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ORIGINAL ARTICLE

The Impact of 4-weeks Dominant Wrist-Forearm Strength Training Ipsilateral and Contralateral on the Strength

OSMAN TARAF[1], MEHMET ÖZAL[2]
[1]*Republic of Turkey Ministry of Youth and Sports, Kırşehir Provincial Directorate of Youth and Sports, Tennis Coach, Kırşehir, osmantaraf38@gmail.com, https://orcid.org/0000-0001-8817-4993*
[2]*ankara Yildirim Beyazit University, Sports Science Faculty, Ankara, mozal@ybu.edu.tr https://orcid.org/0000-0002-9864-5178*
Correspondence to: Osman Taraf, Email: osmantaraf38@gmail.com

ABSTRACT

The aim of this study; To investigate whether 4-week dominant wrist-forearm strength exercises have an effect on contralateral and ipsilateral strength. To work; 27 of them were exercise group (EG) (age: 19.70 ± 1.41 years, height: 176.73 ± 7.22 cm, body weight: 69.22 ± 9.51 kg) and 27 of them were the control group (KG) (age: 20.15 ± 1.66 years, height: 179.374 ± 5.49, body weight: 70.39 ± 7.43 kg) a total of 54 male volunteers participated. EG performed 4 sets of dominant (D) wrist flexion and extension exercises with dumbbells at 70% intensity for 4 weeks, 3 days a week. No study has been done on the non-dominant (ND) side. The repetitions in the sets were continued until the participant could not lift the weight with the appropriate technique (Fatigue). The data were collected by General Information Form, height meter, scale and digital hand dynamometer. Paired sample t-test was used to compare the before-after measurements of the groups. Two-way mixed ANOVA results were given in the examination of the change between the measurements obtained at the beginning of the study and at the end of the 4-week period in the study and control groups.

As a result of the comparison of the pre and post tests' means, statistically notional difference for the D clutch strength and ND clutch strength is respectively as ($p<0.001$). However, there is no notional difference in CG($p>0.05$). A statistically significant time-dependent difference was found on D hand grip strength and ND hand grip strength measurement results ($p<0.001$). While TimeXGroup interaction was found to be statistically significant in the evaluation of D hand grip strength measurement results ($p<0.001$), TimeXGroup interaction was not statistically significant in the evaluation of ND hand grip strength measurement results ($p>0.05$). The main effect of the group variable (Regardless of the time variable) was not statistically significant in all data ($p> 0.05$).

It can be said that this study has a positive impact on D hand clutch strength and ND hand clutch strength.

Keywords: Cross transfer, strength, strength training.

INTRODUCTION

Cross Transfer (CT) is the development of strength and skill (motor) transferred to the contralateral (opposite side) limb as a result of the training program performed with a unilateral limb.[1,2,3,4]

CT was first discovered in 1894 as a result of the unilateral training program applied by Scripture et al., with this scientific study that determined the strength and stability of movement in the opposite limb.[2,4,5]

In scientific studies since the discovery of CT, this subject; It is called CT (cross transfer), strength training effect on the opposite side (contralateral strength training effect) and cross training.[6,7,8,9]

Unilateral limb exercises can generate strength gains in homologous and synergist muscles in the contralateral limb.[2,3,4,5,6,7,8,9,10] The CT effect obtained as a result of unilateral exercises is not specific to any muscle or muscle group. The CT effect can be created in both lower and higher order muscle and muscle design. CT effect can be created by voluntary dynamic contractions, electrical stimulation, mirror feedback, whole body vibration or unilateral mental (non-voluntary) exercises. The CT transfer effect obtained as a result of scientific studies is not dependent on age and gender. [8,11,12]

In a scientific article by Farthing et al. in 2021, they reported that unilateral strength training increased the untrained limb strength of healthy adults by approximately 20%, and this strength increase was usually half the strength increase in the trained limb.[13]

Although many aspects of the cross-transfer issue have been clarified, the neural functioning or the effective mechanism in the CT effect has not been fully elucidated.[8,13,14]

Unilateral limb and cross-transfer exercises can be used for many purposes. CT method can be applied to reduce or eliminate the negative effects that may occur in any limb of people, such as injury, immobilization, nervous disorders or muscle weakness.

