

The Effect of Maximal Leg Press Strength Training on Bilateral Deficit *

Hamit CİHAN¹, Rasim KALE¹, İbrahim CAN², Erdal ARI³

¹ School of Physical Education and Sport, Karadeniz Technical University, Trabzon, Turkey.

² Department of Physical Education, Gümüşhane University, Gümüşhane, Turkey.

³ School of Physical Education and Sport, Ordu University, Ordu, Turkey.

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ABSTRACT

The purpose of this study was to determine maximal isometric strength with bilateral and unilateral muscle contractions and investigate maximal strength training whether or not influenced on this bilateral deficit. For this reason, 34 amateur soccer player (age = 17 ± 2.51 years) were divided into three groups as bilateral training group (n=14), unilateral training group (n=10) and control group (n=10). The unilateral training group performed maximal leg press exercise using each leg unilaterally. The bilateral leg training group was performed to leg press exercise using simultaneously bilateral legs. The control group wasn't trained. The groups in training continued these resistance exercises as 1 hour a day, 3 days a week, for 12 weeks. The improvement in strength brought by training was compared as bilateral training group and unilateral training group. Bilateral deficit also was calculated between two groups. The strength in the trained limbs during training was measured in 4th week (after four weeks) and 12th week (after twelve weeks). It was determined that maximal isometric strength of two training groups was increased significantly by strength trainings (p<0.05). There wasn't any significant difference at strength increase for first four weeks of training period (p>0.05). It was determined that strength was increased significantly for final weeks of training period (p<0.05). The other important consequence of this study was determined that maximal strength training had significant effect on bilateral deficit (p<0.05). As a consequence of this study, maximal strength trainings which involved bilateral muscle contractions were effective for reducing of bilateral deficit.

Key Words: Leg press, maximal strength, bilateral deficit.

INTRODUCTION

When performance analyses of sporting actions are conducted, strength in certain sporting fields is a factor that directly or indirectly affects sporting performance (2). Muratlı (6) defines strength as a capacity of a single muscle or a muscle group voluntarily working together to overcome a particular resistance. Strength from a physical perspective is a product of mass and speed and emerges in 2 forms. These occur during movement of matter and changes in the form of matter or during a combination of both (1).

It has been proposed whether unilateral contractions or bilateral contractions, which are muscle groups working together, effects the ability of skeletal muscle groups to generate maximal forces. Herein, a great deal of research has been conducted which observes whether bilateral contractions of both limbs effect the maximal force generation of single muscle groups. A consistent observation in the literature is evident of the effects of contralateral contractions between the upper and lower limbs on maximal force capacity of muscle groups (3,11,14,20). According to the findings of scientific articles, bilateral contractions during lower resistance activities increases performance, whereas during high resistance activities decreases performance (11,20).

The inhibitory factor of bilateral contractions during resistance activities has been discovered by the scientific work conducted by Henry-Smith (3). In this study the sum of the total maximal force generated by unilateral contractions is greater than the total for the bilateral contractions. Further studies (4,11,14) on this field which conducted similar studies defines this effect as "Bilateral Deficit". Intuitively it is thought that the sum of the total maximal work conducted by both limbs will be equal to the total of maximal efforts of each limb. To the contrary this is further away from the truth in particular research articles. A clear explanation of this phenomenon is that, if an individual in a well controlled, valid and reliable test lifts 50 kg with their right arm and 60 kg with their left arm by using the bicep curl movement, in most cases by using both limbs together will not be able to lift 110 kg which is the sum of the total work conducted by each limb. Furthermore, Howard - Enoka (5) has proposed the below formula that can be used to calculate bilateral deficit.

$$\text{Bilateral Deficit} = \left[100 \times \left(\frac{\text{Bilateral Strength}}{\text{Unilateral Left} + \text{Unilateral Right}} \right) - 100 \right]$$

By applying various training modalities the detrimental effects of the bilateral deficit on performance can be reduced and this can be beneficial in helping to increase performance in various sporting fields. If the aforementioned assumption is proved by

scientific experimentation, athletes that participate in bilateral contraction dominant or non-dominant sports can benefit from training regimes that target to reduce the effect of bilateral deficit. Therefore the aim of this study is to compare bilateral and unilateral contractions during leg press actions and to observe the effects of maximal strength training on bilateral deficit.

