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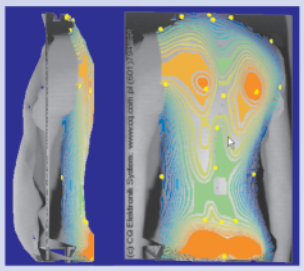

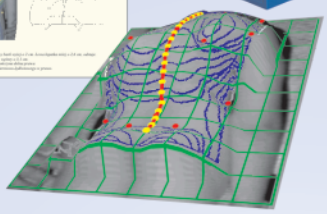

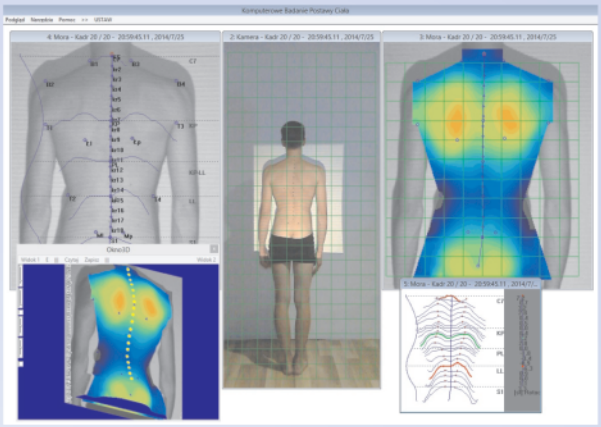

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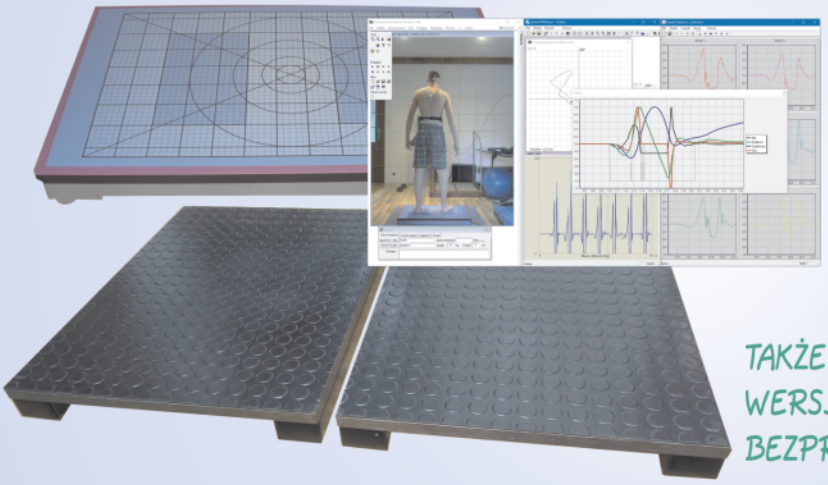

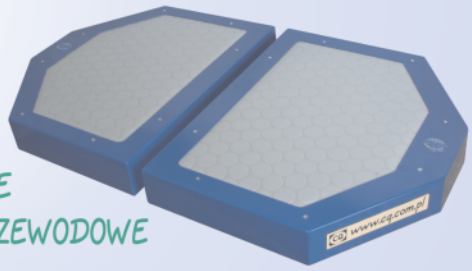

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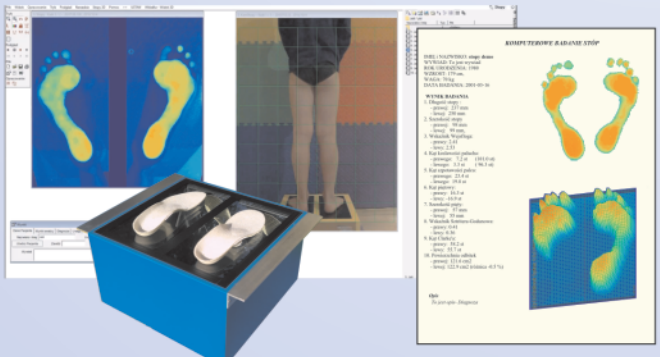