In our literature review, it was determined that in some scientific studies on CT, warming and cooling studies, as well as verbal encouragement and feedback were not sufficiently included in the studies. Since this situation may adversely affect the results of the study, warm-up and cooling-off activities were included in this study, and verbal encouragement and feedback were used.

In this study, it was investigated whether wrist strength exercises performed for 4 weeks had an effect on the opposite and ipsilateral strength.

MATERIAL AND METHODS

Population and Sample: This study was started after the approval of Ankara Yıldırım Beyazıt University Social and Human Sciences Ethics Committee (Decision dated 16.10.2019 and numbered 25). After obtaining the approval of the ethics committee, necessary permission was obtained from the Rectorate of Kırşehir Ahi Evran University for sample selection (Decision dated 12.11.2019 and numbered 67873788-300).

This research was conducted with healthy 54 male volunteer participants, who do not smoke, do not use

alcohol and do not use drugs, between the ages of 18-25, who did not participate in any strength training until 12 months.

The participants were given detailed information about the content and purpose of the study. An “Informed Consent Form” was signed by the participants and a copy was given to the volunteers. In addition, the “World Medical Association Declaration of Helsinki” was read to the participants and a copy of the declaration was given.

Research Group: Using a computer program, 27 of the 54 participants were assigned to the exercise group (age: 19.70 ± 1.41 years, height: 176.73 ± 7.22 cm, body weight: 69.22 ± 9.51 kg) and the other 27 to the control group (age: 20.15 ± 1.66 years, height: 179.374 ± 5.49, body weight: 70.39 ± 7.43 kg) by random assignment method.

Research Pattern: This research was designed as a random (unbiased) design with pretest-posttest control group.

All participants were given codes according to their groups. The researcher is blinded and unaware of who is given what code. The measurement results were recorded by another person who helped with the research. Briefly, a single-blind study was conducted.

Data Collection: The height of the participants participating in the research was measured with a portable stadiometer (Mesilife – 13539) measuring with ± 1 mm precision.[15] The body weights of the participants were measured with a 200 kg scale (Mesilife – By - 810), which can measure 50 gr intervals.[16]

The hand preference of the participants was determined by the "Edinburgh Hand Preference Questionnaire", whose Turkish reliability study was conducted by Uysal et al. (2019).[17,18,19]

For the measurement of dominant and non-dominant hand grip strength, a digital hand dynamometer with a Liquid Crystal Display (LCD) screen (T.K.K. 5401 Grip-D), which can measure in the range of 5.0-100 kg and with an accuracy of 0.1 kg, was used.[20]

Before starting the measurements, how to use the measuring instrument and in which position the measurement will be taken are explained in practice. 10 minutes of general warm-up (10 minutes of jogging at a slow pace), 3 minutes of special warm-up, 3 minutes of flexibility exercises for shoulders and arms. Considering that the measurement time of each hand will take an average of 5 seconds, the participants were given a rest period of 1/5 and a rest period of 25-30 seconds between each measurement. In addition, verbal encouragement was applied to the participants during the measurements. Two measurements were made for each hand. The highest values from the measurements made were taken into consideration as the right and left hand grip strength measurement values. After the tests, 5 minutes of walking at a low pace, 6 minutes of flexibility for the shoulders and arms were applied to cool down.

The 1 maximum repetition (1 MT) method was used to measure the maximum muscle strength. In this study, the multiple repetition 1 MT Epley formula, which is one of the formulas used in the calculation of 1 MT in the measurement of muscle strength with the dynamic method, was used in the calculation of 1 MT.

Epley Formula: 1MT = (1 + 0.0333 x Number of Repetitions) x Weight.[21]

24 hours before the test, all participants were verbally and visually explained how to apply the test, and they were allowed to do a trial with empty dumbbell bars and then with a weight equal to 50% of the weight they thought they could do at most one repetition. The body positions of the participants during the test application were as described in the exercise application section. Before starting the test, 10 minutes of general warm-up (10 minutes of jogging at a slow pace), 3 minutes of special warm-up, 3 minutes of flexibility for shoulders and arms were performed. After warming up, first flexion and then extension exercises were performed.

