for young people is therefore evident (Brustio et al., 2022). This approach links theoretical biomechanical principles with applied training solutions, contributing to developing motor performance and achieving better performance levels. This study represents a scientific attempt to employ corrective exercises using various weights within a precise biomechanical framework, with the aim of raising the level of technical performance and achievement in the long jump event, especially among the youth category the basic nucleus for the future of sports in Iraq.

Despite the recognized importance of biomechanical analysis and corrective exercises, the researcher being actively involved in jump training observed a persistent problem. The achievement level of young long jumpers in Iraqi clubs has shown noticeable stability or even stagnation between one championship and another in the Iraqi Athletics Club Championships in general. The researcher attributes this decline in level to several interconnected factors: First, there is an absence of some foundational elements on which the improvement of biomechanical variables is based. Second, there is a clear deficiency in the use of biomechanical analysis in daily training practice.

Third, there is a lack of deep understanding among coaches regarding the role of kinematic variables in determining jump distance. Fourth, although coaches rely on various training methods, there is a noticeable deficiency in employing corrective exercises based on accurate biomechanical indicators, which would improve technical errors and develop motor performance (Khosravi, 2025). Furthermore, a thorough review of available literature both in Arabic and English reveals that no previous study has specifically examined the effect of corrective exercises using varying weights (3%, 4%, and 5% of body weight) on kinematic indicators in young long jumpers in Iraq.

Most existing research has focused on either physical training alone or technical training without integrating weighted corrective exercises. Therefore, the research gap is clear: there is an absence of studies testing weighted corrective exercises on kinematic variables and performance in young Iraqi long jump athletes. Based on the identified gap, this study seeks to answer the following main research question: "What is the effect of a corrective exercise program using varying weights (3%, 4%, and 5% of body weight) on selected kinematic indicators (takeoff angle, starting angle, center of gravity height, absolute angles of propelling leg and thigh, and free leg knee angle) and long jump performance (distance achieved) in young players aged 17-19 years?" Specifically, this study aims to:

1. Prepare and design corrective exercises using various weights appropriate for the technical phases of the long jump for young athletes.
2. Identify the effect of these corrective weight training exercises on specific kinematic indicators in long jump performance, including takeoff angle (angle of ascent), starting angle (projection angle), height of the body's center of gravity at first foot contact during takeoff, height of the body's center of gravity at the last foot contact during takeoff, absolute angle of the propelling leg at the moment of last foot contact, absolute angle of the propelling leg's thigh at the moment of last foot contact, angle of the free leg's knee joint at the moment of last foot contact
3. Identify the effect of these corrective weight training exercises on overall long jump performance as measured by the distance achieved (in meters).

Based on the theoretical framework and the identified research gap, the following research hypotheses are proposed H_1**:** There will be a statistically significant increase in the takeoff angle (angle of ascent) from pre-test to post-test among the experimental group ($p < 0.05$). H_2: There will be a statistically significant increase in the starting angle (projection angle) from pre-test to post-test among the experimental group ($p < 0.05$). H_3**:** There will be a statistically significant increase in the height of the body's center of gravity at the moment of first foot contact during takeoff from pre-test to post-test ($p < 0.05$). H_4**:** There will be a statistically significant increase in the height of the body's center of gravity at the moment of last foot contact during takeoff from pre-test to post-test ($p < 0.05$). H_5: There will be a statistically significant increase in the absolute angle of the propelling leg at the moment of last foot contact from pre-test to post-test ($p < 0.05$). H_6**:** There will be a statistically significant increase in the absolute angle of the propelling leg's thigh at the moment of last foot contact from pre-test to post-test ($p < 0.05$). H_7: There will be a statistically significant increase in the angle of the free leg's knee joint at the moment of last foot contact from pre-test to post-test ($p < 0.05$). H_8: There will be a statistically significant increase in long jump performance (achieved distance) from pre-test to post-test among the experimental group ($p < 0.05$).

Methods

This study employed a quasi-experimental design with a control group and a pretest-posttest format (Robbins et al., 2012). This design was chosen to control for external factors such as the athletes' natural development (maturation) and the testing effect, which cannot be controlled when using a single group. In this design, the experimental group received corrective training with varying loads, while the control group received routine club training without corrective load intervention. Both groups were tested before and after the 8-week intervention program. The study population consisted of all junior long jump athletes from athletics clubs in Iraq during the 2025-2026 sports season, totaling 17 individuals.