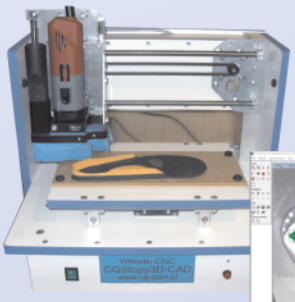

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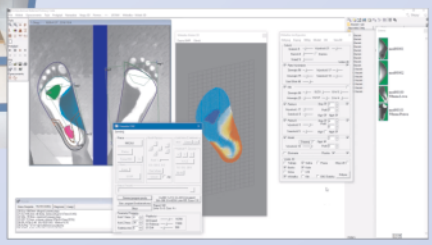

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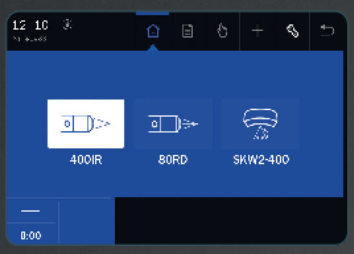

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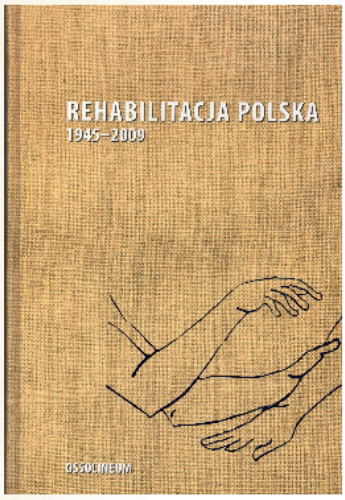