During the test, an estimation weight that they thought they could not lift more than 10 repetitions at the beginning (it was taken into account during the introduction of the test.) was followed by weight increase or weight reduction. When the participants did more than 10 repetitions, the study was stopped and a rest was given for 3 minutes. Depending on the application performance of the participant, the weight was increased by 10-20% and the test was started again. This process was continued until the participants could do 10 repetitions or less.[22]

A rest period of 3 minutes was given between each trial, and 5 minutes of rest between flexion and extension exercises. In addition, verbal encouragement was applied to the participants during the studies. The amount of resistance to be applied to the exercise group in the studies was determined as 70% of the calculated 1 MT. This test was repeated at the end of each week throughout the studies (4 weeks), provided that it was performed 24 hours after the last study. According to the results, the maximals were re-determined and the working weight was adjusted accordingly. Thus, in case of an improvement in strength, it is aimed to prevent the participant from working with low weights in the following weeks. After the tests, 5 minutes of walking at a low pace, 6 minutes of flexibility for the shoulders and arms, and cooling down was done.

Exercise Protocol: Participants do the exercises and maximal strength tests in a chair, etc., next to the coffee table. they did it in a sitting position.

Before starting the study, the height of the coffee table and chair was adjusted to a height where the participant's upper body would stand straight and comfortably. Participants were asked to adjust their wrists so that they protrude forward enough (average 5 cm) to comfortably work from the bench. Participants were asked to stop the non-dominant hand on the other side (on the leg) in order to prevent the non-dominant arm from being active by creating a certain force in the non-working arm when the non-working hand grasped the working arm.

Verbal encouragement was applied to the participants in the studies and measurements.

Participants were able to perform repetitions in the range of 10-14 in exercise practices.

After the exercises, 5 minutes of walking at alow pace, 6 minutes of flexibility for the shoulders and arms were applied to cool down.

Statistical analysis: Paired sample t-test was used to compare the before-after measurements of the groups.

Two-way mixed ANOVA results were given in the examination of the change between the measurements

obtained at the beginning of the study and at the end of the 4-week period in the study and control groups.

Microsoft Excel 2016, IBM SPSS Statistics 22.0 (IBM Corp. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was used for statistical calculations and analysis.

The following formula was used to calculate the percentage change of numerical variables in the study and control groups.

{[(END - FRONT) / FRONT] X 100}

The following formula was used for the calculations of the contralateral force transfer.[10,23]

{[(ESON - EÖN) / EÖN] X 100} - {[(KSON - KÖN) / KÖN] X 100}

Statistical significance level was accepted as $p<0.05$.

Table 1: Exercise Protocol

Exercise Type	Dominant wrist flexion and extension	Force	70% of maximal force
Exercise Groups	Three groups of 9 each.	Number of Sets	4
Duration	4 weeks	The Number of Repetitions	Fatigue (Until you cannot lift the weight with proper technique)
Frequency	3 days a week (provided that there is a break of at least 24 hours between the days)	Contraction Speed	Fast
Method	Sherry	Rest	3-5 minutes between repetitions, 5 minutes between exercises (flexion and extension)

RESULTS

Table 2: Comparison of Dominant and Non-Dominant Hand Grip Strength Measurements in Exercise and Control Groups

	Test Sequence	x̄	±ss	t	p	Cohen's d	%CT
Exercise (Dominant Hand)	Pre-Test	43.36 (kg)	6.79	-15.115	.000*	.80	
	Post-Test	48.47 (kg)	6.04				
Control (Dominant Hand)	Pre-Test	43.16 (kg)	5.63	-0.423	.676		
	Post-Test	43.21 (kg)	5.69				
Exercise (Non-Dominant Hand)	Pre-Test	42.01 (kg)	6.82	-6.45	.000*	.28	4.70
	Post-Test	43.91 (kg)	6.71				
Control (Non-Dominant Hand)	Pre-Test	42.55 (kg)	6.45	.387	.702		
	Post-Test	42.48 (kg)	6.31				

**p<0,01

When Table 2. is examined, a statistically significant difference was found as a result of the comparison of the dominant hand grip strength pre-test and post-test averages of the exercise group ($t = -15.115$; $p<0.001$, $d = 0.80$).

According to the effect size value (Cohen's $d = 0.80$), a high level of effect size was determined. As a result of the comparison of the dominant hand grip strength pre- and post-test averages of the control group, no statistically significant difference was found ($t = -0.423$; $p>0.05$).