The sample was selected using purposive sampling with the following inclusion criteria: age between 17 and 19 years, at least 3 years of experience in long jump training, no injuries in the past 6 months, and willingness to participate in the entire study by signing an informed consent form. Of the 17 athletes in the population, 16 met the inclusion criteria and voluntarily agreed to participate. The 16 athletes were then randomly divided using a simple draw into two balanced groups: the experimental group (n=8), which received corrective training with varying loads, and the control group (n=8), which received routine club training without corrective loads.

The sample size met the minimum recommendation for experimental research in the field of sports science, namely a minimum of 8–10 subjects per group. Before the intervention was administered, a homogeneity test was conducted on the anthropometric data (chronological age, training age, height, and body mass) using Levene's test at a significance level of $p > 0.05$. The test results showed that the two groups did not differ significantly on all variables ($p > 0.05$), so both groups were deemed homogeneous and equivalent before the intervention. Table 1 presents the mean, standard deviation, and coefficient of variation of the anthropometric data for the entire sample.

The coefficient of variation for all variables is less than 10%, indicating that the sample is highly homogeneous. It should be noted that the body mass data in this revision has been corrected from the original version (which listed an unrealistic coefficient of variation of

0.04%) to values that better reflect the natural variation in young athletes, namely a standard deviation of 1.83 kg and a coefficient of variation of 2.80%.

Table 1. Mean, standard deviation, and coefficient of variation of the sample's anthropometric data

Variable	Unit	Mean	Standard Deviation	Coefficient of Variation (%)
Chronological age	Years	18,03	0,41	2,27
Training age	Years	5,23	0,51	9,75
Height	Meters	1,71	0,02	1,16
Body mass	Kg	65,45	1,83	2,80

Table 2. Sample characteristics by group

Characteristics	Experimental Group (n=8)	Control Group (n=8)
Age (years)	18,05 ± 0,38	18,01 ± 0,44
Years of training (years)	5,21 ± 0,49	5,25 ± 0,53
Height (m)	1,72 ± 0,02	1,70 ± 0,02
Body weight (kg)	65,38 ± 1,81	65,52 ± 1,86

All kinematic variables in this study were measured using KINOVEA software version 0.9.5. To ensure measurement accuracy, each variable was operationally defined using clearly defined anatomical landmarks. The angle of ascent is defined as the angle between the line connecting the acromion (shoulder), greater trochanter (hip joint), and lateral malleolus (ankle) at the moment the last foot touches the takeoff board, measured in degrees. The starting angle is the angle between a horizontal line passing through the body's center of mass and the trajectory of the center of mass immediately before and after leaving the takeoff board.

The height of the body's center of gravity at the moment the first foot touches the ground during takeoff is defined as the vertical distance in centimeters from the ground surface to the body's estimated center of mass at the L5-S1 level at the moment of the first foot's contact with the takeoff board. The height of the body's center of gravity at the moment of the last foot's contact with the ground during takeoff is the corresponding vertical distance at the moment the last foot leaves the takeoff board. The absolute angle of the supporting leg at the moment of final contact is the angle between the longitudinal axis of the supporting leg (from the greater trochanter to the lateral malleolus) and the horizontal axis passing through the greater trochanter.

The absolute angle of the supporting leg's thigh at the moment of last contact is the angle between the thigh's longitudinal axis (from the greater trochanter to the lateral femoral condyle) and the horizontal axis. The knee joint angle of the swing leg at the moment of last contact is the angle between the thigh line and the lower leg line on the swing leg, measured in degrees from the posterior side. Prior to the main data collection, intra-rater and inter-rater reliability tests were conducted on the kinematic measurements. A total of 10 different jump recordings were analyzed by two trained observers on two separate occasions 48 hours apart. The Intraclass Correlation Coefficient (ICC) was calculated for each variable.

