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Investigation of the Relationship Between Upper Extremity Neuromuscular Control and Grip Strength with Shooting Accuracy in Elite Handball Players

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Abstract

In sports such as handball, where the overhead throw is commonly used, athletes must be physically fit to fulfill the requirements of the throw. This fitness includes neuromuscular control, muscle strength, power, flexibility, balance, and agility. The purpose of this study was to investigate the relationship between upper extremity neuromuscular control and grip strength with shooting accuracy in elite handball players. The study was conducted with the participation of 26 male handball players with an average age of 20.23 ± 2.47 years, average body weight of 72.34 ± 8.01 kg, average height of 180.5 ± 5.90 cm, average playing experience of 8.65 ± 2.92 years, and average BMI of 22.1 ± 2.13 kg/m^{-2}. Data collection tools contained a "Personal Information Form," a "Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)," a "Shooting Accuracy Test," and a "Grip Strength Test." Pearson Correlation Test analyzed the study data from descriptive statistics in the SPSS package program. In all analyses, $p<.05$ was considered statistically significant. According to the study's results, no significant correlation was found between hand grip strength, upper extremity neuromuscular control, and strength with shooting accuracy in handball. A high positive correlation was found between dominant hand strength and non-dominant hand strength. As a result, it was determined that shooting performance is not only related to strength but also closely related to the player's technical skills.
Keywords: Shooting accuracy, Handball, Grip Strength, Closed kinetic chain

Elit Hentbolcularda Üst Ekstremite Nöromuskuler Kontrol ve Kavrama Kuvveti ile Atış İsabeti Arasındaki İlişkinin İncelenmesi

Öz

Baş üstü atışın yaygın olarak kullanıldığı hentbol gibi branşlarda sporcular atışın gerekliliklerini yerine getirebilmek için fiziksel olarak yeterli olmalıdır. Bu yeterlilikler nöromusküler kontrol, kas kuvveti, güç, esneklik, denge, çeviklik gibi parametreleri içermektedir. Bu noktadan hareketle çalışmanın amacı; elit hentbolcularda üst ekstremite nöromuskuler kontrol ve kavrama kuvveti ile atış isabeti arasındaki ilişkiyi incelemektir. Araştırmaya yaş ortalaması 20.23±2.47 yıl, vücut ağırlık ortalaması 72.34±8.01 kg., boy uzunluğu ortalaması 180.5±5.90cm., spor yaşı ortalaması 8.65±2.92 yıl ve BKİ ortalaması 22.1±2.13 kg/m^{-2} olan 26 elit erkek hentbolcu katılmıştır. Araştırmada veri toplama aracı olarak "Kişisel Bilgi Formu," "Kapalı Kinetik Zincir Üst Ekstremite Stabilite Testi Test (KKZÜEST)," "Atış İsabeti Testi" ve "Kavrama Kuvveti Testi" kullanılmıştır. Çalışma verileri SPSS paket programında tanımlayıcı istatistiklerden Pearson Korelasyon Testi ile analiz edilmiştir. Tüm analizlerde $p<.05$ istatistiksel olarak anlamlı kabul edilmiştir. Çalışmanın bulgularına göre; hentbolda el kavrama kuvveti, üst ekstremite nöromusküler kontrol ve kuvveti ile atış isabeti arasında anlamlı bir ilişki tespit edilemedi. Doninat el kuvveti ile nondominat el kuvveti arasında yüksek pozitif ilişki saptandı. Sonuç olarak; atış performansının sadece kuvvet ile ilgili olmadığı oyuncuların teknik yetenekleri ile de yakından ilişkili olduğu tespit edilmiştir.
Anahtar kelimeler: Atış isabeti, Hentbol, Kavrama kuvveti, Kapalı kinetik zincir

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INTRODUCTION

Handball is a professional Olympic sport played all around the world. It is a sport that requires mobility and collective thinking, the ability to draw precise and accurate results, the ability to think carefully in a short time, and courage and strong will (Alp et al., 2015). In recent years particularly, what has gained increasing importance in handball is to reach the result with as few passes as possible (Çelikbilek et al., 2011). Handball has become one of the sports branches with the highest number of athletes and fans worldwide. Moreover, it has started playing in many areas, from physical education and sports lessons to sports activities in European countries (Cetin & Ozdol, 2012).