As a result of the comparison of the non-dominant hand grip strength pre and post test averages of the exercise group, a statistically significant difference was found ($t = -6.45$; $p<0.001$, $d = 0.28$). A small effect size was determined according to the effect size value (Cohen's $d = 0.28$). As a result of the comparison of the non-dominant hand grip strength pre- and post-test averages of the control group, no statistically significant difference was found. ($t = .387$; $p>0.05$). The contralateral cross-transfer effect was found to be 4.70%.

When Table 3. is examined, a statistically significant difference was found on the dominant hand grip strength measurement results (regardless of the Groups variable) over time [$F (1.52) = 206.054$, $p = 0.000$, $\eta p2 = 0.80$].

TimeXGroup interaction was statistically significant [$F(1.52) = 197,860$, $p = 0.000$, $\eta p2 = 0.79$].

The main effect of the group variable (regardless of the time variable) was not statistically significant [$F(1.52) = 2.777$, $p = 0.102$, $\eta p2 = 0.05$].

Table 3: Two-Way Mixed Anova Table of Dominant Hand Grip Force Measurements

Measurement Unit: kg	SS	sd	SM	f	p	η_p^2
Between Groups						
Time	179.929	1	179.929	206.054	.000*	.80
TimeXGroup	172.774	1	172.774	197.860	.000*	.79
Error	45.407	52	,873			
Within Groups						
Group	201.174	1	201.174	2.777	.102	.05
Error	3766.446	52	72.432			

*p<0.001

When Table 4. is examined, a statistically significant time-dependent difference was found on the non-dominant hand grip strength measurement results (regardless of the Groups variable) [$F (1.52) = 27.016$, $p = 0.000$, $\eta p2 = 0.34$].

TimeXGroup interaction was statistically significant

[F(1.52) = 26.305, p = 0.000, ηp2 = 0.38].

The main effect of the group variable (regardless of the time variable) was not statistically significant [F(1.52) = 0.062, p = 0.805, ηp2 = 0.001].

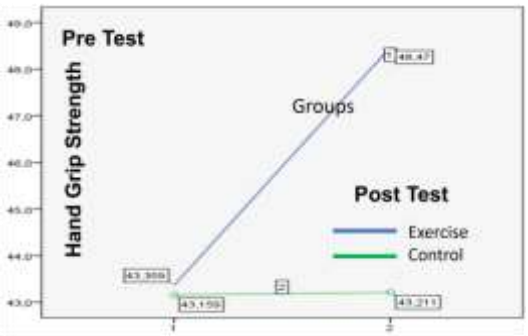

Fig1: Comparison of Dominant Hand Grip Force Measurements of the Groups

Table 4: Two-Way Mixed Anova Table of Non-Dominant Hand Grip Force Measurements

Measurement Unit: kg	SS	sd	SM	f	p	η_p^2
Between Groups						
Time	22.505	1	22.505	27.016	.000*	.34
TimeXGroup	26.305	1	26.305	31.578	.000*	.38
Error	43.316	52	,833			
Within Groups						
Group	5.289	1	5.289	.062	.805	.001
Error	4453.835	52	85.651			

*p<0.001

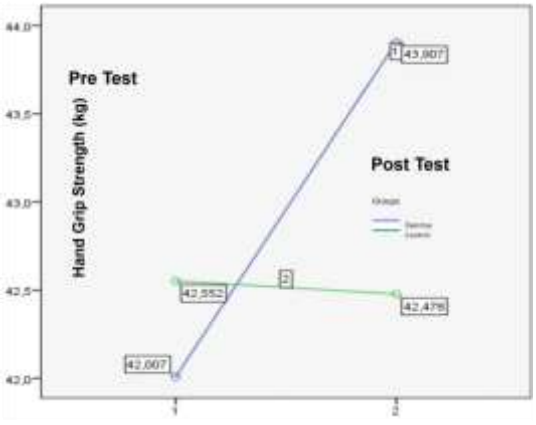

Fig1: Comparison of Non-Dominant Hand Grip Strength Measurements of the Groups

DISCUSSION

In this study, the effects of flexion and extension strength exercises performed with the dominant wrist-forearm for 4 weeks on contralateral and ipsilateral strength were examined and interpreted.

