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The effect of corrective exercises on ground reaction forces in male students with upper crossed syndrome during throwing

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Declarations:

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of Hormozgan University of Medical Sciences (IR.HUMS.REC.1402.135) of and carried out in accordance with relevant guidelines and regulation. Besides, this study has been registered at the Iranian Registry of Clinical Trials (IRCT20200622047888N2). The study protocol was clearly explained to all participants before the data was collected. Informed consent was obtained from all participants included in the study. For participants under 18 years old, their legal guardians will be asked to sign the informed consent. Participants voluntarily participate in the present study and can withdraw at any time without stating the reason. For participants under 18 years old, their legal guardians will be asked to sign the informed consent to publish the information/image(s) in an online open-access publication.

Availability of Data and Material (ADM)

The datasets generated and/or analysed during the current study are not publicly available due to the privacy of the subjects, but are available from the corresponding author on reasonable request.

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Abstract

Purpose: Poor posture has a negative impact on physical capability, and is associated with changes in bio mechanics and motor control. The purpose of this study was to assess the effect of corrective exercises on ground reaction forces in male student handball players with upper-crossed syndrome during throwing.

Methods: The present study is a double-blind randomized controlled trial (IRCT20200622047888N2). Thirty male handball students with upper-crossed syndrome participated in this study ((IR.HUMS.REC.1402.135). During handball throwing,ground reaction force information was measured by force plate. During handball throwing, to measure the ball release speed, the linear velocity of the centre of the ball was calculated. The forward head and rounded shoulder angles were measured with a highly reliable photogrammetric method. All measurements were performed at the beginning and after 8 weeks of corrective exercises.

Results: A significant improvement was observed in the experimental group compared to the control group for the time to reach the maximum ground reaction force forthe left and right leg, anterior, posterior and vertical in the experimental group ($p<0.05$). Also, a significant improvement was observed in forward head angle, rounded shoulder and kyphosis in the experimental group ($p<0.05$). Significant group× time interaction effects were found for the Forward head angle, ($p=0.03$; effect size (95% CI), = 0.87 (-2.34 to 0.13), Forward shoulder angle, ($p=0.05$; effect size (95% CI), = 0.68 (0.32 to 1.22), Thoracic kyphosis angle($p=0.02$; effect size (95% CI), = 0.64 (0.54 to 1.25).

Conclusion: The results of this study showed that corrective exercises are useful for male students with upper crossed syndrome during throwing. Therefore, corrective exercises may be applied to obtain functional improvements in male student handball players with upper-crossed syndrome during throwing.

Key words: ground reaction force, corrective exercises, handball player, upper crossed syndrome

Introduction

Functional activities begin with static postures, and because of the potential relationship between posture and movement, movement patterns probably be affected by lower extremity malalignments[1]. Posture has a significant impact on performance capability.

Forward head and shoulder posture with thoracic kyphosis are the most common abnormalities in athletes with overhead movement activities [2]. Studies showed that players with overhead activities have 38.67% and 53.33% of head forward and rounded shoulders, respectively [3]. On the other hand, other studies showed that handball players have forward head posture and roudded shoulder and kyphosis[4-6].

Upper crossed syndrome (UCS) is an aberrant posture that matching to Vladimir Janda (1923–2002) refers to a specifcally changed muscle activation pattern (especially in the neck, trunk and scapular muscles) and altered movement patterns (scapular dyskinesis) along with postural deviations (forward head and shoulder posture, and increased thoracic Kyphosis) [7, 8]. Although there are no clear diagnostic criteria for UCS, but, for the assessment of UCS, the alignment and its side effects are often evaluated, such as increase in thoracic kyphosis or forward head angles, while less attention has been paid to the keystone, i.e., the scapulae, and the relevant altered muscle activation and movement patterns[9].

In persons with upper-crossed syndrome, the deviation from optimal posture [10, 11], is associated with changes in muscle activity, movement patterns [8, 10], and biomechanics [12]. It is well established that biomechanical deficiencies including excessive adduction and internal rotation of the scapula and, subsequently altered muscle activity patterns during functional activities can be associated with overuse injuries [13-15].

In handball players, upper-crossed syndrome has a negative impact on the biomechanics of throwing [16], and increases the ground reaction forces during throwing [17, 18] that not only has a negative impact on throw performance, but also increases the risk of injuries of the upper and lower limbs.

Throughout the throwing motion, a player generates kinetic energy at certain parts of the body and transfers it to other parts of the body in an effort to maximize throw velocities [19, 20]. Improving throwing strategies may reduce the risk of injury and even enhance throwing performance [16], particularly when handball players suffer from postural abnormalities, such as the common upper-crossed syndrome [16, 21]. This syndrome is among the most common abnormalities in athletes with overhead movement activities and is characterized by forward head posture and shoulder and spine changes [22-24]. Thus, it is important to assess and correct the movement defects, otherwise, over time this can cause more malalignment, exacerbating the symptoms of scapula, increasing the risk of overuse injuries and leading to other problems [25].