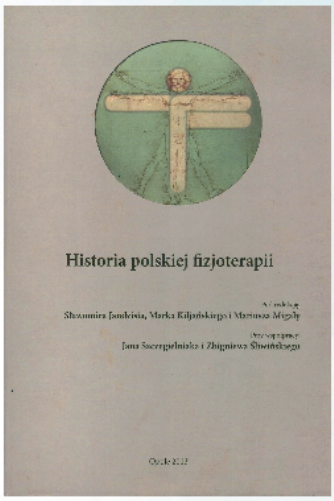

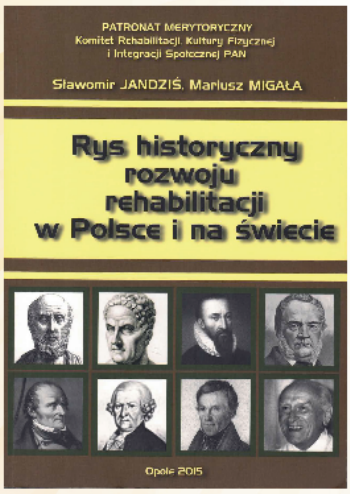

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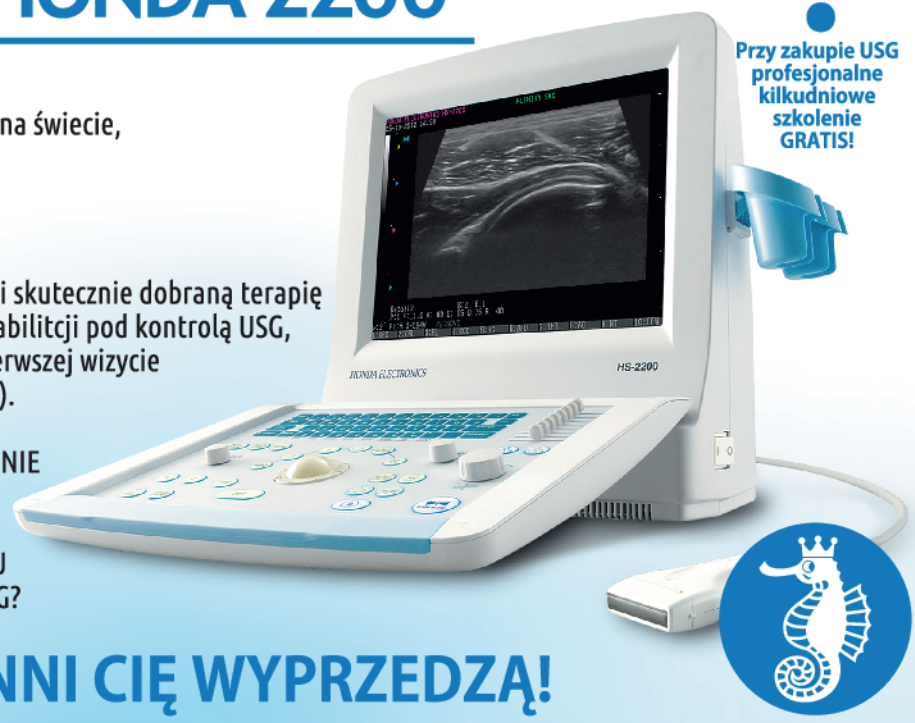

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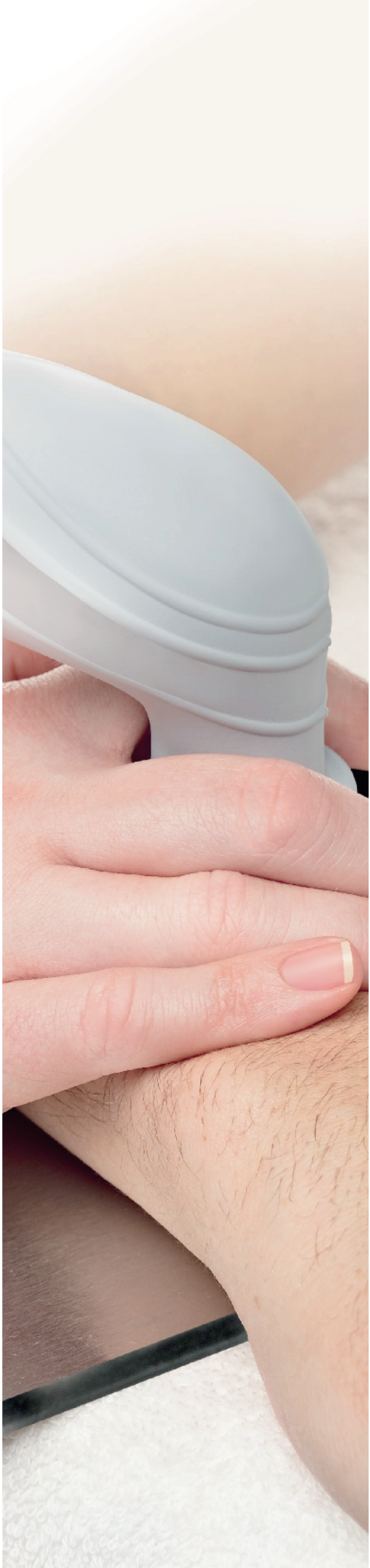

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Effect of plyometrics, closed kinetic chain versus quadratus lumborum strengthening exercises on vertical jump height in volley ballplayers: A randomized controlled trial

Wpływ pliometryki, zamkniętego łańcucha kinetycznego w porównaniu z ćwiczeniami wzmacniającymi mięśnie czworobocznych lędźwi na wysokość skoku wzwyż u siatkarzy: Randomizowane badanie kontrolowane

Yasmein M. Mahmoud[1(A,B,C,D,E,F,G)], Wadeda H. Elsayed[2(A,B,C,D,E,F)], Amira H. Draz[3(A,B,C,D,E,F)]

[1]Department of Physical Therapy for Basic Science, Faculty of Physical Therapy, Kafr El Sheikh University, Egypt
[2]Basic Science Department, Cairo University, Egypt