METHODS

Participants

34 male, amateur football players between the ages of 16-19, that have no previous strength training history participated in this study. Participants were randomly assigned to single leg group (n=10), both legs (n=14) or the control group (n=10).

Protocol

Before commencing with the experiment procedures, the participants were fully informed with daily experimental routines, experiment duration and the purpose of the experiment. Participants were informed that they can withdraw from the experiment at any given time. Participants were also asked to report if they suffered from any previous or current injuries in their back, hip, femoral, knee or ankle regions. Isometric strength was determined in a 20 meter square room. Special care was taken to ensure that the measurements were taken during early hours in the day and on the same day. Strength training was conducted in a certified gym.

Determination of 1 Repetition Maximum (1RM)

Participants were asked to complete a 1 RM on voluntarily chosen weight with a leg press movement. Each set consisted of a single repetition. After completing concentric contraction by flexing the knee the participants completed an eccentric contraction by extending the knee, with the self-determined weight. Upon successful completion of 1RM the incremental increase in resistance was determined by the participants and was performed after a passive 1-minute rest. This pattern continued until the participant failed to lift the assigned resistance. When participants failed to lift the assigned weight a resistance between their failed attempt and successful attempt was chosen and if successfully completed this resistance was recorded as their 1RM score. If that attempt also failed their last successful lift was recorded as their 1RM score.

Strength Training

Loading a muscle group by resistance training is considered as the best method to strengthen a particular muscle group. In this study out of the diverse maximal strength protocols, the classical pyramid system was used.

Measurements

Isometric strength of the lower extremities was determined by using an electro-mechanical dynamometer (Prosport TMR 1000 Isometric Hand Back Dynamometer). The flexion angles of the knee were determined by Ciba-Going goniometry. Before taking measurements the participants completed a 5 minute warm-up protocol and a 10 minute stretching protocol. In order for the participants to adapt to the equipment, light weight resistance training was performed. The participants performed 3 sets with their right, 3 sets with their left and 3 sets with both legs, maximal isometric testing in leg press position. A particular order was not followed during collecting these variables. The participants voluntarily determined the order in which they conducted the activities. After each attempt a total of 3mins resting period was given and the highest value was recorded as the maximal isometric strength.

Organizing the Variables

MS basic program was used to determine and transfer strength variables as numerical values at 0.001 gr sensitivity in ASCII format to a computer. The measurements taken by the dynamometer was recorded in Kilograms (kg) in every 0.01seconds according to ACSII format. The variables collected in ACSII format was later transferred to a MS EXCEL spreadsheet for further statistical analysis.

Analyzing the Variables

The statistical significance alpha level was set at $\alpha = 0.05$. The variables of interest were further analyzed by a one way ANOVA and repeated measured ANOVA statistical tests.

RESULTS

Bilateral Deficit

The repeated measures ANOVA test conducted, displayed a statistical significant ($F_{2,31} = 340.47$; $P < 0.02$) relationship of the bilateral deficit effect between bilateral and unilateral isometric maximal leg press strength at a $\alpha = 0.05$ level for the groups.

In order to determine where the significant lies, a Tukey's test ($HSD = 3.01$) and Matrix comparisons was used. The results showed that single leg training groups average bilateral deficit values (25.91 ± 2.151 kg) were significantly greater compared to bilateral training group (17.55 ± 1.818 kg) and the control group (21.93 ± 2.151 kg) values. Furthermore the average bilateral deficit values of the control group (21.93 ± 2.151 kg) were significantly greater compared to the bilateral training (17.55 ± 1.818 kg) group (figure 1).