Interestingly, other studies reported that many dysfunctional movement patterns can be improved by providing exercise interventions [12]. Exercise interventions are among the most effective to improve this condition [26, 27], and reduce ground reaction forces during a throw [28-30]. Most studies have supported the effectiveness of stretching or strengthening exercises on posture and balancing the agonist and antagonist muscle strength around the scapula and shoulder, providing dynamic glenohumeral joint stability, restoring scapula and shoulder muscles activation in overhead athletes [31-34]. The design and implementation of the training protocol in study are based in which stretching exercises for short muscles and strengthening exercises for weak muscles are prescribed at the site of malalignmen[9].

Aas far as we know, no study has yet investigated the effect of regular exercise on the ground reaction force during throwing in persons with upper crossed syndrome, and it is unknown which training techniques elicit the best result. In past studies, more emphasis has been placed on improving muscle activity and posture. Past studies have shown that muscle activity and biomechanics defects cause throwing defects, so in the present study, we investigated the effect of exercises on ground reaction force and throw performance.

Corrective interventions typically contain both stretching and strength exercises to increase the range of motion and muscle strength that can contribute to improving balance, symmetry of body movement and biomechanics. As far as we know, there are however no studies that assessed the effects of a period of corrective exercises on the ground reaction forces during throwing in men with upper-crossed syndrome. Therefore, the aim of this study was to determine the effect of a corrective exercise on ground reaction force and forward head, rounded shoulder, kyphosis angles in male student handball players with upper-crossed syndrome during throwing.

Materials and methods

Study design

This was a double-blind, randomized controlled study, in which the participants received their intervention for 8 weeks. Participants were randomized by the slot-drawing method to experimental and control groups. All players were committed to finish the training session unless they were injured. In the present study, four players withdrew from the intervention due to injuries, such as an injury in a during training in the second week (two players in experimental group). In addition, two player from control group did not participate in the post test. Therefore, 30 players were considered for further analysis into the two groups: experimental group (EG) and control group (CG).

Ethical approval was obtained from the Research Ethics Committee of Hormozgan University of Medical Sciences (IR.HUMS.REC.1402.135) of and adhered to the ethical standards of the Declaration of Helsinki. Informed consent was obtained from all participants included in the study. For participants under 18 years old, their legal guardians will be asked to sign the informed consent. Participants voluntarily participate in the present study and can withdraw at any time without stating the reason. For participants under 18 years old, their legal guardians will be asked to sign the informed consent to publish the information/image(s) in an online open-access publication.

Participants

The participants were male student handball players with upper-crossed syndrome, selected by physiotherapists working in a private center. The necessary sample size was estimated using G*Power 3.1.7 for Windows (G*Power©, University of Dusseldorf, Germany). To detect between-group differences in the primary outcome measure (ground reaction forces), and secondary outcomes (forward head, rounded shoulder, kyphosis) with an 80% statistical power ($1 - \beta$ error probability) and an α error level probability of 0.05, in a repeated-measure analysis of variance (ANOVA) with interaction, and a medium effect size of 0.50 17 participants per group (total sample size of 34 subjects) were required. Unfortunately, four players did not complete the assessments and we ended up with 15 participants in each group (Fig. 1). The participants consisted of 30 men with the upper crossed syndrome (UCS).

The eligibility criteria were as follows: (1) aged between 14 and 20 years; (2) shoulder angle (SA > 49°) (3); cervical angle (CA > 44°), (4); thoracic kyphosis angle (tkA> 42°), [35]; (5); activity history between 2 to 5 years (6); normal body mass index (7) no other abnormalities (except upper crossed syndrome). The exclusion criteria were as follows: (1) having significant neurologic or cardiovascular disorders; (2) a history of surgery on the upper limbs in the previous six months; (3) the beginning of any analgesic intervention for musculoskeletal pain within the previous six weeks.

Randomization

Participants were randomized by the slot-drawing method to experimental and control groups. The randomization sequence was not disclosed until participants had completed their baseline assessments. Allocation was by sealed opaque envelopes. Participants were assigned to each (experimental or control) group by a sealed envelope containing the name of one of the two groups.

Intervention

The experimental group (n=15) received an 8-week corrective exercise (CE) programme (Appendix 1). The participants of the experimental group were asked not to reveal the corrective exercises given. The experimental group had never done any corrective exercises before. CE were taken from previously published studies[36, 37]. The duration of the CE protocol was about an hour. The intervention consisted of three group sessions with up to 7 participants per week supervised by a clinically experienced physical therapist. The participants did not conduct any extra exercises at home, but were asked to avoid poor postures (slump posture and forward posture. One notable sitting posture identified is slumped sitting, which to this point has been generally defined as pelvic posterior rotation along with a relaxed (into flexion) thoracolumbar/trunk [38]. The forward head posture (FHP) is [39], that the head shown on the sagittal plane is not stable, which appeared by the external auditory meatus that passes through the shoulder joint before the plumb line).

Each exercise session initiated with 10 min of warm-up activity, ended with 5 min of cool-down. It included four strengthening exercises and three stretching exercises. The aim of the strengthening exercises was to activate the rotator cuff - teres minor and infraspinatus -, the scapula stabilizers, such as the trapezius (mainly the medium trapezius and lower trapezius), the rhomboids and the deep cervical flexor muscles. Stretching exercises (Fig 1) targeted the pectoralis minor and the neck muscles, such as sternocleiomastoid and levator scapulae [12, 36]. Each stretching exercise should be sustained about 30–60 s[36]. Each participant performed three sets of 12 repetitions of each exercise during the first four weeks[36]. increased to three sets of 15 repetitions in the following two weeks, ending with as many repetitions as possible with the goal of 3 sets of 20 repetitions in week seven and 8. All repetitions were at maximum load with a 1-min rest interval between sets.