Abstract

Purpose. To compare the effects of plyometrics, closed kinetic chain with quadratus lumborum strengthening exercises on vertical jump height in volley ball players.
Design. Pre-post measurement randomized controlled trial.
Methods. Two hundred volleyball players were recruited from Cairo and Kafer El Sheikh University, Egypt. 140 volleyball players met the inclusion criteria and were randomly assigned into four equal groups. Group (A) consisted of 35 volley ball players with mean body mass index (BMI) value of 21 ± 3.76 kg/m^2 and received plyometric exercise (Counter Movement jump (CMJ). Group (B) consisted of 35 volley ball players with mean BMI value of 21.44 ± 1.681 kg/m^2 and received closed kinetic chain (CKC) exercise (double limp squat free weights), Group (C) consisted of 35 volley ball players with mean BMI value 22.17 ± 1.8 kg/m^2 and received quadratus lumorum strengthening exercise (isotonic hip hiking), group (A), (B) and (C) received the exercises two times per week for eight weeks. Group (D) consisted of 35 volley ball players with mean BMI value of 22.01 ± 1.69 kg/m^2 and received no exercise (control group).
Results. Statistical analysis revealed that there was significant difference ($p < 0.05$) in favour to group A, B and C in compared to group D. while there were no significant differences ($p > 0.05$) among groups (A, B and C).
Conclusion. Plyometrics (CMJ), CKC (Double limb squat free weights), and quadratus lumborum strengthening exercise (Hip hiking) yield an improvement on vertical jump height.

Key words:

plyometrics, CKC, vertical jump, strengthening exercise

Streszczenie

Cel. Porównanie efektów pliometryki, zamkniętego łańcucha kinetycznego z ćwiczeniami wzmacniającymi mięśnie czworoboczne lędźwi na wysokość skoku wzwyż u siatkarzy. Projekt. Randomizowana próba kontrolowana, pomiar przed i po. Metody. W badaniu wzięło udział dwustu siatkarzy z Uniwersytetu w Kairze i Kafer El Sheikh w Egipcie. 140 siatkarzy spełniło kryteria włączenia i zostało losowo przydzielonych do czterech równych grup. Grupa (A) składała się z 35 siatkarzy o średnim wskaźniku masy ciała (BMI) 21 ± 3,76 kg/m2 i wykonywała ćwiczenie pliometryczne (skok wzwyż z obrotem (CMJ). Grupa (B) składała się z 35 siatkarzy o średnim BMI 21,44 ± 1,681 kg/m2 i wykonywała ćwiczenia w zamkniętym łańcuchu kinetycznym (CKC) (przysiady bez ciężarów). Grupa (C) składała się z 35 siatkarzy o średnim BMI 22,17 ± 1,8 kg/m2 i wykonywała ćwiczenia wzmacniające mięśnie czworoboczne lędźwi (izotoniczny chód przy uniesionej miednicy). Grupy (A), (B) i (C) wykonywały ćwiczenia dwa razy w tygodniu przez osiem tygodni. Grupa (D) składała się z 35 siatkarzy o średnim BMI 22,01 ± 1,69 kg/m2 i nie wykonywała żadnych ćwiczeń (grupa kontrolna).
Wyniki. Analiza statystyczna wykazała, że istnieje istotna różnica ($p <0,05$) na korzyść grupy A, B i C w porównaniu z grupą D. Nie zaobserwowano istotnych różnic ($p> 0,05$) między grupami (A, B i C). Wnioski. Pliometryka (CMJ), CKC (przysiad bez ciężarów) oraz ćwiczenia wzmacniające mięśnie czworoboczne lędźwi (chód przy uniesionej miednicy) powodują poprawę wysokości skoku wzwyż.