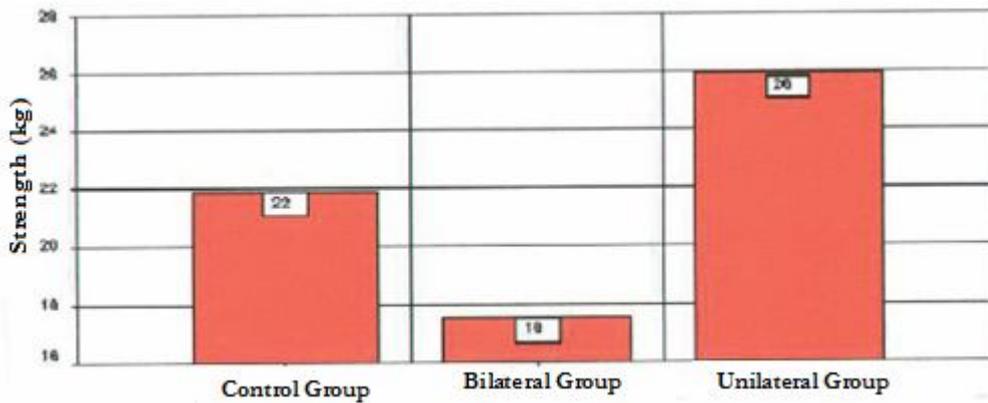


Figure 1. The average bilateral deficit values for the groups.

A meaningful statistical significance was determined for the variables during repeated measures ANOVA Tests ($F_{2,62} = 4.111$; $P < 0.021$). In order to determine where the significant lies, a Tukey's test ($HSD=3.01$) and Matrix comparisons was used. The results showed that the average pre-bilateral deficit values (23.537 ± 1.412 kg) were significantly greater compared to the post-bilateral deficit values (19.297 ± 1.56 kg) (figure 2).

Repeated measured ANOVA test conducted for the variables and the groups at $\alpha=0.05$ displayed a meaningful statistical significance ($F_{4,62} = 15.783$; $P < 0.001$). The Tukey's multiple comparison test used

to determine where the significance lies reported $HSD=5.32$. The results showed that, the average bilateral deficit during the post measurements for the unilateral group (25.871 ± 2.402 kg) was significantly lower compared to pre-measurements (25.75 ± 2.173) and during-measurements (21.029 ± 2.26 kg) for the same group and was also significantly lower compared to all the measurements for the control group (23.27 ± 2.57 , 25.79 ± 2.67 and 28.69 ± 2.84 kg). Moreover, for the single leg group the average post-training bilateral deficit measurements (28.69 ± 2.84 kg) were significantly greater compared to the post-training (23.27 ± 2.57 kg) measurements (figure 3).

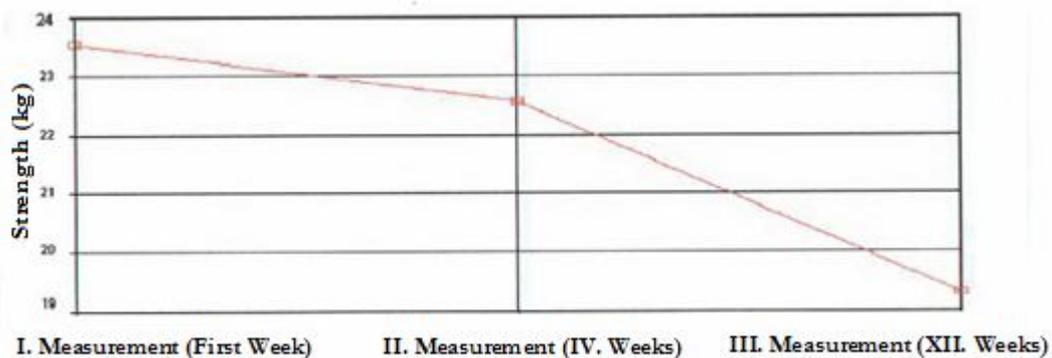


Figure 2. The average bilateral deficit values for the variables.

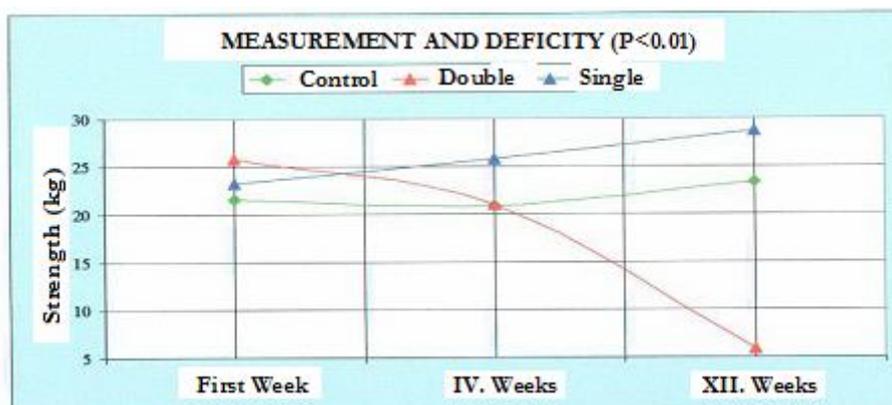


Figure 3. Bilateral deficit values recorded during training duration.