In handball, another critical factor besides the physical features is bio-motor performance. It requires good running speed, reaction timing, and strength to attack as early as possible against the opponent's position, make the defense, pass as quickly as possible, and defend the shot effectively (Karadenizli & Karacabey, 2002). It is well known that strength plays a crucial role in team sports performances. Strength denotes the force of contraction of a muscle. The term is used for muscular endurance, especially in competitions, and stands out as contractility (Özer, 1993). Strength is essential for successful physical activity (Tamer, 1995). Grip strength denotes hand grip strength controlled by many muscle groups in the hands and forearms. The muscles in this area enable activities such as holding or manipulating objects in different situations (Bassey & Harries, 1993). Research shows a relationship between body and general muscle strength with hand grip strength (Akbal, 1998). In this connection, grip strength also plays a significant role in performing the handball maneuvers required to throw the ball at the right angle in the desired direction. In handball, the upper extremity muscles are the most important ones for shooting. Shoulder, elbow, and wrist joints are critical for accurate shooting (Demirdizen Taşkıran, 2012; Karadenizli & Karacabey, 2002; Pilça, 2017). As a sporting skill requirement, throwing accuracy is one of the critical skills in many team sports. The accuracy and speed of the shots are critical in determining the winning team in handball (Taborsky, 2007).

Scoring a goal is the factor that determines the outcome of the struggle between the two teams. For this reason, the speed and accuracy of the shots are at the forefront. These two factors are interrelated events (Garcia et al., 2013; Kawamura et al., 2016; Müller & Brandes, 2015). It is known that every shot is of great value in a handball game where two teams with similar strengths are matched. In the game, the players try to shoot and avoid interference from the defenders. For this reason, offense players should be able to try various modifications to find the right shot (Kovacs, 2011).

In this case, athletes can apply different movements accurately in the competition with neuromuscular control. Neuromuscular control is the body's dynamic responses to internal and external sensory inputs and irregularities (Özer-Kaya, 2017). Neuromuscular control creates motor responses by providing controlled muscle activity in voluntary movements, unexpected situations, internal and external stimuli (Silfies et al., 2015; Ustasaraç-Camcıoğlu, 2018). The joints connecting successive body parts, such as the shoulder, elbow, and wrist, form a kinetic chain in the upper extremity. Starting from the chest, the kinetic chain extends to the shoulder, elbow, wrist, and fingers. Neuromuscular control is transmitted along the kinetic chain to ensure smooth and controlled movement of each structure (Wu et al., 2005). Weaknesses in

neuromuscular control negatively affect the control of the musculoskeletal system. This may cause impairment in postural control (İnal, 2013; Lepley et al., 2017).

Reasonable neuromuscular control is essential for maintaining ball continuity in competition and applying the proper strength to the ball when shooting. At this point, conscious and unconscious proprioception is involved, providing stability to certain joints and revealing appropriate movement patterns during action. Moreover, sufficient muscle strength and fast reaction time are required for the anticipated movement after an excellent sensory process (Pekmez, 2019). In a handball throw, the hip, trunk, shoulder, arm, forearm and hand produce maximum linear mechanical energy from the beginning to the end of the throwing action. Energy is transferred from the trunk to the shoulder complex, from the shoulder to the arm, from the arm to the forearm, and finally to the hand. When the kinematic chain is examined to observe the ball reaching its maximum speed during a throw, it appears to reach maximum speed first at the shoulder, then at the elbow, at the wrist, and finally at the ball (Wit & Eliasz, 1998).

Considering this information, it is necessary to identify the active muscles at the time of throwing to increase the shooting efficiency of an athlete. It is seen that planning and training to enable the development of specific active muscles can benefit athletes' performance (Emre, 2022). In the literature, limited studies examine upper extremity, grip strength, and shooting accuracy. From this standpoint, this study aimed to investigate the relationship between upper extremity neuromuscular control and grip strength with shooting accuracy in elite handball players.

METHOD

Research Model

This study employed the correlational survey model from among the quantitative research methods. The correlational survey model is designed to determine whether or not there is a variation between two or more variables or its degree, if any (Karasar, 2011).

Study Sample

The study sample consisted of volunteer male athletes aged between 17 and 26 who played handball in the 2nd League in the 2022/23 season and continued training with at least 3 years of team experience as licensed athletes. The participants participate in technical and tactical training for at least 3 hours 5 days a week and strength training 2 days a week. Exclusion criteria included participants with (a) potential medical issues or a history of ankle, knee, or back pathology that compromised their study participation or performance and (b) any lower or upper extremity surgery or unresolved musculoskeletal disorder in the past 2 years. According to the G*Power analysis, the number of participants required to participate in the study was determined as 26 athletes with a 95% confidence level, 80% difficulty level, and a 5% acceptable margin of error. After all athletes and coaches were informed about the protocol and experimental risks, the participants under the age of 18 were asked to sign an information contract in addition to parental consent so they could participate. Table 1 presents some descriptive data about the participants.