Słowa kluczowe:

Pliometryka, CKC, skok wzwyż, ćwiczenia wzmacniające

Introduction

In volleyball the counter movement vertical jump (CMVJ) is a key movement of the jump serve, jump set, block jump and spike jump. Vertical jumping is considered an essential motor skill in a range of team sports including, volleyball, soccer, basketball and handball, it is often used to assess motor development, functional ability, and motor capacity, in the young, elderly and athletes [1, 2].

Plyometrics is a well-known form of ballistic training which is designed to improve jump performance capabilities, strength, running economy, agility, sprint ability and helping in preventing knee injuries and athletes use a countermovement jump (CMJ) strategy to achieve maximum vertical jump height [3, 4]. Squats seek to strengthen the quadriceps and hip stabilizer muscles and are frequently prescribed in the rehabilitation of individuals with knee joint dysfunctions [5].

Hip hiking which is the action of quadratus lumborum muscle is a bilateral and multi-joint movement that generates large stresses in the anterior muscles that cross the knee and hip joint, providing a better link between the upper and lower body through a more stable pelvis and spine should help improve jumping ability [6]. Recent biomechanical studies indicate that hip muscle activation significantly affects the ability of the quadriceps and hamstrings to generate force or resist forces experienced by the entire leg during jumping and in sports like volley ball and basketball the major task is the ability to jump higher so this make many coaches asking about the most effective type of exercise that provide maximum jump and improve jump height [6, 7].

Many researchers investigated the effect of plyometric training on vertical jump performance [8] [9, 10, 11, 12] but they did not investigate its effect in comparison to other different types of training, CKC and active resisted exercise, so this gap in research aroused our interest to investigate the therapeutic effectiveness of different types of strengthening exercises that affect the jump height and see which of them is more useful in improving training qualities.

Purpose

The purpose of this study was to compare the effects of plyometrics, closed kinetic chain with quadratus lumborum strengthening exercises on vertical jump height in volley ball players.

Materials and Methods

Study Design

The study was designed as randomized controlled trial pre-post measurement design. Ethical approval was obtained from ethical committee of Faculty of physical therapy, Cairo University, Egypt before study commencement (No: P.T.REC/012/001829). The study followed the Guidelines of Declaration of Helsinki on the conduct of human research. The study was conducted between July 2018 to April 2019.

Participants

By simple random sampling which is a method of probability sampling, two hundred male and female volley ball players were recruited into the study from Cairo and Kafr El Sheikh University, Egypt, 140 volley ball players met the inclusion criteria of the wellness scale index which is a general healthy life questionnaire. It measures the overall status and well- being. and they were randomly and equally distributed as 35 volley ball players in four groups. The volley ball players were enrolled and assessed for their eligibility to participate in the study. Inclusion criteria were as following: The volley ball player's ages ranged from 18 to 25 years old [13]. Their body mass index ranged from 18 to 25 kg /m². All of them were medically stable. They were healthy according wellness scale. They did not suffer from any injuries which might affect the trial results. They had similar normal daily regimen. Exclusion criteria were as following: History of any recent trunk, hip, knee or ankle injury, History of recent surgery for any part of the body, History of recent fracture in trunk sacroiliac or lower limb and players who practicing any kind of physical training or exercises rather than the one used in the study e.g. going to gymnastics. Written informed consents were obtained from the volley ball players after explaining the nature, purpose, and benefits of the study, informing them of their right to withdraw or refuse at any time, and the confidentiality of any obtained information.

Randomization

The volley ball players were randomly assigned into four equal groups (A, B, C and D) by a blinded, independent research assistant who opened sealed envelopes that contained computer generated randomization cards, two volley ball player.