Improvements in Strength

The repeated measures ANOVA test conducted, displayed a statistical significant ($F_{2,31} = 1.261$; $P < 0.02$) improvement for bilateral and unilateral leg press strength at a $\alpha = 0.05$ level for all the groups. Results showed that bilateral groups average leg press strength (268.05 ± 12.38 kg) and unilateral groups average leg press strength (239.37 ± 14.66 kg) was higher than the control group (239.37 ± 14.66 kg) however statistical test did not reports a meaningful difference (figure 4).

The repeated measures ANOVA test conducted, displayed a statistically significant ($F_{2,62} = 196.68$; $P < 0.001$) improvements for bilateral and unilateral leg press strength at a $\alpha = 0.05$ level for all the groups. The Tukey's multiple comparison test used to determine

where the significance lies reported $HSD = 11.42$. The Tukey's multiple comparison test for the strength variables reported a significant difference between the post-test (283.36 ± 8.34 kg), pre-test (236.166 ± 8.03 kg) and mid-test (253.34 ± 8.128 kg). Furthermore, a meaningful difference was also observed between mid-test (253.34 ± 8.128 kg) and pre-test (236.166 ± 8.03 kg) values (figure 5).

The repeated measures ANOVA test conducted, displayed a statistical significant ($F_{1,31} = 340.47$; $P < 0.001$) improvement for bilateral and unilateral leg press strength at a $\alpha = 0.05$ level for the groups. Unilateral leg pres strength (268.523 ± 8.02 kg) was significantly greater than the bilateral leg pres strength (246.724 ± 8.121 kg) (figure 6).

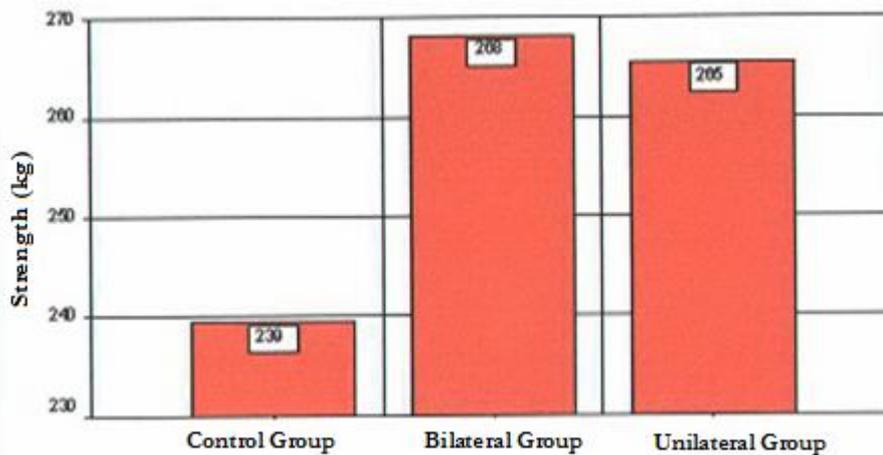


Figure 4. Average leg press strength for bilateral, unilateral and the control group.