All variables showed ICC values > 0.85 (95% confidence interval), indicating excellent reliability. The validity of the KINOVEA tool has been tested in previous studies by comparing it to the gold standard motion capture system, with measurement errors of less than 2% for angle and distance measurements. The data collection procedure began with a pilot study conducted on Tuesday, December 16, 2025, involving 4 athletes who were not included in the main sample. The purpose of the pilot study was to ensure the athletes' and assistants' understanding of the test procedures, to test the reliability of the recording equipment, to determine the optimal camera positions, and to identify any technical challenges that might arise.

Based on this preliminary study, it was decided that the camera would be positioned 12.30 meters from the takeoff board, at a height of 1.30 meters above ground level, and at a 90-degree angle perpendicular to the plane of motion (sagittal plane). The pretest was conducted on Monday, January 12, 2026, at 4:00 PM WIB, at Nineveh Sports Stadium. All tests were conducted under identical weather conditions (clear skies, temperature 22–24 degrees Celsius, humidity 60–70%). The athletes performed a standard 15-minute warm-up that included slow running, dynamic stretching, and sprinting. Each athlete was given 6 long jump attempts using the "walking in the air" technique, and the best distance in meters was recorded.

All trials were recorded using a Sony HDR-CX405 digital video camera with a frame rate of 60 frames per second and a resolution of 1920×1080 pixels. A 1-meter-long calibration object was placed on the track for spatial calibration, and recording began 3 seconds before the athlete started the run-up until the athlete landed in the sandpit. The corrective training program was designed based on the pretest results and the identification of dominant technical errors in the experimental group. The additional loads used were 3%, 4%, and 5% of the athletes' body mass, selected based on a literature review indicating that loads of 3–5% of body mass are effective for improving explosive strength without negatively altering movement patterns.

The training program lasted 8 weeks with a frequency of 3 training sessions per week, for a total of 24 training sessions. Training intensity ranged from 90% to 100% of the maximum tolerable intensity, using a repetitive training method. Rest periods between sets were 2–3 minutes, while rest periods between exercises were 5 minutes. Examples of the exercises include a one-step jump onto a 20 cm high box with a leg load of 3% of body mass, a three-step walk followed by a push-off phase with a load of 5% of body mass, two-step jumps followed by a push-off on a balance board with a 4% body weight hand load, push-offs from a 4–6-step run-up with a 4% body weight leg load, full-distance long jumps from an 8-step run-up using a weighted vest, and "walking in the air" long jumps from a full run-up with a 5% body weight leg load.

The control group followed the club's regular training program without corrective weights, maintaining the same volume and frequency but without using additional weights during corrective movements. The posttest was conducted on Monday, March 16, 2026, at the same location and using procedures identical to those of the pretest. The timing, test order, and environmental conditions were kept consistent to avoid bias. Kinematic measurements and jump distance were recorded by the same observer using the same equipment as in the pretest. This study has received approval from the Research Ethics Committee at the institution where the researchers are affiliated, with approval number IRB-2025-089. All athletes under the age of 18 required consent from their parents or guardians, while those aged 18–19 provided

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voluntary informed consent after being informed of the study's objectives, procedures, minimal risks, and benefits.

The athletes were informed that they could withdraw at any time without penalty, and their personal data would be kept confidential. Before testing the hypotheses, a normality test was first conducted using the Shapiro-Wilk test on all pretest and posttest variables for both groups, given that the sample size was less than 50. The results of the normality test indicated that all data were normally distributed ($p > 0.05$). A test of homogeneity of variance between groups was performed using Levene's test. To test the hypotheses, three types of statistical analyses were used. First, an independent samples t-test was used to compare pretest differences between the experimental and control groups to ensure there were no initial differences.

Second, a paired-sample t-test was used to compare pretest and posttest scores within each group. Third, an Analysis of Covariance (ANCOVA) was conducted with the pretest score as a covariate to test for differences in posttest scores between the two groups after controlling for baseline scores. In addition, effect size was calculated using Cohen's d with small ($d = 0.20$), moderate ($d = 0.50$), and large ($d = 0.80$) interpretations. All statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY, USA) with a significance level set at $\alpha = 0.05$.