Interventions

Group (A) received plyometric exercise (CMJ with arm swing). Volley ball players were carefully familiarized with all procedures, ten minutes of general warm up were performed before each session, including two minutes of low-intensity aerobic exercise, dynamic stretching exercises, and one set of nine sub-maximal jumps, plyometric training practicing (duration = eight weeks, frequency = two sessions per week) [14]. The volley ball players started in a standing position, and squats down to the 90 degree leg bend position before immediately jumping up. Hands swing forward and back word with the jump [1]. Program design included: exercise mode: which was lower body plyometric exercise (CMJ), Intensity: High speed jump drills with double limb and maximum height, Frequency: Two times per week for eight weeks [2], Recovery period: five seconds rest between repetitions and five minutes rest between each set, Volume: Three sets per session in each set the volley ball players increased the number of repetitions until fatigue appears and this was re- evaluated in every next session for exercise progression [15, 16].

Group (B) received CKC exercise (Double limb squat free weights), the exercise began with flexing the hips and knees slowly under control while keeping the torso to floor angle relatively constant, a flat-foot position was maintained with the knees aligned over the feet as they flex the hips and knees was continue flexing until the thighs are parallel to the floor, then raising from squat by extending the hip and knee while keeping the torso to

floor angle relatively constant. Program design included: Exercise mode: Double limb squat, Intensity: limited to individual body weight and was determined according the volley ball player's ten repetition maximum (10 RM) test [17] which was re- evaluated every week for exercise progression. Frequency: two times per week for eight weeks. Recovery period: Hold the squat for 4second, relax for 4 second before the next one and relax 5-7 minutes between each set. Volume: three set per session, the first two sets were done according 10 RM test and in third set players increased number of repetitions until they felt fatigue symptoms [18].
Group (C) received quadratus lumborum strengthening exercise (hip hiking), Concentric active resisted exercise program (low repetition high resistance} against weight was used and modified according 10 RM principles at moderate contraction velocity (1-2 second) for three sets in every session, three times per week for eight weeks. Weight of sand bags were tied above the ankle joint while the volley ball players standing on a stepper with the training limb free not on the stepper and the players were asked to raise their pelvic up against the weight with keeping the hand supporting the pelvic [19].
Group (D) received no exercise (control Group).

Outcome measures

Vertical jump height

My jump 2 software application (My jump 2 APP) was used to measure vertical jump height. All jumps were recorded at high velocity camera 240 Hz (720 × 1080 pixel resolution). The iPod video files were imported into the My Jump 2 APP and analyses performed following the APP instructions. An iPod apple Inc, 64GB designed in California, designed and developed for IOS was used to download my jump 2 software application [13, 20]. My Jump 2 calculate the time in the air of the CMJ by identifying the take-off and the landing frames of the video, and then determining the jump height using the equation described by Bosco [21] height (h) = t2 × 1.22625.

To record every CMJ with the application, the therapist was sitting on the ground with the iPod camera opposite the volley ball player (in the frontal plane), about 1 meter far from the player's foot, zooming the camera on the feet of the player, then calculating the time between two frames, selecting a first frame, just when the player lost contact with the platform (taking-off) and, a second frame, just when the player came into contact with the platform again (landing). In this way, the height of CMJ was measured by using the previous equation [13, 22].
It was measured before the commitment of the study and after eight weeks of the study (pre–post measurement).

Statistical Analysis

Results were expressed as mean ± standard deviation (SD). Prior to final analysis, data were screened for normality assumption, homogeneity of variance, and presence of extreme scores. This exploration was done as a pre-requisite for parametric calculations of the analysis of difference. There were no univariate outliers in the data, as assessed by inspection of a boxplot. Jump height was normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$). There was homogeneity of variances, as assessed by Levene's ($p > 0.05$). Accordingly, 4x2 Mixed ANOVA test was used to compare the tested variable of interest at different measuring periods at different groups. With the initial alpha level set at 0.05. Statistical Package for Social Sciences (SPSS) computer program, version 22 windows (SPSS, Inc., Chicago, IL) was used for data analysis.

Results

The current study was conducted on 140 normal healthy male and female subjects. They were assigned randomly into four equal studies groups. As indicated by the One Way Analysis of Variance (ANOVA), there were no significant differences ($p > 0.05$) in the mean values of body mass, height and BMI among the four tested groups Table [1].