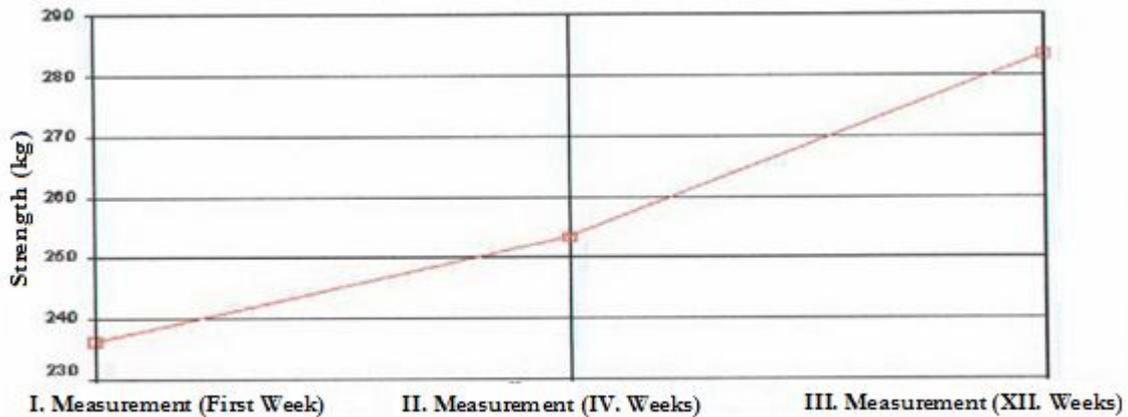


Figure 5. Average leg strength values for pre-test, mid-test and post-test.

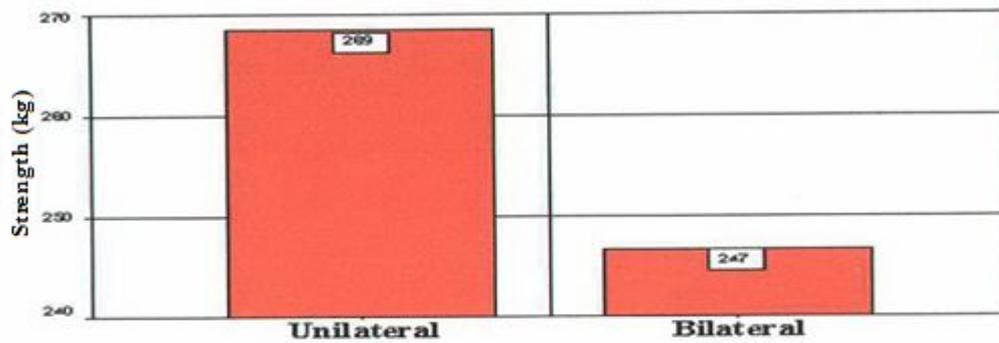


Figure 6. Average bilateral and unilateral leg strength values.

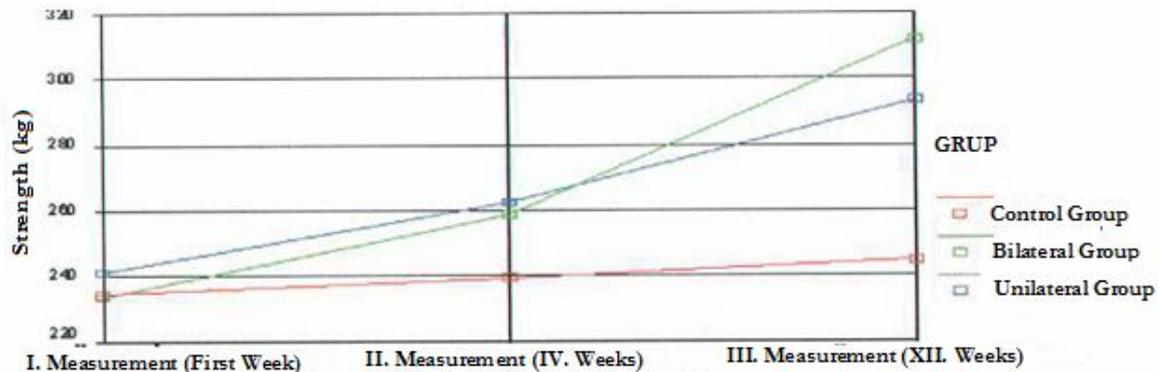


Figure 7. Average bilateral, unilateral and control group pre-test, mid-test and post-test values.