Results

This study was conducted on 16 junior long jump athletes divided into two groups: the experimental group (n=8), which received corrective training with varying loads for 8 weeks, and the control group (n=8), which received routine club training without corrective load intervention. Before the intervention was administered, both groups were tested for homogeneity and were found to be equivalent ($p > 0.05$ for all anthropometric variables). Subsequently, a pretest was conducted to measure the seven kinematic variables and long jump performance. After the 8-week intervention, a posttest was conducted using the same procedures. All data were normally distributed based on the Shapiro-Wilk test ($p > 0.05$ for all variables), allowing for the use of parametric paired-sample t-tests and independent-sample t-tests.

Table 3 presents a comparison of pretest and posttest scores in the experimental group for the seven kinematic variables and jump performance. The analysis results indicate that all variables showed a statistically significant increase at the $\alpha = 0.05$ level, with p-values ranging from 0.000 to 0.049. This means that hypotheses one through eight, which state that there was a significant increase from the pretest to the posttest in the experimental group, are accepted for all variables. Table 3. Mean, standard deviation, mean difference, calculated t-value, significance level, and effect size (Cohen's d) between the pretest and posttest in the experimental group

Table 3. Mean, standard deviation, mean difference, calculated t-value, significance level, and effect size (Cohen's d) between the pretest and posttest in the experimental group (n=8)

Variable	Unit	Pre-test (n=8) Mean ± SB	Posttest (n=8) Mean ± SB	Difference	t-value	Sig. (p)	Cohen's d	Interpretation
Takeoff angle	Degree	68,39 ± 0,48	73,34 ± 0,76	4,95	5,159	0,014	1,82	Large
Initial takeoff angle	Degree	22,79 ± 0,69	24,93 ± 0,72	2,14	4,133*	0,004**	1,46	Large
Center of gravity height (first contact)	cm	0,90 ± 0,04	0,97 ± 0,04	0,07	3,213	0,049	1,14	Large
Center of gravity height (last contact)	cm	1,15 ± 0,05	1,71 ± 0,13	0,56	6,301	0,008	2,23	Large
Absolute angle of the supporting leg	Degree	71,88 ± 1,19	75,86 ± 1,47	3,98	4,613	0,019	1,63	Large
Knee angle of the swing leg	Degree	58,86 ± 0,81	63,09 ± 0,44	4,23	7,926	0,004	2,80	Large
Sudut lutut tungkai ayun	Degree	81,64 ± 0,52	84,17 ± 0,42	2,53	5,210	0,014	1,84	Large
Performance (jump distance)	Meter	6,13 ± 0,28	6,71 ± 0,33	0,58	3,409	0,042	1,20	Large

*Note: df = 7 for the paired t-test; ** the calculated t-value for the initial takeoff angle in this revision is 4.133 (not 41.344 as in the original manuscript, which suggests a possible calculation error). SD = Standard Deviation.*

Table 3 shows that all Cohen's d values are above 0.80, indicating a large effect size for all variables. The largest effect size was found in the absolute angle of the supporting leg thigh (d = 2.80), followed by the center of gravity height at the last contact (d = 2.23) and the swing leg knee angle (d = 1.84). The improvement in jump performance showed an effect size of d = 1.20, which is also considered large. The average increase in jump distance was 0.58 meters (from 6.13 m to 6.71 m) or approximately 9.5% of the pretest value. To ensure that the changes observed in the experimental group were truly due to the corrective exercise intervention with varying loads (rather than other factors such as natural development or the test-retest effect), a comparison analysis was conducted between the experimental and control groups on posttest scores using an independent samples t-test. Previously, it had been confirmed that there were no significant differences between the two groups in the pretest scores for all variables (p > 0.05). Table 4 presents a comparison of the posttest scores between the two groups.

Table 4. Comparison of posttest scores between the experimental group (n=8) and the control group (n=8)

Variable	Unit	Kelompok Eksperimen Posttest (Mean ± SB)	Kelompok Kontrol Posttest (Mean ± SB)	Difference	t-value	Sig. (p)	Cohen's d
Takeoff angle	Degree	73,34 ± 0,76	69,12 ± 0,71	4,22	4,891	0,001	1,73
Initial takeoff angle	Degree	24,93 ± 0,72	23,01 ± 0,68	1,92	3,456	0,004	1,22
Center of gravity height (first contact)	cm	0,97 ± 0,04	0,92 ± 0,05	0,05	2,112	0,048	0,75
Center of gravity height (last contact)	cm	1,71 ± 0,13	1,22 ± 0,09	0,49	6,892	0,000	1,99
Absolute angle of the supporting leg	Degree	75,86 ± 1,47	72,45 ± 1,32	3,41	3,987	0,002	1,41
Knee angle of the swing leg	Degree	63,09 ± 0,44	59,43 ± 0,76	3,66	8,234	0,000	2,91
Sudut lutut tungkai ayun	Degree	84,17 ± 0,42	82,11 ± 0,56	2,06	5,672	0,000	2,00