Control group

The control group was asked to maintain their ordinary daily activities and not to participate in any exercise programs The participants of the control group were asked not to reveal the ordinary daily activities given. After the study was completed, the control group did also perform the exercise intervention protocol for ethical reasons.

Primary outcomes

Ground reaction forces

During handball throwing, ground reaction force information was recorded by two force plates (Kistler, type 9281, Kistler instrument AG, Winterthur, Switzerland) with a sampling rate of 1000 Hz (Fig 1). These two force plates were located in the center of the calibrated space. All ground reaction force data were filtered using a fourth-order low-pass Butterworth filter with a frequency cutoff of 20 Hz [40].The data was recorded while throwing the handball ball. Ground reaction forces were recorded along the left leg, right leg and the vertical, anterior, posterior, axes. The data ground reaction forces were recorded for three consecutive repetitions of each trial. All GRF data was normalized by body weight (bw) and the product of body weight and height (h), respectively. For simultaneous data recordings of the throw and GRF the following from the markers were used. Before data collection, fourteen anatomical reflective markers (15-mm diameter) were attached bilaterally according to the Plug-in Gait upper extremity model on each participant's 1) acromioclavicular joint (three markers), 2) acromion process (one marker), 3) lateral and medial epicondyli (two markers), 4) styloid processes of the ulna and radius (two markers), 5) middle radius bone (one marker) 6) second metacarpal bones (one marker), 7) process of the seventh cervical vertebrae and process of the tenth back vertebrae (two marker), 8) the broad upper part of the sternum (one marker), 9) the lower end of the sternum (one marker), 10) head of the second metatarsal of the finger (one marker) 11) In addition, two other reflective markers were attached on opposite sides of the ball.

To perform simultaneous data recordings of the throw and GRF capture, a four-camera three-dimensional motion analysis system (Motion Lab Systems, Inc.15045 Old Hammond Highway, Baton Rouge, LA 70816 oxford, Uk) at a sampling rate of 250 Hz was used. In this stage, the throw was divided into two phases (preparation phase and throw phase) according to previous researches[41]. The preparation phase is from the moment the person lifts the ball from the side until the shoulder takes maximum external rotation, and the throw phase was divided from the moment of maximum external rotation of the shoulder to the creation of internal rotation and the release of the ball, and the throw phase ends at the moment the ball leaves the hand. The GRF data were recorded from the moment the person lifts the ball from the side until the at the moment the ball leaves the hand. Then, the average of the data obtained from three throws was used to calculate these variables. The of time to reach the GRFwere recorded during the throwing ball before and after interventions. The mean and standard deviation of ground reaction force were recorded during the throwing ball before and after interventions. All data processing including marker trajectories and GRF was carried out using Vicon Nexus (version 2.5) and MATLAB (Mathworks, Natick, MA) software.

Speed ball

Subjects performed five throws at high-power of the handball ball and five throws at slow speed of which three were chosen for further analysis. Five slow throws were performed, of which three were chosen for further analysis. Five high-power throws were performed, of which three were chosen for further analysis [42]. In the high-power throw, the subject was asked to shoot the ball with as much power and speed as possible, and in the slow throws, the subject was asked that to perform the throw normally without maximum power and speed (Figure 2).

To measure the ball release speed, the linear velocity of the centre of the ball was calculated. The centre of the ball was defined as the middle point of 2 markers that were positioned on the opposite sides of the ball. To determine the moment of ball release, the distance between the centre of the ball and the hand marker (head of the second metatarsal) was calculated. The distance between the centre of the ball and the hand marker increases abruptly at ball release [43].

Secondary outcomes

Posture (forward head and rounded shoulder angles)

Forward head and protracted shoulder angles were measured before and 48 h after the 8-week CE. The angles were measured with a highly reliable photogrammetric method [44], and postural assessment Software (PAS) [45], which allow quantitative assessment of postural alterations [46], Two angles were measured: forward head, and rounded shoulder angles. Forward head angle: the angle between the intersection of a horizontal line through the spinous process of C7 and a line to the tragus of the ear. If the angle was less than 50°, the participant was considered to have FHP [47].

Rounded shoulder angle: the angle between the intersection of the line between the acromion and the spinous process of C7 and the horizontal line through the acromion [36]. The same researcher who was experienced in the assessment of postural alignment and blind to group assignment performed all measurements. Before photographing the subject, the researcher placed reflective markers on the skin of the following anatomical points: the tragus of the ear, spinous process of C7, and acromion [36]. Subjects stood next to a wall so that their left arm was toward the wall. A digital camera on a tripod was placed at distance of 265 cm from the wall, and its height was set to the level of the subject's right shoulder [46]. Then, the subject was instructed to lean forward three times moving their hands above the head three times and the to stand relaxed in a natural position looking at an imaginary spot on the opposite wall level of the horizon. Subsequently, the examiner took three lateral view photos, after a 5-s pause. Ultimately, the mentioned photos were transferred into a computer and the forward head angle measured using AutoCAD software. The average of three angles recorded was given as the angle for forward head (19). The Flexicurve method, which is a well-established, valid, and reliable technique [48, 49], was used to measure the thoracic kyphosis angle. A detailed description of the procedure can be found in previous studies [50, 51].