As a result of this study, it was determined that the dominant hand grip strength of the exercise group increased by 11.79% and the non-dominant hand grip strength by 4.52%. In the control group, a 0.12% increase in dominant hand grip strength and a 0.17% decrease in non-dominant hand grip strength were detected.

In the hand grip force measurement calculations, the contralateral force transfer (Cross transfer) effect was determined as 4.70%.

In the 6-week study conducted by Green and Gabrel with 40 volunteer participants in 2018, a 24% increase was found in the arm to which maximal strength increase exercise (wrist flexion) was applied. They reported the cross-training effect (force transfer to the non-exercised arm) as 6%. They did not report an increase in any of the control groups.[2]

In 2018, Andrushko et al. conducted a study with 16 volunteer participants (non-dominant forearms were immobilized with a plaster cast), 8 of whom were in the exercise group and the other 8 were in the control group, 3 days a week for 4 weeks. In the group, a 30.8% increase in right wrist flexion strength and a 2.4% decrease in immobilized left wrist flexion strength were detected. A 7.4% decrease in the right hand flexion strength and a 21.6% decrease in the left hand flexion strength were detected in the control group. In the related study, the authors concluded that right wrist eccentric flexion work preserves the size and strength of the immobilized contralateral homologous muscle.[24]

In a study by Farthing et al. in 2011, in which they applied isometric hand grip exercise to the right dominant hand, an increase of 10.7% in the right hand grip strength and 0.8% in the immobilized left hand grip strength was found in the exercise group. There was an increase of 4.1% in the right hand grip strength of the control group, and a decrease of 11% in the immobilized left hand grip strength. In the related study, the authors reported that free limb hand grip strength exercises prevented the reduction of hand grip strength of the immobilized limb.[25]

In this study, the non-exercise arms of both the exercise and control group participants were not immobilized during the study period. All participants continued their daily lives normally. This is thought

to be the reason for the high rate of increase in strength, especially in the contralateral limb, in the results of this study. When the results of scientific studies (Andrushko et al. 2018, Farthing et al. 2011) performed with immobilization in one limb are examined, this idea is supported.

In addition, the presence of a control group in the studies is thought to strengthen the conclusion that the strength increases are due to cross-transfer that may occur as a result of unilateral training, rather than an outcome resulting from increased familiarity with repeated tests and training materials used. For this reason, the control group was used in this scientific study.

In the study conducted by Lee et al. (Dominant right wrist extension) in 2009, an increase of 31.5% in the right wrist and 9.3% in the left wrist was detected in the exercise group. In the control group, an increase of 1.5% was found in the right wrist and a decrease of 0.4% in the left wrist.[26]

The findings obtained as a result of the literature research show similarities with the results of this study.

When the effect size results in the exercise group were examined, it was determined that the effect size was

large (d = 0.80) in the dominant hand grip strength and small (d = 0.28) in the non-dominant hand grip strength.

In the meta-analysis study conducted by Green et al. (96 studies) in 2018, the effect size was both in the dominant limb (result of 81 young <50 years old participants d = 1.11) and in the non-dominant limb (total of 86 young <50 years old participants d = 0.71) has been detected to a large extent.[4]

The findings obtained as a result of the literature research show similarities with the results of this study.

According to the meta-analysis of Sastre et al. in 2017, it was determined that the cross-transfer effect was higher in studies with 3-5 sets, 1-2 minutes rest between sets and 8-15 repetitions.[27]

In a study by Hendy et al. in 2011, they reported that when CT was evaluated in terms of load intensity, successful results were obtained in studies performed with 60% and above maximum voluntary contractions. [28]

According to another meta-analysis by Manca et al. (31 studies, total 785 participants) in 2017, it was reported that eccentric studies cause greater cross-transfer effect. On the other hand, the cross-transfer effect was determined as 8.2% in isometric studies, 15.9% in isotonic-dynamic studies, and 11.3% in concentric studies. In the same study, when the cross-transfer effect in the lower and upper extremities was examined, a greater cross-transfer effect (16.4%) was observed in the lower extremities. This effect was determined to be 11.9% in the upper extremities. Both the results of this meta-analysis and the findings obtained as a result of the literature research are similar to the results of this study.[6]

Manca et al. reported in their scientific study in 2021 that in order to increase strength as a result of unilateral exercises, the exercises should be planned between 13-18 sessions and lasting 4-6 weeks.[29,30,31]

When the results and methods of the studies in the literature reporting a significant increase in strength and CT effect are compared with the results and method of this study, the study shows similarity. This similarity is thought to be effective in the high rates of increase in strength and CT effect in the contralateral and ipsilateral limbs in the results of this study.