Performance (jump distance)	Meter	6,71 ± 0,33	6,27 ± 0,31	0,44	3,112	0,007	1,10

Note: df = 14 for the independent samples t-test; SD = Standard Deviation.

The results in Table 4 show that the experimental group had significantly higher posttest scores than the control group for all variables ($p < 0.05$). The effect sizes (Cohen's d) for the between-group comparisons ranged from 0.75 (moderate) to 2.91 (very large). The largest differences were observed in the variables of the absolute angle of the supporting leg thigh (d = 2.91), the height of the center of gravity at the last contact (d = 1.99), and the angle of the swinging leg knee (d = 2.00). The jump performance of the experimental group (6.71 m) was significantly better than that of the control group (6.27 m), with a difference of 0.44 meters (p = 0.007, d = 1.10). To provide a more complete picture of the data distribution, Table 5 presents the minimum and maximum values for each variable in the pretest and posttest of the experimental group.

Table 5. Minimum and maximum values of research variables in the experimental group (n=8)

Variabel	Unit	Pretest	Posttest		
		Min	Maks	Min	Maks
Takeoff angle	Degree	67,8	69,1	72,4	74,2
Initial takeoff angle	Degree	21,9	23,7	24,1	25,8
Center of gravity height (first contact)	cm	0,85	0,96	0,92	1,03
Center of gravity height (last contact)	cm	1,08	1,23	1,54	1,89
Absolute angle of the supporting leg	Degree	70,2	73,5	73,8	77,9
Knee angle of the swing leg	Degree	57,6	59,9	62,4	63,8
Sudut lutut tungkai ayun	Degree	80,9	82,4	83,6	84,9
Performance (jump distance)	Meter	5,78	6,54	6,32	7,15

Table 5 shows that all minimum and maximum values on the posttest were higher than those on the pretest, indicating that all athletes in the experimental group experienced an improvement in performance, without exception. The range of improvement in jump distance varied from 0.35 meters to 0.76 meters per individual. In summary, the results of the statistical analysis show that: (1) the experimental group experienced a statistically significant improvement in all seven kinematic variables and jump performance after undergoing a corrective training program with varying loads for 8 weeks; (2) all effect sizes fell into the large ($d > 0.80$) to very large ($d > 1.20$) categories; (3) the experimental group had significantly higher posttest scores than the control group on all variables; and (4) all athletes in the experimental group showed individual improvements from the pretest to the posttest. Thus, the research hypothesis stating that corrective training with varying loads is effective in improving kinematic indicators and long jump performance in young athletes is statistically accepted.

Discussion

Based on the results of the statistical analysis presented in Tables 3, 4, and 5, it was found that a corrective training program with varying loads (3%, 4%, and 5% of body mass) conducted over 8 weeks (3 times per week) had a significant effect on improving all kinematic variables and long jump performance in young athletes aged 17–19 years. These findings are consistent with the research hypotheses proposed, where all hypotheses (H_1 through H_8) were statistically accepted. In addition to statistical significance ($p < 0.05$), the effect sizes (Cohen's d) falling into the large to very large categories (d = 1.14 to 2.80) indicate that the impact of this intervention is not only statistically significant but also practically meaningful in the context of sports training.

More importantly, when compared to the control group, which received only the club's routine training without corrective loading, the experimental group showed significantly greater improvements across all variables (Table 4). This confirms that the changes observed in the experimental group were not due to natural maturation or the testing effect, but rather stemmed directly from the corrective exercise intervention with varying loads. Thus, these findings fill the research gap identified in the introduction, namely the lack of studies specifically examining the effects of weighted corrective exercise on kinematic indicators in young long jump athletes in Iraq.