Statistical analysis

Statistical analysis was performed using IBM SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA). All variables were reported as descriptive statistic (mean, standard deviation). A Shapiro Wilk test was used to assess the normality of data. A two-way (group x time) ANOVA with repeated measures was used to compare differences between groups and the impact of the 8-week CE intervention. An interaction indicated that the 8-week intervention had an effect different from no intervention. Finally, the effect size was calculated using the Cohen method. The significance level was set at $p < 0.05$.

Result

Of the 150 men recruited, 120 did not meet the entry criteria. The remaining 30 participants were randomized to the experimental and control group (Fig. 2).

Table 1 shows the baseline characteristics for each group. There was no significant difference between the two groups for any of the variables.

As per Table 2, a two-way (group x time) ANOVA with repeated measures results revealed significant effects of the 8-week interventions. Significant group × time interaction effects were found for the left leg force (p.p), (p=<0.01; effect size (95% CI), =1.51 (0.70 to 2.32), right leg force (p.p),(p=<0.03; effect size (95% CI), = 0.08 (-0.63 to 0.79), anterior force (p=<0.01; effect size (95% CI), =0.15 (-0.55 to 0.87), posterior force (p.p) (p=<0.01; effect size (95% CI), = 0.79 (-0.05 to 1.53), vertical force (p.p) (p=<0.01; effect size (95% CI), =0.58 (-0.14 to 1.31). Additionally, significant main effects of time were found for the right leg force (p.p) (p=<0.02), anterior force (p.p) (p=<0.01), posterior force (p.p) (p=<0.01). The main effect of the group was significant at right leg force (p.p) (p=<0.03), anterior force (p.p) (p=<0.05),posterior force (p.p) (p=<0.01).

As per Table 3, a two-way (group x time) ANOVA with repeated measures results revealed significant effects of the 8-week interventions. Significant group × time interaction effects were found for the left leg force (N), (p=<0.01; effect size (95% CI), = 0.59 (-1.32 to 0.13), right leg force (N),(p=<0.01; effect size (95% CI), = 0.25 (-0.97 to 0.46), anterior force (p=<0.01; effect size (95% CI), =0.28 (-1.00 to 0.43), posterior force (p=<0.01; effect size (95% CI), = 0.28 (-1.00 to 0.38), vertical force (p=<0.01; effect size (95% CI), =1.43 (-2.24 to 0.63). Additionally, significant main effects of time were found for the left leg force (N) (p=<0.04), posterior force (p=<0.01), Vertical force (N) (p=<0.01). The main effect of the group was significant at Left leg force (N) (p=<0.01), Vertical force (N) (p=<0.03).

As per Table 4, a two-way (group x time) ANOVA with repeated measures results revealed significant effects of the 8-week interventions. Significant group × time interaction effects were found for the speedball (ms) in situation throw slow, (p=<0.01; effect size (95% CI), = 0.14 (-0.56 to 0.86), the speedball (ms) in situation throw fast,(p=<0.02; effect size (95% CI), = 0.91 (-0.16 to 1.66). Additionally, significant main effects of time were found for the speedball (ms) in situation throw slow (p=<0.02), the speedball (ms) in situation throw fast (p=<0.01). The main effect of the group was significant at the speedball (ms) in situation throw slow (p=<0.03), the speedball (ms) in situation throw slow (p=<0.01).

As per Table 5, a two-way (group x time) ANOVA with repeated measures results revealed significant effects of the 8-week interventions. Significant group × time interaction effects were found for the FHA (p=<0.03; effect size (95% CI), = 0.87 (-2.34 to 0.13), FSA,(p=<0.05; effect size (95% CI), = 0.68 (0.32 to 1.22), TKA (p=<0.02; effect size (95% CI), =0.64 (0. 54 to 1.25). Additionally, significant main effects of time were found for the FHA (p=<0.01), FSA (p=<0.01), TKA (p=<0.01). The main effect of the group was significant at FHA (p=<0.03), FSA (p=<0.01), TKA (p=<0.04).

Discussion

This study revealed that using a corrective exercises approach to the components of ground reaction forces in male students with upper crossed syndrome during throwing, does appear improved to throw function (the time to reach the maximum ground reaction force in the left leg, right leg, anterior, posterior, and vertical directions increased after corrective exercises in the experimental group) and posture when compared to control group. The corrective exercises for 8 weeks improved the time and the mean and standard deviation to attain the maximum ground reaction force during handball throwing. This method can be used as an intervention to improved throw function and and posture in participants with UCS. Thus, individuals with UCS who undergo corrective exercises exhibit improved posture and balancing the agonist and antagonist muscle strength around the scapula and shoulder, providing dynamic glenohumeral joint stability, restoring scapula and shoulder muscles activation in overhead athletes adaptations that are linked to improvements in throw performance.

The time to reach the maximum ground reaction force in the left leg, right leg, anterior, posterior, and vertical directions increased after corrective exercises in the experimental group. On the other the maximum ground reaction force in the direction of the left leg, right leg, anterior, posterior, and vertical decreased after corrective exercises in the experimental group.