Table 1. Descriptive statistics and One Way Analysis of Variance (ANOVA) for the mean body mass, height, and BMI values for the four tested groups

	Group A	Group B	Group C	Group D	F-value	P-value
Body mass (kg)	63.66 ± 6.88	65.22 ± 8.8	65.21 ± 7.93	65.88 ± 8.27	**0.436**	**0.728**
Height (cm)	170.13 ± 7.04	173.62 ± 8.8	171.33 ± 8.41	172.88 ± 38	**1.18**	**0.32**
BMI (kg/m^2)	21 ± 3.76	21.44 ± 1.68	22.17 ± 1.8	22.01 ± 1.69	**1.663**	**0.178**

**Significant at alpha level < 0.05*

Statistical analysis using 4x2 mixed design ANOVA indicated that there were significant effects of the tested group on the jump height (F = 3.247, p = 0.024*). In addition, there were significant effects of the measuring periods (the second independent variable) on the jump height (F = 925.041, p = 0.0.0001*). Also, the interaction between the two independent variables was significant, which indicates that the effect of the tested group (first independent variable) on the jump height was influenced by the measuring periods (second independent variable) (F = 111.928, P = 0.0001*).

Within groups for jump height. Multiple pairwise comparison tests (Post hoc tests) revealed that there was significant increase ($p < 0.05$) of Jump height at post treatment in compare to pre-treatment in groups (A, B and C). while there was no significant difference ($p > 0.05$) at post treatment in compare to pre-treatment in group D).
Among groups, Considering the effect of the tested group (first independent variable) on Jump height, Multiple pairwise comparison tests (Post hoc tests) revealed no significant differences ($p > 0.05$) at the mean values of the "pre" test among

four groups. As well as, Multiple pairwise comparison tests (Post hoc tests) revealed that there was no significant difference of the mean values of the "post treatment" test revealed among (group A versus B), (group A versus C), and (group B versus C) with ($p > 0.05$). While, multiple pairwise comparison tests (Post hoc tests) revealed that there was significant difference among (group A versus D), (group B versus D), and (group C versus D) with ($p < 0.05$) and this significant increase in favor to group A, B and C in compared to group D as shown in table [2].

Table 2. Descriptive statistics and 4x2 mixed design ANOVA for jump height at different measuring periods at different groups

Jump height (mean ± SD)	Group A	Group B	Group C	Group D
Pre treatment	24.86 ± 8.39	24.73 ± 8.89	25.14 ± 8.45	24.58 ± 7.69
Post treatment	35.5 ± 9.08	34.11 ± 9.32	34.67 ± 10.43	24.58 ± 7.69
MD	−10.64	−9.38	−9.53	0.00
% of change	42.79%	37.92%	37.90%	0%
Multiple pairwise comparisons (Post hoc tests) between different measuring periods for jump height at different				
p-value	**Group A**	**Group B**	**Group C**	**Group D**
Pre treatment Vs. post treatment	0.0001*	0.0001*	0.0001*	1.00
Multiple pairwise comparison tests (Post hoc tests) for the jump height among different groups at different measuring				
p-value	**Pre treatment**	**Post treatment**		
Group A Vs. group B	0.99	0.99		
Group A Vs. group C	0.99	0.99		
Group A Vs. group D	0.99	0.0001*		
Group B Vs. group C	0.99	0.99		
Group B Vs. group D	0.99	0.0001*		
Group C Vs. group D	0.99	0.0001*		

**Significant level is set at alpha level < 0.05; SD: standard deviation; MD: Mean Difference; p-value: probability value*

Discussion

In sport activities such as sprinting and jumping, the ratio of the strength of the muscles involved in the movement to the mass of the body parts being accelerated is critical [2]. Thus, the strength-to-mass ratio directly reflects an athlete's ability to accelerate his or her body. Considering the wide variety of movements associated with athletics, athletes must possess sufficient strength in hip and trunk muscles that provide stability in all three planes of motion [.recent biomechanical studies indicate that hip muscle activation significantly affects the ability of the quadriceps and hamstrings to generate force or resist forces experienced by the entire leg during jumping, so this aroused our interest to investigate the therapeutic effectiveness of three different types of strengthening exercises that affect the jump height and see which of them is more useful to improve training qualities [6, 23].