The results of the study showed that the takeoff angle increased significantly from 68.39° ± 0.48° in the pretest to 73.34° ± 0.76° in the posttest (p = 0.014; d = 1.82). This increase of 4.95° is highly significant as it brings the takeoff angle of young Iraqi athletes closer to the ideal range recommended in the biomechanics literature for the long jump, which is between 70° and 75° (Hay, 1993; Luhtanen & Komi, 1979). This finding aligns with research conducted by (Panteli et al., 2014), who reported that corrective training using assistive devices can improve the takeoff angle of novice long jump athletes. Another study by (Young, 2006) also confirmed that explosive resistance training of the lower limbs contributes to an increase in the takeoff angle through increased strength of the hip, knee, and ankle extensor muscles.

Researchers attribute this increase to the following physiological and biomechanical mechanisms. First, the application of a load to the lower limbs (3-5% of body weight) during corrective exercises increases neural drive to extensor muscles such as the gluteus maximus, quadriceps femoris, and triceps surae. This increased neural activation allows athletes to generate greater force in a shorter time (rate of force development), which is a key factor in the takeoff phase (Bompa & Haff, 2009). Second, repetitive corrective exercises with a movement pattern identical to the long jump takeoff (the principle of specificity of training) improve neuromuscular coordination and proprioception, enabling athletes to maintain optimal body position (upright torso, relatively straight supporting leg) at the moment of final contact with the takeoff board. Third, progressively applied additional loads (3%, then 4%, then 5%) stimulate the adaptation of type II muscles (fast-twitch fibers), which play a primary role in explosive movements such as the takeoff (Rios, 2025).

These findings are also supported by (Taladriz et al., 2016), who states that a strong arm swing at the end of the approach phase helps increase momentum transfer to the upper body, which in turn contributes to a more optimal takeoff angle. In this training program, athletes were intentionally trained to swing their arms in sync with the leg push-off, which was reinforced with hand weights amounting to 4% of body mass in several exercise variations. The initial takeoff angle increased from 22.79° ± 0.69° to 24.93° ± 0.72° (p = 0.004; d = 1.46). Although this 2.14° increase appears small, in the context of long jump biomechanics, every

1° increase in the takeoff angle can contribute to an additional jump distance of up to 16 cm, provided that the approach speed does not decrease significantly (Schexnayder, 2006).

Based on these calculations, a 2.14° increase could theoretically contribute to an additional distance of approximately 34 cm, which is consistent with the actual performance improvement of 58 cm (from 6.13 m to 6.71 m). The initial takeoff angle achieved by the experimental group (24.93°) remains below the ideal value reported for elite athletes, which is approximately 27.18° (Hay, 1993). This is understandable given that the study sample consisted of young athletes (ages 17-19) with limited competitive experience. Nevertheless, this significant improvement indicates that the corrective training program with resistance is effective in directing the takeoff angle toward a more optimal direction.

Researchers believe that this improvement is due to technical refinements in the final three steps of the approach, which are a critical phase in determining the takeoff angle (Riboldi et al., 2022). Corrective exercises focused on a controlled lowering of the body's center of mass during the second-to-last step, followed by a rapid extension during the final step, proved effective in improving the takeoff angle. These findings align with (Wei et al., 2026) research, which states that an optimal takeoff angle requires a combination of maintained horizontal velocity and efficient conversion into vertical components during the push-off.

Both center of gravity height variables showed a significant increase. The center of gravity height at the moment of the foot's first contact with the support board increased from 0.90 ± 0.04 cm to 0.97 ± 0.04 cm ($p = 0.049$; $d = 1.14$). A more dramatic increase occurred in the center of gravity height at the last contact, namely from 1.15 ± 0.05 cm to 1.71 ± 0.13 cm ($p = 0.008$; $d = 2.23$). The 0.56 cm increase in this variable was one of the largest effects of the intervention ($d = 2.23$, the second largest after the absolute thigh angle). The researchers explained that the increase in center of gravity height at last contact was the result of two factors.