Table 1. Results on the supplementary information about the participants

Variables	N	$\bar{X}$	S	Min./ Max.
Age (years)	26	20.23	2.47	17-26
Weight (kg)	26	72.34	8.01	61-90
Height (cm)	26	180.5	5.90	168-190
Playing experience (years)	26	8.65	2.92	3-14
BMI (kg/m^{-2})	26	22.11	2.13	18-27

$\bar{X}$: Mean, **Sd:** Standard Deviation, **BMI:** Body Mass Index, **kg:** Kilogram, **m^{-2}:** Square meters, **Min:** Minimum, **Max**: Maximum, **N:** Number of Participants

As seen in Table 1, the participants consisted of 26 male handball players with an average age of 20.23±2.47, an average body weight of 72.34±8.01 kg, an average height of 180.5±5.90 cm, average years of playing experience of 8.65±2.92, and a mean BMI of 22.1±2.13 kg/ m^{-2}.

Ethical Approval

The necessary official permissions were obtained from the Scientific Research and Publication Ethics Committee of Erzurum Technical University by meeting No 4 and decision No 10, dated 30.03.2023, and the study began in line with publication ethics.

Research Procedure

The participants were tested individually in a single session. First, anthropometric measurements were made. Weight (kg) was measured using a portable scale, and height was measured using a measuring tape. The BMI was calculated by dividing weight (in kilograms) by height in meters squared. The participants performed typical handball warm-up exercises consisting of low-intensity running and general exercises, lateral leg movements, forearm and back arm turns. After the warm-up, the CKCUEST, grip strength and shooting accuracy tests were administered randomly.

Data Collection Tools

The "Personal Information Form," the "Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)," and the "Shooting Accuracy Test" were used to collect data in the study.

Personal Information Form

The "Personal Information Form" prepared by the researcher was composed of information aiming to collect descriptive data such as age, height and weight, as well as the total number of years of playing experience of the participants in the study sample.

Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

It is a performance test that does not require high technology. It provides quantitative data (score) for an upper extremity task in a closed kinetic chain (CKC) to more effectively examine shoulder endurance and functional capacity in sports or clinical settings. This test evaluates upper extremity strength, endurance, and closed kinetic chain. The test is conducted by counting how many times the subject can touch the supporting hand with the swinging hand, which takes a push-up position for 15 seconds. The two hands' distance is 91.4 cm (36 inches). After the test is carried out 3 times, the average of the three values is taken as a score. In order to prevent fatigue from high-intensity activity, 45 seconds of rest periods are given between tests, taking into account the 1/3 activity/rest ratio. The test is considered both easy to

administer and understandable (Ellenbecker et al., 2000). The test results were calculated according to the following formulas:

1- Contact Score: The total number of contacts in 15 seconds (Ellenbecker et al., 2000; Tucci et al., 2014).

2- Normalization Score: It is calculated by dividing a participant's contact score by his/her height (Tucci et al., 2014).

3- Strength Score: It is calculated by multiplying the participant's contact score by 68% of the body weight (the percentage corresponding to the weight of the arms, head, and trunk) and dividing by 15 (test time in seconds) (Tucci et al., 2014).

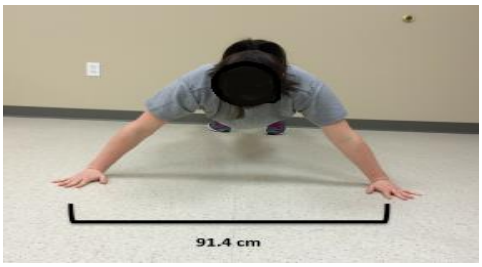

Figure 1. CKCUEST (Silfies., et al. 2015).

Grip Strength Test

A Baseline Hydraulic Hand Dynamometer was used to roughly measure the hand's grip strength. During the measurement, the athlete was seated with the arm close to the body in neutral rotation, the elbow bent at 90°, the forearm rotated in the middle and supported from the seat, and the wrist in the resting position. Athletes completed the test by maintaining this position. The test started with the dominant arm and continued with the non-dominant arm. A rest period of 60 seconds was allowed between the tests repeated 3 times, and the average values of the 3 tests (Fess & Moran, 1981; Gąsior, 2018) were recorded in kilograms (Pizzigalli et al., 2016).

Shooting Accuracy Test

A total of 8 different zones were created by drawing horizontal and vertical lines at a distance of 50 cm from the handball goal posts. The corner throws were given 5 points, the middle sections 3 points, and the section in the middle of the goal post 0 points. The participants were asked to take the balls 11 meters away from the goal post and shoot the goal by jumping from 9 meters. The shots to the designated areas were recorded and the points collected were calculated (Chittibabu, 2014).