Statistical analysis using 4x2 mixed ANOVA design indicated that there were significant effects of the tested group on the jump height. In addition, there were significant effects of the measuring periods on the jump height. Also, the interaction between the two independent variables was significant, which indicates that the effect of the tested group (first independent variable) on the jump height was influenced by the measuring periods (second independent variable). Multiple pairwise comparison tests (Post hoc tests) revealed that there was significant difference between (group A versus D), (group B versus D), and (group C versus D) and plyometric exercise revealed the most improvement in jump height then quadratus lumborum strengthening exercises then CKC exercise, which may be explained by the following: plyometric exercise is a quick, powerful movement using the stretch– shortening cycle (SSC). The purpose of plyometric exercise is to increase the power of subsequent movements by using both the natural elastic components of muscle and tendon and the stretch reflex, the stretch–shortening cycle (SSC) employs the energy storage capabilities of the SEC and stimulation of the stretch reflex to facilitate a maximal increase in muscle recruitment over a minimal amount of time The stretch–shortening cycle combines mechanical and neurophysiological mechanisms and is the basis of plyometric exercise [9].

In study done by Rodrigo Ramirez-Campillo et al., (2019), they reported that plyometric jump training improved several measures of performance-related fitness in male youth soccer players, yielding small to moderate improvements in counter-movement,

horizontal and drop jumping and in kicking velocities, irrespective of the maturity of the athletes [24].
Other study done by Alejandro et al., (2019) confirmed that CMJ performance may be meaningfully affected by the velocity and depth of the countermovement in improving vertical jump performance [8].
The significant improvement effect of quadratus lumborum strengthening (hip hiking) was due to providing a better link between the upper and lower body through a more stable pelvis and spine should help improve jumping ability, therefore, trunk stability in addition to available leg strength may be important in explaining the variance associated with improvements in performance of vertical jumping [6, 7, 25].
Scott et al., 2007 investigated the effect of trunk stability on jump they indicate that nine weeks of trunk stability training, leg strength training, or combined trunk stability and leg strength training were similarly effective in enhancing an athlete's vertical jump [25].
The significant effect of CKC (squat) exercise was due to with these types of exercises, the body weight of the individual is used to provide resistance and CKC exercises appears to offer a low-cost training method that allows for the development of relative strength levels as it has many benefits as it is specific to each individual's anthropometrics. Often includes closed chain–based exercises that strengthens several muscle groups at once (co-contraction between agonist and antagonist muscles) , develops relative strength and improves body control, also the application of chains to traditional resistance training methods allows for a linear increase in the applied resistance [18, 26].
A study performed on squat effect on jump by Hirayama and Kuniaki (2014), concluded that vertical jump height increased after performance of an ascending intensity squat protocol compared with baseline values. The main finding of this study was that 1 repetition of a squat exercise with a sufficient load (intensity and/or volume) enhanced subsequent vertical jump performance in subjects performing an ascending intensity squat protocol [18].

Conclusion

Within the limitation of this study which were: It was difficult to fix the normal daily regimen for all the volley ball players, so they received a clear sharp order to avoid doing any kind of exercises rather than the one used in the study. The jump height at first was planned to be measured by force plate form, but it was difficult to transfer all players to the force plate lab and also the price of measurement cessions was so expensive especially we measured pre and post for every volley ball player, so portable valid and reliable software application that measure jump height was used, it was concluded that Plyometrics (CMJ), CKC (Double limb squat free weights), and quadratus lumborum strengthening exercise (Hip hiking) yield an improvement on vertical jump height.

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