CONCLUSION

Studies on cross-transfer provide important information on how to work and methods to eliminate or reduce inequality between the limbs. Knowing the level of effect on the other limb by working on one side, or knowing what type and duration of work will create a cross-transfer effect can create important source information when planning exercises and other training programs aimed at ensuring inequality between the limbs.

REFERENCES

1 Scripture EW, Smith TL, Brown EM. On the Education of Muscular Control and Power, Studies from the Yale Psychological Laboratory, 1894, 2: 114-119. İçinde: The Virtual Laboratory Max Planck Institute fort he History of Science,Berlin.https://vlp.mpiwgberlin.mpg.de/library/data/lit23174?mo=q1. 5 September 2019.

2 Green LA, Gabriel DA. The Cross Education of Strength and Skill Following Unilateral Strength Training in the Upper and Lower Limbs, American Physiological Society, 2018, 120: 468-479.

3 Zult T, Goodall S, Thomas K, Solnik S, Hortobagyi T, Howatson G. Mirror Training Augments the Cross Education of Strength and Affects İnhibitory Paths, Medicine and Science in Sports and Exercise, 2015, 48(6): 1001-1013.

4 Green LA, Gabriel DA. The Effect of Unilateral Training on Contralateral Lim Strength in Young, Older and patient Populations: a Meta Analysis of Cross Education, Physical Therapy Reviews, 2018, 23(4-5): 238-249.

5 Kidgell DJ, Frazer AK, Rantalainen T, Ruotsalainen I, Ahtiainen J, Avela J, Howatson G. Increased Cross Education of Muscle Strength and Reduced Corticospinal Inhibition Following Eccentric Strength Traininng, Neuroscience, 2015, 300: 566-575.

6 Manca A, Dragone D, Dvir Z,Deriu F. Cross Education of Muscular Strength Following Unilateral Resistance Training: a Meta Analysis, European Journal of Applied Physiology, 2017, 117: 2335-2354.

7 Fimlans MS, Helgerud J, Solstad GM, Iversen VM, Leivseth G, Holf J. Neural Adaptations Underlying Cross Education After Unilateral Strength Training, Springer European Journal of Applied Physiology, 2009, 107: 723-730.

8 Lee M, Carroll TJ. Cross Education Possible Mechanisms for the Contralateral Effects of Unilateral Resistance Training, Sports Medicine, 2007, 37 (1): 1-14.

9 Zhou S. Chronic Neural Adaptations to Unilateral Exercise: Mechanisms of Cross Education, Exercise and Sport Sciences Reviews, 2000, 4: 177-184.

10 Mason J, Frazer AK, Horvath DM, Pearce AJ, Avela J, Howatson G, Kidgell DJ. Ipsilateral Corticomotor Responses are Confined to the Homologous Muscle Following Cross Education of Muscular Strength, Applied Physiology Nutrition and Metabolism, 2018, 43 (1): 11-22.

11 Carr JC, Ye X, Stock MS, Bemben MG, DeFreitas JM. The Time Course of Cross Education-During Short-Term İsometrik Strength Training, European Journal of Applied Physiology, 2018, 119 (6): 1395-1407.

12 Ranganathan VK, Siemionow V, Liu JZ, Sahgal V, Yue GH. From Mental Power to Muscle Power-Gainging Strength by Using the Mind, NeuroPsychologia,2004, 42 (7): 944-956.

13 Farthing JP, Zehr EP, Hendy AM, Andrushko JW, Manca A, Deriu F, Loenneke J, Minetto MA, Hortobágyi T. Cross-education: Is it a viable method for rehabilitation?, Brazilian Journal of Motor Behavior, 2021,15:1-4.

14 Carroll TJ, Herbert RD, Munn J, Lee M, Gandevia SC. Contralateral Effects of Unilateral Strength Training: Evidence and Possible Mechanisms, Journal of Applied Physiology, 2006, 101: 1514-1522.