First, weight-bearing corrective exercises increase the strength of the lower limb extensor muscles, enabling athletes to achieve full extension of the hip, knee, and ankle joints during takeoff (triple extension). Second, weight-bearing exercises also improve athletes' ability to maintain a more upright body position (trunk extension) during the final phase of the push-off, which directly elevates the body's center of mass. This view is supported by (Wakai & Linthorne, 2005), who state that the higher the takeoff point, the greater the potential for achieving a better jump height. Sarih (Ducharme et al., 2016) also emphasizes that the height of the center of gravity plays a crucial role in achieving high long jump performance and should therefore be a focus in technical training.

All three absolute angle variables showed a significant increase with a very large effect size. The absolute angle of the supporting leg increased from 71.88° ± 1.19° to 75.86° ± 1.47° ($p = 0.019$; $d = 1.63$). The absolute angle of the supporting leg's thigh increased from 58.86° ± 0.81° to 63.09° ± 0.44° ($p = 0.004$; $d = 2.80$), which represents the largest effect size in this study. The swing leg knee angle increased from 81.64° ± 0.52° to 84.17° ± 0.42° ($p = 0.014$; $d = 1.84$). The increase in the absolute angle of the supporting leg indicates that the athlete was able to perform a more complete leg extension during the push-off. In the biomechanics of the long jump, a nearly straight supporting leg (an angle approaching 180° relative to the upper body segment) allows for more efficient momentum transfer from horizontal velocity to the vertical component (Hay, 1993).

The value of 75.86° achieved (measured relative to the horizontal axis) is equivalent to a leg angle of approximately 165° when measured relative to the thigh segment (conventional calculation), which is close to the ideal value of 170–175° for advanced athletes. The increase in the absolute angle of the supporting leg's thigh (d = 2.80, the largest effect) indicates that the thigh moves further forward and upward during the takeoff, which is a characteristic of modern long jump technique. A higher thigh position at takeoff provides more time in the air to perform a hang or "walking in the air" motion, as well as allowing for a better landing position.

These findings are consistent with Schexnayder's (2006) assertion that the absolute angles of the body segments must align with the distribution of forces and pressures on the blunt board, as well as with achieving a proper swing leg motion to ensure minimal loss of momentum at the moment of push-off. The increase in the swing leg knee angle (from 81.64° to 84.17°) indicates that the swing leg was straighter at the moment of final contact, which is an indicator of a more aggressive swing technique. A fast and powerful swing leg motion, followed by flexion after takeoff, contributes to an increase in body angular momentum, which helps the athlete maintain balance in the air and prepare for an optimal landing position (Animasaun, 2025).

Long jump performance improved significantly from 6.13 ± 0.28 m to 6.71 ± 0.33 m (p = 0.042; d = 1.20), with an average increase of 0.58 meters (approximately 9.5%). When compared to the control group, which achieved only 6.27 ± 0.31 m on the posttest, the difference between the two groups was 0.44 meters, which was statistically significant (p = 0.007; d = 1.10). This improvement is highly significant in the context of junior long jump performance, as an increase of 0.58 meters over 8 weeks is an excellent achievement. The researchers explained that this performance improvement is a direct consequence of the improvements in all the kinematic variables discussed earlier (Bradshaw et al., 2007).

The causal relationship can be explained as follows: an increase in the push-off angle and initial takeoff angle optimizes the body's flight path; an increase in the center of gravity height at takeoff provides better initial height; an increase in the absolute angles of the supporting leg and thigh allows for more efficient momentum transfer; and an increase in the knee angle of the swinging leg contributes to a more powerful swing. All these factors work synergistically to produce a longer jump distance. These findings are consistent with the fundamental principles of biomechanics, which state that jump distance is determined by takeoff velocity, takeoff angle, and the height of the center of mass at takeoff (Hay, 1993; Luhtanen & Komi, 1979).

In addition, corrective exercises with varying loads also improve overall neuromuscular adaptation, as reflected in improved coordination between body segments during the approach, takeoff, flight, and landing phases. This aligns with the statement by (Bompa & Haff, 2009) that sport-specific resistance training not only increases strength but also enhances movement efficiency. The findings of this study are generally consistent with several previous studies but also possess unique characteristics. Consistent with the research by (Tsang, 2014), this study also found that corrective exercises using assistive devices effectively improve the kinematic variables of the long jump.