The repeated measures ANOVA test conducted, reported statistical significance ($F_{4,62} = 370.41$; $P < 0.001$) at $\alpha = 0.05$ level for the group and variables effect. In order to determine where the significant lies, pair-wise comparison Tukey's test ($HSD = 3.01$) reported a significant difference between the post-test leg strength values (312.064 ± 12.83 kg), pre-test (233.53 ± 12.36 kg) and mid-test (258.57 ± 12.509 kg) for the bilateral group. Furthermore, bilateral group values were significantly greater than the pre-test, mid-test and post-test values (234.17 ± 14.62 , 239.35 ± 14.8 and 244.57 ± 15.19 kg) for the control group and post-test, mid-test and post-test values (293.44 ± 15.19 , 262.1 ± 14.8 and 240.78 ± 14.62 kg) for the unilateral group. Moreover, for the unilateral group, post-test strength values (293.44 ± 15.19 kg) were significantly greater than the pre-test and mid-test values for the same group and was also significantly greater than pre-test, mid-test and post-test values of the control group (figure 7).

The repeated measures ANOVA test conducted for the variables, displayed a statistical significance ($F_{2,62} = 4.411$; $P < 0.021$) at $\alpha = 0.05$ level for the unilateral and bilateral groups. In order to determine where the significant lies, a pair-wise comparison Tukey's test ($HSD = 7.1$) reported a significant difference between post-test unilateral leg press strength (293.01 ± 8.08 kg) and mid-test leg press strength (264.62 ± 8.19 kg), furthermore significance was also detected between post-test unilateral leg press strength (293.01 ± 8.08 kg) and pre-test unilateral leg

press strength (247.93 ± 8.217 kg). Moreover, unilateral post-test leg strength was also significantly greater than bilateral, pre-test, mid-test and post-test values (224.39 ± 7.9 ; 242.06 ± 8.12 and 273 ± 8.66 kg). Also, post-test bilateral leg press strength was significantly greater than bilateral mid-test and pre-test (figure 8).

The repeated measures Anova test conducted for the groups, displayed statistical significance ($F_{2,62} = 4.473$; $P < 0.02$) at $\alpha = 0.05$ level for the unilateral and bilateral groups.

In order to determine where the significant lies, a pair-wise comparison Tukey's test ($HSD = 6.1$), reported a significant difference between groups and leg press strength. Observations showed that, single leg groups bilateral strength (278.4 ± 14.6 kg) is significantly greater than both leg groups bilateral strength (252.48 ± 14.78 kg), control groups bilateral and unilateral groups leg press strength. Furthermore, statistical tests further reported that both leg groups unilateral leg press strength (276.83 ± 12.34 kg) is significantly greater than the single and both leg strengths of the bilateral group and the unilateral strength of the control group. Moreover, both leg groups bilateral press strength (259.28 ± 12.49 kg) is reported to be significantly greater than the bilateral press strength of the single leg and the control groups (figure 9).

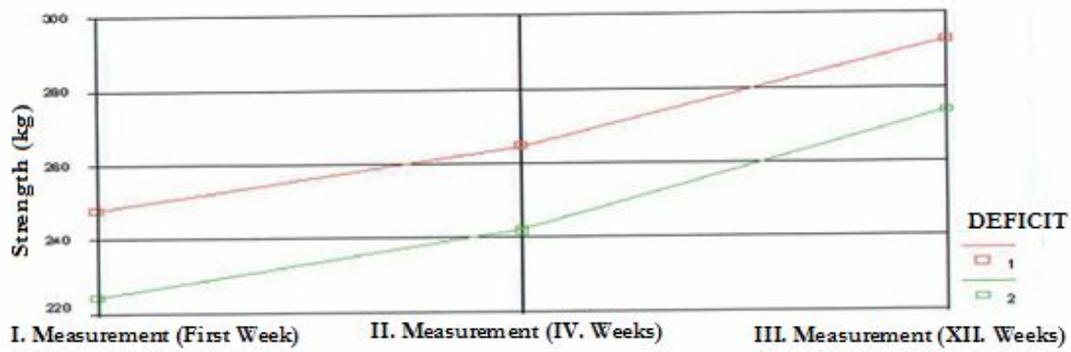


Figure 8. Pre-test, mid-test and post-test strength values for bilateral and unilateral groups.