15 Mesitaş. https://www.mesitas.com.tr/product-detail.php?product_id=40&cat_id=3&brand_id=1. 15 December 2020.

16 Mesitaş. https://www.mesitas.com.tr/product-detail.php?product_id=48&cat_id=3&brand_id=1. 15 December 2020.

17 Atasavun Uysal S, Ekinci Y, Çoban F, Yakut Y. Investigation of Turkish reliability of the Edinburgh Hand Preference Questionnaire, Journal of Exercise Therapy and Rehabilitation, 2019, 6 (2): 112-118.

18 Şahan, N. Investigation of Motor Skill, Visual Perception and Quality of Life of Childhood Attention Deficit Hyperactivity Disorder (ADHD) Among Different Comorbidity Groups, Hacettepe University, Graduate School of Health Sciences, Physical Therapy and Rehabilition Program Doctorate Thesis, Ankara, 2019.

19 Akça F, Çekin R, Ziyagil MA. Effects of Hand Dominance on Overarm Shooting Accuracy in Young Males, CBU Journal of Physical Education and Sport Sciences, 2015, 10 (2): 1-8.

20 Takei. https://www.takei-si.co.jp/en/productinfo/detail/49.html. 17 Aralık 2020.

21 Paul DJ, Nassis GP. Testing Strength and Power in Soccer

Players: The Application of Conventional and Traditional Methods of Assessment, Journal of Strength and Conditioning Research, 2015, 29 (6): 1748-1758.
22 McNair PJ, Colvin M, Reid D. Predicting Maximal Strength of Quadriceps from Submaximal Performance in Individuals with Knee Joint Osteoarthritis, Arthritis Care & Research, 2011, 63 (2): 216-222.
23 LeSuer DA, McCormick JH, Mayhew JL, Wasserstein RL, Arnold MD. The Accuracy of Prediction Eqution for Estimating 1RM Performance in the Bench Press, Squat and Deadlift, Journal of Strength and Conditioning Research, 1997, 11 (4): 211-213.
24 Andrushko JW, Lanovaz JL, Björkman KM, Kontulainen SA, Farthing JP. Unilateral Srength Training Leads to Muscle-Specific Sparing Effects During Opposte Homologous Limb İmmobilization, Journal of Applied Physiology, 2018, 124 (4): 866-876.
25 Farthing JP, Krentz JR, Magnus CRA, Barss TS, Lanovaz JL, Cummine J, Esopenko C, Sarty GE, Borowsky R. Changes in Functional Magnetic Resonance Imaging Cortical Activation with Cross Education to an Immıbilized Limb, Medicine and Science in Sports and Exercise, 2011, 43 (8): 1394-1405.
26 Lee M, Gandevia SC, Carroll TJ. Unilateral Strength Training Increases Voluntary Activation of Opposite Untrained Limb, Clinical Neurophysiology, 2009, 120 (4): 802-808.
27 Sastre RC, Garrido JVB, Corbi F. Contralateral Effects After Unilateral Strength Training: a Meta Analysis Comparing Training Loads, Journal of Sports Science and Medicine, 2017, 16: 180-186.
28 Hendy AM, Spittle M, Kidgell DJ. Cross Education and İmmobilisation: Mechanisms and İmplications for Injury Rehabilitation, Journal of Science and Medicine in Sport, 2011, 15: 94-101.
29 Ilkım M. Çelik T., Mergan B.(2021) Investigation of Sports Management Students' Perceptions and Attitudes towards the COVID-19 Pandemic, Pakistan Journal Of Medical & Health Sciences, Volume15 Issue 2 Page799-803
30 Ilkim M, Ozdemir M, Tanir H. Evaluation of some physical and motoric characteristics of athletes with down syndrome. SHS Web Konf. 2017 (37) 01030.
31 Manca A, Hortobágyi T, Carroll TJ, Enoka RM, Farthing JP, Gandevia SC, Kidgell DJ, Taylor JL, Deriu F. Contralateral Efects of Unilateral Strength and Skill Training: Modifed Delphi Consensus to Establish Key Aspects of Cross-Education, Sports Medicine 2021, (51):11–20.