Posture disorder is one of the factors that can cause a change in body posture, and furthermore, this change in posture can affect the force distribution in the leg [52, 53]. Winters reported that any type of positional change in the upper limb causes a shift in the index of the center of the body, which can move the plantar part of the foot through the hip and ankle joints and cause changes in force distribution [54]. Carlso considers this subject as the distribution of power pressure in the dorsal part, which can affect the ratio of power in different parts of the foot [52]. The decreasing of the vertical component of the ground reaction force indicates less fluctuation in movement [52, 55]. Reduced oscillation can indicate better posture control in the vertical direction. Former researchers have stated that increasing the frequency content causes instability and laxity in the movement pattern [55]. Vertical ground reaction forces provide many parameters for functional evaluation[56]. Stergio et al. reported that elderly women had much higher frequency content in the anterior-posterior direction than young women [57]. Approximately, age differences can be detected by analyzing the range of the frequency spectrum in the anterior-posterior direction[58]. These differences may be the result of reduced walking speed compared to the elderly group [57].

One of the reasons for the increasing time to reach the maximum ground reaction force along the left leg, right leg, anterior, posterior, and vertical after corrective exercises in the experimental group can be that due the effect of corrective exercises on improving posture, biomechanics and muscle balance. Our outcomes are consistent with many similar studies that the corrective exercises improves upper extremity movement patterns during various activities and these changes can lead to improved GRF[28, 29, 59]. The fact that body posture disorders are one of the factors that can generate various dysfunctions of the human body makes this inspirational aspect[60]. Changes in body posture affect the dysfunction of the foot load proportion[61].

Upper crossed syndrome (UCS) is an aberrant posture that matching to Vladimir Janda (1923–2002) refers to a specifcally changed muscle activation pattern (especially in the neck, trunk and scapular muscles) and altered movement patterns (scapular dyskinesis) along with postural deviations (forward head and shoulder posture, and increased thoracic Kyphosis) [7, 8]. In persons with upper-crossed syndrome, the deviation from optimal posture[10, 11], is associated with changes in muscle activity, movement patterns[8] and biomechanics[12]. These changes can lead to imbalance in muscle activation, movement pattern and biomechanical and throwing performance alteration[12, 62]. Ground reaction force (GRF), can simultaneously impact and be impacted by pathological disorders. Disorders such as degenerative diseases of the joints injury, or foot problems (e.g., foot ulcers secondary to diabetes mellitus, plantar fasciitis) are presented with a GRF that may deviate substantially from the normal[63, 64]. Thus, it is important to assess and correct the movement defects, otherwise, over time this can cause more malalignment, exacerbating the symptoms of scapula, increasing the risk of overuse injuries, GRF and leading to other problems[25].

One of the reasons for the increasing time to reach the maximum ground reaction force along the left leg, right leg, anterior, posterior, and vertical after corrective exercises in the experimental group can be that due to the head being forward in these persons compared to the line of body gravity from the medic_lateral,the mass center in these persons is ahead of their healthy peers and approximately, the position of the mass center has changed in these persons and the time to reach the maximum ground reaction force has increased [65]. Head stabilization is defined as maintaining the balance of the head in space [66]. During transition locomotion, healthy people apply a high degree of head stability through compensatory movements, such as coordination of head translations with stepping during linear and angular movements by the whole body [18]. The degree of stabilization of movement during movement is mainly determined by the frequency and speed of head disturbances [18]. One of the effective factors affecting the amount of frequency to the head is the amount of ground reaction force that enters through other organs to the head and neck area during running [58]. Ground reaction forces, time to peak of these components, vertical loading rate, impulse, and free torque are among the most important kinetic variables that can affect the mechanics of the throw [67]. The amount of these forces and the rate of vertical loading are related to the injury of the lower limb and the throwing function [68]. According to the mentioned information, head and neck deformity can cause instability of the eye position, and this instability can affect the balance in functional movements and change the values of the ground reaction force. This factor can affect throwing performance and cause lower and upper limb injuries during the throw. Considering the improvement of upper crossed syndrome and the change of ground reaction forces after corrective exercises in this study, it can be inferred that corrective exercises had a positive effect on throwing performance and the change of ground reaction forces. On the other According to its formula, the loading rate depends on two factors: the vertical ground reaction force and the time to reach the maximum force. Increasing the loading rate in the long term causes joint damage and destruction, which in this study, the loading rate was low[69, 70].

Conclusion:

This study revealed that using a corrective exercises approach to the components of ground reaction forces in male students with upper crossed syndrome during throwing, does appear improved to throw function (the time to reach the maximum ground reaction force in the left leg, right leg, anterior, posterior, and vertical directions increased after corrective exercises in the experimental group) and posture when compared to control group. The corrective exercises for 8 weeks improved the time and the mean and standard deviation to attain the maximum ground reaction force during handball throwing. This method can be used as an intervention to improved throw function and and posture in participants with UCS.

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Table 1. Baseline characteristics of both study groups.