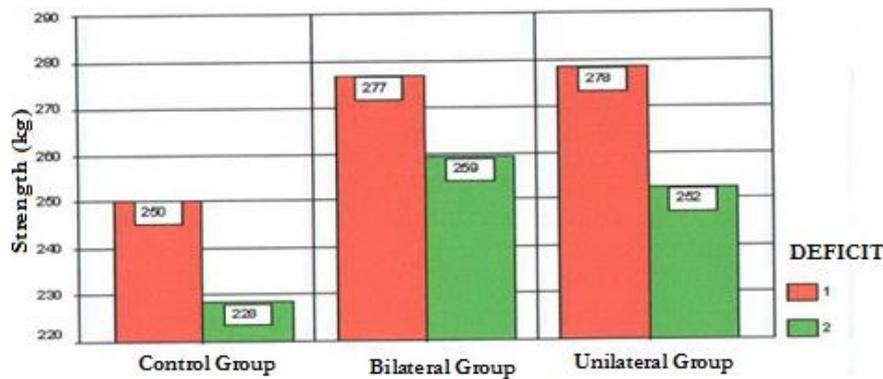


Figure 9. Average Bilateral and Unilateral Leg pres strengths for the groups.

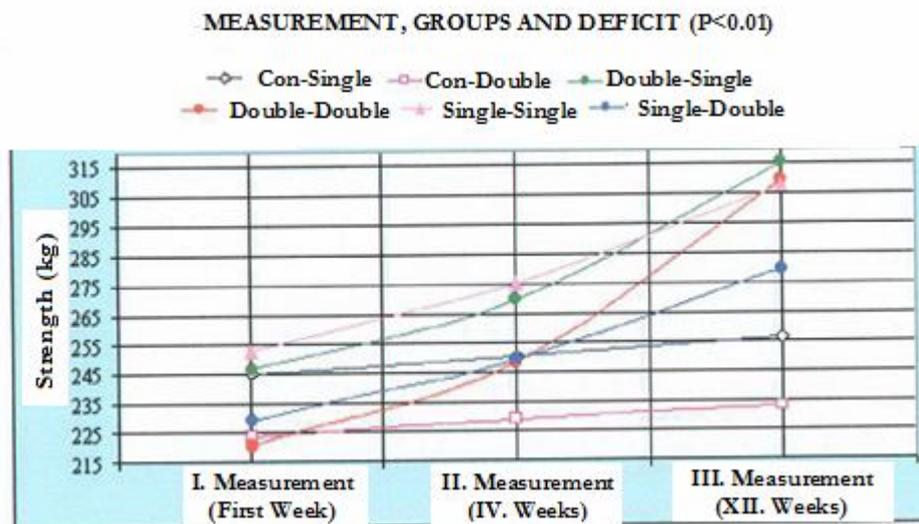


Figure 10. Average pre-test, mid-test and post-test values for the groups.

It was further reported that both legs unilateral post-test strength values (315 ± 12.44 kg) were significantly greater than the post-test single leg (307.79 ± 14.72 kg) and post-test control groups values. Significant relationship was not detected between the press strengths values for the control group (Figure 10).

DISCUSSION

A simple human motor activity requires at an exact time frame, a simultaneous activation of

numerous motor units. It is accepted that during maximal bilateral contractions, motor unit recruitment is lower compared to unilateral contractions. This is phenomenon is termed as the 'bilateral deficit' (11,20). Studies that utilized IEMG (integral electromyography) equipment has shown that during leg knee extension (20) finger flexions (10) and at the biceps brachi muscle group the bilateral contraction activity is reduced. When compared against unilateral contractions, there are differences in bilateral contractions in individuals that have been training

bilaterally for up to a year. However individuals who are not performing bilateral training the IEMG activity failed to report any meaningful difference between total bilateral and unilateral contractions.

Ohstuli (11), in a study that observed unilateral and bilateral strength of the arms reported positive correlation which was determined by EMG activity. The 0.75 and 0.80 bilateral and unilateral range which exists during elbow flexion of the arms is also in line with EMG bilateral and unilateral ranges of 0.74 and 0.81. The positive correlation between unilateral and bilateral muscle contraction range and the EMG range coefficient values for right and left elbow extensions is reported to be 0.726 and 0.750 respectively and for right and left elbow flexions is 0.560 and 0.540 respectively.

Similar findings were also reported by other researchers. The bilateral and unilateral strength correlation coefficients were reported to be 0.836 and 0.788 for men and 0.875 and 0.763 for woman (10). Furthermore Vandervoort *et al.* (20) also reported the decrements in EMG activity during bilateral movements.