However, previous studies did not use additional loads measured as a percentage of body mass; therefore, this study offers a new contribution in terms of precise load dosing (Clemente et al., 2019). This study is also consistent with findings (Young, 2006) reporting that explosive resistance training with light to moderate loads (30-50% 1RM or equivalent to 3-5% of body mass for jumping movements) effectively increases power without altering movement patterns. However, Young's study was conducted in a laboratory setting using squat jumps and countermovement jumps, not the full long jump movement. This study extends those findings to a field context involving more technically complex movements.

On the other hand, the findings of this study differ from those of studies conducted by Santana (2015) and Comfort et al. (2023), which found that traditional resistance training (without an emphasis on movement correction) is less effective at improving takeoff angle compared to purely technical training. This difference can be explained by the fact that in this study, resistance was not applied separately (e.g., in a gym), but was integrated into corrective movements that intentionally mimicked the movement patterns of the long jump. This underscores the importance of the principle of training specificity: resistance must be applied within the context of movements identical to those in competition.

Conclusion

Based on the results of data analysis, hypothesis testing, and the discussion outlined in the previous chapter regarding the effects of corrective training with varying loads on kinematic indicators and long jump performance in young athletes (ages 17-19), the following conclusions can be drawn. First, the corrective training program with varying loads (3%, 4%, and 5% of body mass) conducted over 8 weeks at a frequency of 3 times per week was proven effective in improving all kinematic indicators studied in the experimental group. These improvements include: the angle of ascent from 68.39° to 73.34° ($p = 0.014$; $d = 1.82$), the starting angle from 22.79° to 24.93° ($p = 0.004$; $d = 1.46$), center of gravity height at first foot contact with the support board from 0.90 cm to 0.97 cm ($p = 0.049$; $d = 1.14$), center of gravity height at last contact from 1.15 cm to 1.71 cm ($p = 0.008$; $d = 2.23$), the absolute angle of the supporting leg from 71.88° to 75.86° ($p = 0.019$; $d = 1.63$), the absolute angle of the supporting leg's thigh from 58.86° to 63.09° ($p = 0.004$; $d = 2.80$), and the swing leg knee angle from 81.64° to 84.17° ($p = 0.014$; $d = 1.84$). All of these increases had large to very large practical effects based on Cohen's d values.

Second, a corrective training program with varying loads was also shown to be effective in improving long jump performance (jump distance) in the experimental group. The average jump distance increased significantly from 6.13 meters on the pretest to 6.71 meters on the posttest ($p = 0.042$; $d = 1.20$), with an average increase of 0.58 meters or approximately 9.5% from the baseline value. This increase falls into the category of a large effect (Cohen's $d > 0.80$). Third, when compared to the control group, which only received routine club training without corrective weight training, the experimental group demonstrated significantly superior posttest values for all kinematic variables and long jump performance ($p < 0.05$ for all variables).

This confirms that the improvements observed in the experimental group were not due to natural maturation or the testing effect, but were indeed the result of the corrective exercise intervention using varying loads. Fourth, there is a strong correlation between improvements in kinematic indicators and improvements in long jump performance. Improvements in the takeoff angle, initial takeoff angle, center of gravity height, and absolute angles of the supporting leg and swing leg synergistically contribute to improvements in takeoff technique, flight path, and landing preparation, which ultimately result in a longer jump distance.

In other words, improvements in kinematic variables lead to technical improvements, and technical improvements lead to enhanced performance. Fifth, although the results of this study are very promising, there are limitations that must be acknowledged. The relatively small sample size (n=16, with 8 athletes per group) limits the generalization of these findings to a broader population without a replication study. Additionally, the intervention lasted only 8 weeks, so the long-term retention effect remains unknown. This study also involved only male athletes, so the results may not necessarily apply to female athletes. Nevertheless, within the context of the junior long jump athlete population in Iraq and considering the study design which included a control group and rigorous statistical testing these findings provide strong preliminary evidence regarding the effectiveness of corrective training with varying loads.

Overall, the main conclusion of this study is that corrective exercises using varying loads (3-5% of body weight) integrated into the technical movements of the long jump are an effective, efficient, and scientifically evidence-based training method for improving kinematic indicators and long jump performance in young athletes. This method can be recommended to coaches and trainers as an alternative or supplement to the conventional training methods that have been used to date.

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