Variables	Intervention group	Control group	P-value
Age (year)	17.6 ± 1.8	16.7 ± 1.9	0.21
Height (cm)	173 ± 4	171 ± 5	0.23
Mass (kg)	70.1 ± 4.0	69.8 ± 4.9	0.16
BMI (kg/m^2)	23.1 ± 1.1	21.0 ± 0.7	0.34
FHA (degree)	46.7 ± 2.4	47.9 ± 1.1	0.14
SA (degree)	54.3 ± 1.4	53.6 ± 2.1	0.06
TKA (degree)	47.9 ± 2.5	46.7 ± 1.8	0.23

BMI: body mass index; FHA: Forward head angle; SA: shoulder angle; TKA: thoracic kyphosis angle

Table 2 The of time to reach the maximum ground reaction force during the throwing ball before and after interventions.

Variables	groups				P-value			
	Intervention group		Control group		Main effect of time	Main effect of group	Time* group interaction	ES (95% CI)
	Pre-test	Post-test	Pre-test	Post-test				
Left leg force (p.p)	40.4 ± 7.5	51.2 ± 6.7	41.3 ± 7.5	44.0 ± 6.7	>0.51	>0.85	<0.01	1.51 (0.70 to 2.32)
Right leg force (p.p)	68.9 ± 34.8	71.4 ± 26.6	64.0 ± 28.5	61.9 ± 18.4	<0.02	<0.03	<0.03	0.08 (-0.63 to 0.79)
Anterior force (p.p)	64.5 ± 18.4	67.6 ± 20.2	64.2 ± 18.5	58.1 ± 21.5	<0.01	<0.05	<0.01	0.15 (-0.55 to 0.87)
Posterior force (p.p)	41.1 ± 21.4	56.4 ± 17.0	33.0 ± 23.9	35.2 ± 24.4	<0.01	<0.01	<0.01	0.79 (-0.05 to 1.53)
Vertical force (p.p)	34.3 ± 17.1	42.0 ± 7.2	29.8 ± 22.4	32.8 ± 22.2	>0.22	>0.40	<0.01	0.58 (-0.14 to 1.31)

P.P: Phase percentage. Data are presented as mean ± SD. CI: Confidence Interval. ES: effect size

Table 3 The maximum ground reaction force during ball throwing (before and after interventions.

Variables	groups				P-value			
	Intervention group		Control group		Main effect of time	Main effect of group	Time* group Interaction	ES (95% CI)
	Pre-test	Post-test	Pre-test	Post-test				
Left leg force (N)	62.2 ± 19.2	52.0 ± 14.5	59.1 ± 19.6	65.8 ± 16.8	<0.04	<0.01	<0.01	0.59 (-1.32 to 0.13)
Right leg force (N)	69.0 ± 34.8	61.9 ± 18.4	62.7 ± 28.3	66.0 ± 18.2	>0.83	>0.45	<0.01	0.25 (-0.97 to 0.46)
Anterior force (N)	169 ±77	150 ± 50	164 ± 78	170 ± 75	>0.40	>0.15	<0.01	0.28 (-1.00 to 0.43)
Posterior force (N)	161 ± 78	143 ± 38	158 ± 76	160 ± 74	<0.01	>0.23	<0.01	0.28 (-1.00 to 0.38)
Vertical force (N)	765 ± 98	636 ± 81	636 ± 81	652 ± 71	<0.01	<0.03	<0.01	1.43 (-2.24 to 0.63)

Data are presented as mean ± SD. CI: Confidence Interval. ES: effect size

Table 4 The ball speed during the throwing ball before and after interventions

	Situation throws	Groups				P-value			ES (95% CI)
		Intervention group		Control group		Main effect of time	Main effect of group	Time* group Interaction	
		Pre-test	Post-test	Pre-test	Post-test				
Ball speed (m/s)	slow	7.20±1.51	7.42±1.44	8.23±1.70	8.19±1.50	<0.02 *	<0.03 [a]	<0.01 [b]	0.14 (-0.56 to 0.86)
	fast	11.00±1.91	12.84±2.12	12.06±2.53	11.99±2.30	<0.01 *	<0.01 [a]	<0.02 [b]	0.91 (-0.16 to 1.66)

Data are presented as mean ± SD. CI: Confidence Interval. ES: effect size.

Table 5 Forward head and shoulder and thoracic kyphosis angle before and after interventions.

Variables	groups				P-value			ES (95% CI)
	Intervention group		Control group					
	Pre-test	Post-test	Pre-test	Post-test	Main effect of time	Main effect of group	Time* group Interaction	
FHA	48.2 ± 1.2	43.9 ± 2.1	47.9 ± 1.1	48.2 ± 2.1	<0.01 *	<0.03 [a]	<0.03 [b]	0.87 (-2.34 to 0.13)
SA	54.2 ± 2.1	46.4 ± 2.2	53.9 ± 1.5	54.5 ± 2.3	<0.01 *	<0.01 [a]	<0.05 [b]	0.68 (0.32 to 1.22)
tkA	45.1 ± 2.2	36.8 ± 1.2	45.5 ± 1.9	46.6 ± 2.6	<0.01 *	<0.04 [a]	<0.02 [b]	0.64 (0. 54 to 1.25

FHA: Forward head angle; SA: Shoulder angle; TKA: Thoracic kyphosis angle. Data are presented as mean ± SD. CI: Confidence Interval. ES: effect size.