Howard-Enoka (5) conducted a study that observed bilateral contractions at upper and lower extremities on individuals that participate in cycling and weight lifting. The experimental groups were formed of both legs-arms, right arm-left leg or left arm-right leg. This study failed to report a bilateral deficit effect according to unilateral contraction for the cyclist however for the untrained group bilateral deficit was found. In contrast the weightlifting group during bilateral contractions managed to exceed strength expectations by lifting over the limit calculated from unilateral activities.

Observing the causes and the levels of bilateral deficit was conducted since Henry-Smith (3). The studies that observed this phenomenon used various populations (5,18) and diverse muscle groups (5,10,20). These studies calculated strength values of contralateral muscle groups and reported a bilateral deficit effect of between %3 to 25%.

In line with other findings Peter-Scott (12) reported that the difference between maximal strength created during bilateral contractions compared to the total of two contralateral muscle groups unilateral contractions can be between 3-20%.

Nevertheless there is another hypothesis which questions the effects of bilateral deficit during submaximal motor activities. This notion tested the likelihood of the bilateral deficit during submaximal motor activity which observed bilateral contractions during elbow flexion and measuring isometric strength (12). This study which tested 20 college students

reported that bilateral deficit also exists in submaximal motor activities.

Vandervoort *et al.* (20) at high isokinetic speeds and during bilateral contractions reported that the generated torque during bilateral leg press strength is 0.51 of the total unilaterally generated torque. However the magnitude for the bilateral deficit effect on strength is %3 to %25.

Henry-Smith (3) found that when the dominant arm is contracted alongside the contralateral arm the generated strength is %3 less than the strength generated when contracted alone. Ohtsuki (9) observed bilateral contractions during postural moments by adopting the methods utilized by Henry-Smith (3) and reported that bilateral deficit is responsible for a reduction of % 5 - % 14 in strength on male and females participants. During bilateral contractions it is evident that both limbs experience a loss in strength; however the repression observed on the dominant arm is greater.

Ohtsuki (11) reported a 9.5 newtons difference between a dominant and a non-dominant limb when stimulated. However when the limbs work bilaterally the difference reduces to 3 newtons. Furthermore research articles observed the recruitment patterns of white or red fibers during bilateral contractions. When the white fibers were inhibited the red fibers contributed to the strength generation and that the bilaterally generated strength was 39 % less than the total strength generated unilaterally. In contrast, when the red fibers were blocked and white fibers were responsible for force generation, strength reduction was further reduced by % 8.

In depth and further analysis of this phenomena showed that white fibers are compared to the red fibers are more dominant in strength reduction during bilateral contractions (16,17). This goes to show that if the white fibers are not inhibited the bilaterally generated strength.

Vandervort *et al.* (20), found in relation to inhibiting fast responsible units during bilateral contractions to most revealing evidence. This study showed when the lower extremities were individually contracted at various speeds the generated torque is greater compared to bilaterally contraptions of the same extremities. At this point it is worth pointing out that the contraction speeds were responsible for greater deficiency in bilateral force generation. During 105 deg. sec (1.83 rad s⁻¹) a maximal effort the bilateral torque force loss is less compared to unilateral torque force loss.

Thorstensson *et al.* (19) reported that squat training is responsible for great gains in strength however other bilaterally performed activities are not as effective. This goes to show that the reduction in

inhibitory signals transmitted from the cerebral cortex is related to the tasks individual are performing.

In a study conducted by Secher *et al.* (18) in line with the findings of Howard-Enoka (5) reported that bilaterally muscle force generation is greater compared to unilateral contraction on rowers. Howard-Enoka (5) reported that on individuals who are actively involved in strength training, the bilateral strength generation is not compromised however force generation is greater compared to unilateral strength generation and Secher *et al.* (18) also provided evidence for this on rowers.

In conclusion this study showed that during when unilateral and bilateral leg pres isometric contractions are compared a bilateral deficit effect is evident. Furthermore, evidence was further provided on the effectiveness of strength training in eliminating and reducing the effect of bilateral deficit on strength generation. If individuals due to the nature of the sporting field are not involved in bilateral training, should by specific training protocols train to reduce these inhibitory factors. This will help to improve their sporting performances.

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