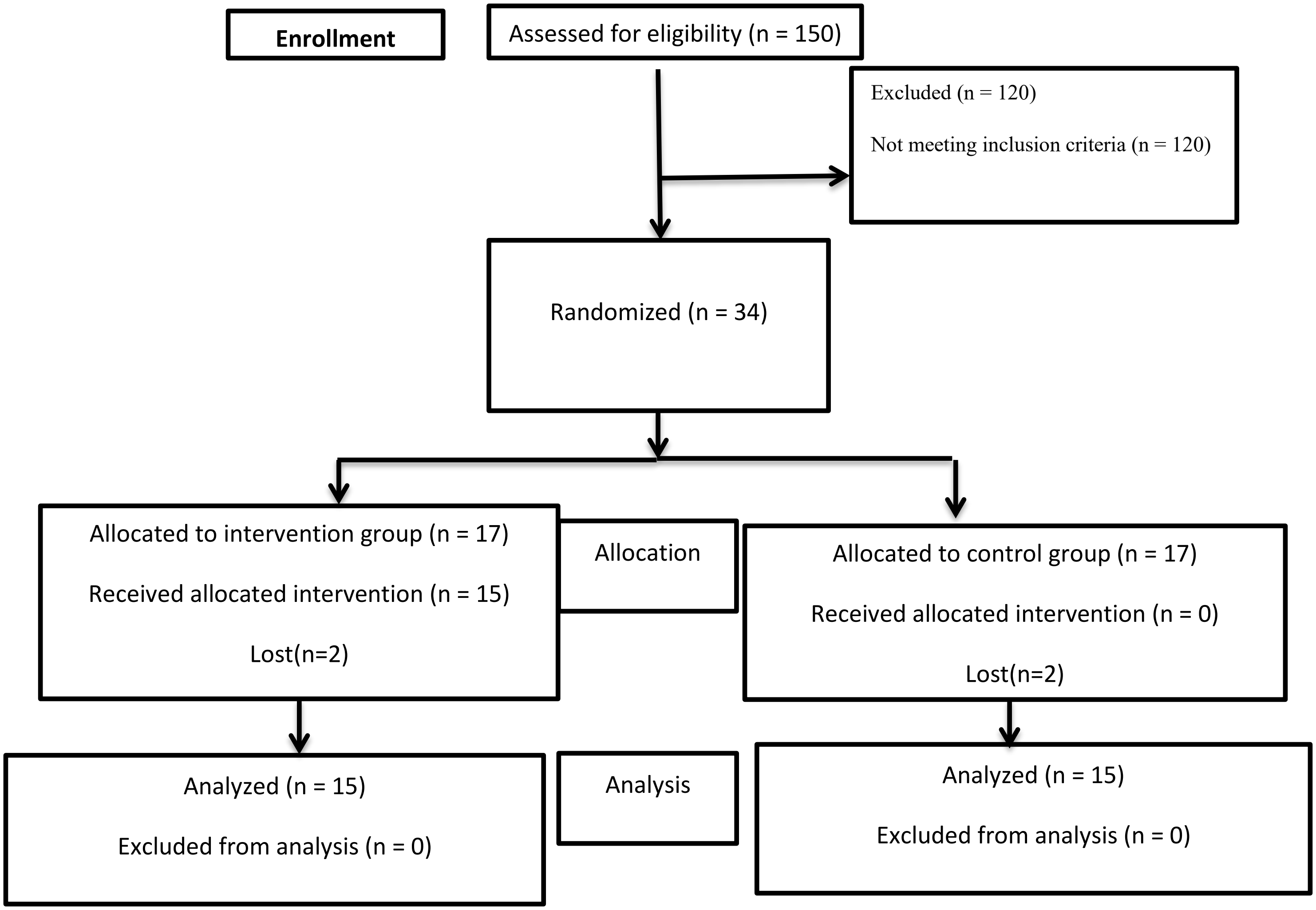


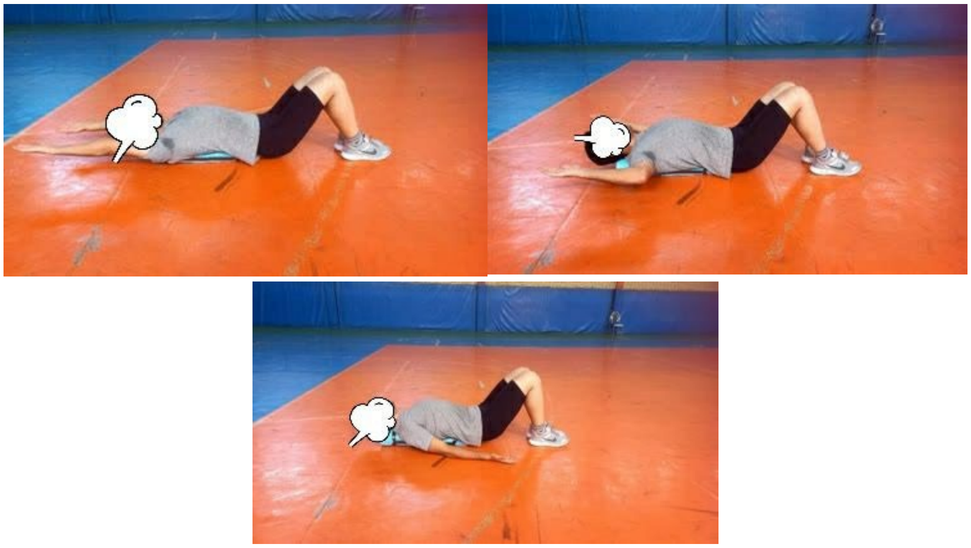
Fig. 1 Flow diagram of the of study

Fig. 2. Recording ground reaction force data during throwing

Appendix 1

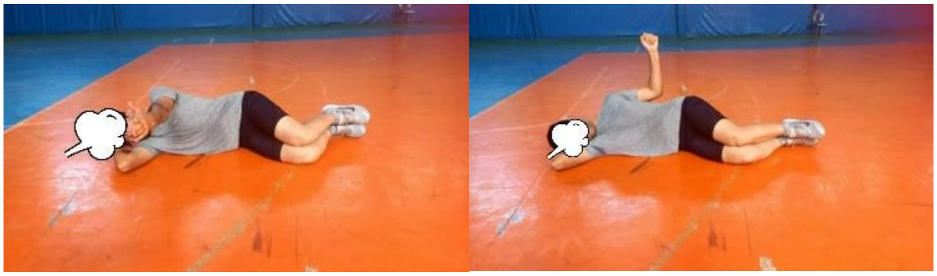
Therapeutic Exercise

Exercise 1: Lay supine on the foam roll in three different arm abduction angles,



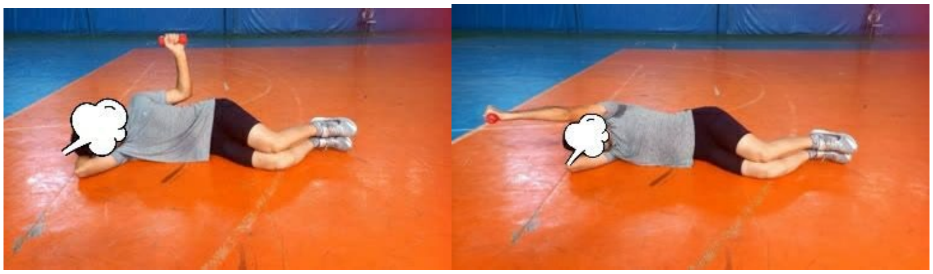
(1)

Exercise 2: Side-lying forward flexion; Exercise 3: Side-lying external rotation



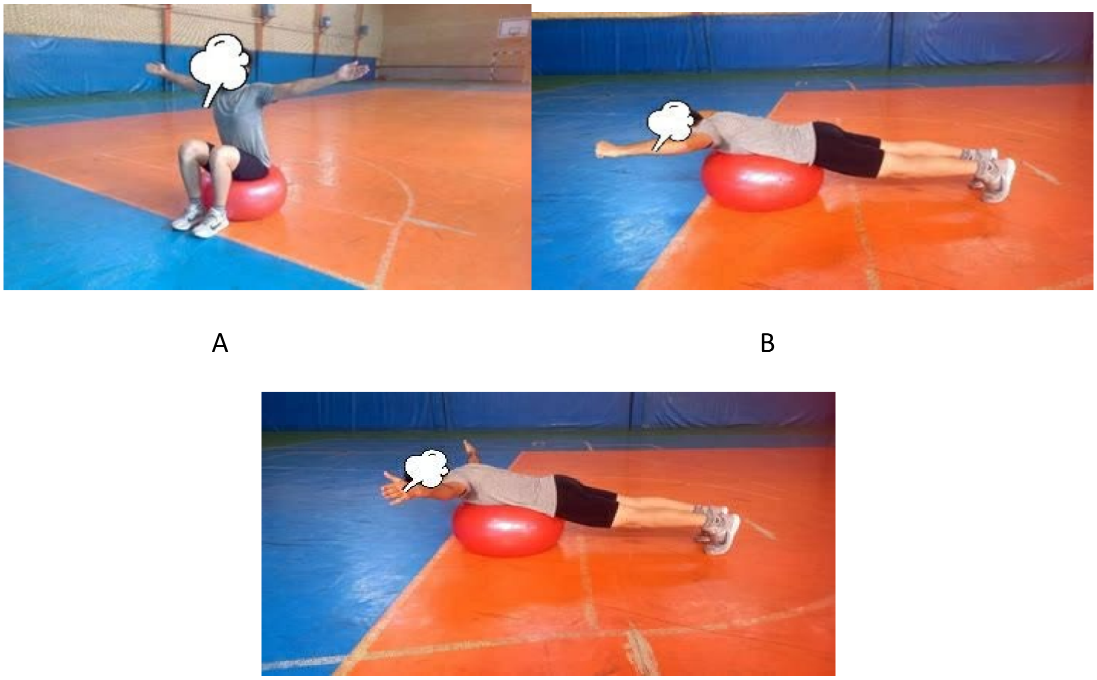
(2,3)

Exercise 4: Side-lying external rotation with dumbbell; Exercise 5: Side-lying forward flexion with dumbbell



(4,5)

Exercise 6: Lying prone T(A) and W (B) V(C), exercises (6)



A

B

C

(6)

Exercise 7: Standing external rotation with Tera-band; Exercise 8: Standing diagonal fexion with Tera-band

(7,8)

Exercise 9: Standing diagonal flexion; Exercise 10: Standing diagonal fexion with dumbbell

(9) (10)

Exercise 11: Military press; Exercise 12: Abduction in standing on the balance board

(11,12)