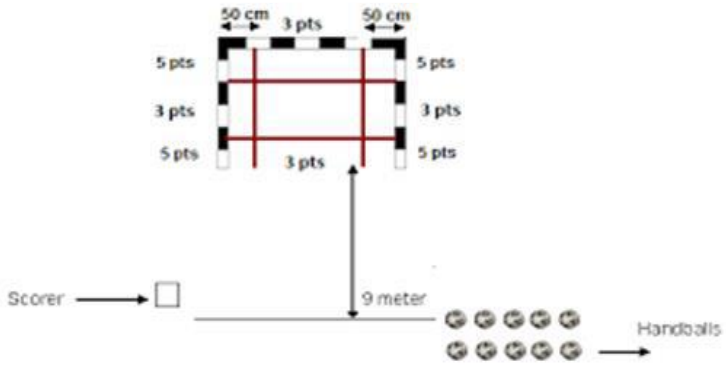

Figure 2. Shooting Accuracy Test (Emre, 2022).

Data Analysis

Skewness and kurtosis tests were applied to the data obtained from the study to determine whether they were normally distributed. The skewness and kurtosis values of the study were determined as Skewness (-.554 and .693), Kurtosis (-.658 and .169). Since skewness and kurtosis values between +1.5 and -1.5 are accepted as a normal distribution (Tabachnick & Fidell, 2007). Therefore, parametric tests were used in the study. The Pearson correlation test was used to determine the relationship between the data obtained from the study, with the significance level being p<.05. In this test, the correlations were fixed at the level of p <.05 and were interpreted as low if r values were below 0.30, moderate if they were between 0.30- 0.70 and high if they were between 0.70-1.00 (Büyüköztürk et al., 2017). Frequency (n), mean ($\bar{X}$), standard deviation (S), min (minimum), and max (maximum) values were used as descriptive statistical methods in the evaluation of the data obtained from the study.

RESULTS

Table 2. Participant's descriptive results on accuracy and grip strength and closed kinetic chain upper extremity stability test

Test Scores	$\bar{X}$	S	Min./Max.
Contact Score	31.07	3.30	24-35
Normalization Score	17.21	1.76	13-20
Strength Score	102.29	17.97	71-134
Dominant Hand Strength	54.88	7.14	45-70
Non-dominant Hand Strength	49.80	7.93	36-70
Shooting Accuracy Score	33.15	6.37	22-46

Normalization Score= Number of touches /height; **Strength Score** = Number of touches x 68% of body weight in kg /15.

As shown in Table 2, the average contact score of the participants was 31.07±3.30, normalization score 17.21±1.76, strength score 102.29±17.97, dominant hand score 54.88±7.14, non-dominant hand score 49.80±7.93, and shooting accuracy score 33.15±6.37.

Table 3. Correlation values of the participant's grip strength and throwing accuracy and closed kinetic chain upper extremity stability test

	CS	NS	SS	DHS	NDHS	SAS
CS	1					
NS	953**	1				
SS	.781**	.691**	1			
DHS	-111	-.162	.140	1		
NDHS	-.238	-.261	.041	.829**	1	
SAS	-0.31	-.005	.231	.036	.133	1

CS: Contact Score, **NS:** Normalization Score, **SS:** Strength Score, **DHS:** Dominant Hand Strength, **NDHS**: Non-dominant Hand Strength, **SAS**: Shooting Accuracy Score

*p <.05, **p < .01

When Table 3 is examined, a high level of positive correlation was found between the participants' normalized score and contact score (r= .953), between the power score with contact and normalized scores (r= .781, r= .691 respectively), between non-dominant hand strength and dominant hand strength (r= .829), In contrast, no significant difference was found in any parameter with the shooting accuracy score.

DISCUSSION

This study investigated the relationship between upper extremity neuromuscular control and grip strength with shooting accuracy in elite handball players. Upper extremity neuromuscular control transfers strength from the trunk to the wrist (Neumann, 2002; Wu et al., 2005). Therefore, upper extremity neuromuscular control is essential for shooting accuracy in handball. Handball is a sport branch in which fitness and coordinative skills are harmoniously affected (Gündüz et al., 2002; Rannou et al., 2001). It is argued whether technical and tactical skills or muscular strength and power are more essential factors in high-level competitions (Cardoso-Marques and González-Badillo, 2006). In this study, the existence of a relationship between upper extremity and hand grip strength and shooting accuracy and its degree were determined as a hypothesis.

The participant's upper extremity neuromuscular control, strength, and endurance were measured with the CKCUEST. In the study, the participants' average contact scores were compatible with the reference value of CKCUEST performed by Borms and Cools (2018) in male athletes. According to these findings, the literature supported the study's results. The percentage of average shooting accuracy of the participants in the study was determined as 33.15±6.37. In the relevant literature, a study conducted with national and foreign athletes reported the average foreign athletes' shooting accuracy as 39% (Emre, 2022). Another study conducted with the same test protocol found that 30 handball players scored an average of 27.52 in the shooting accuracy test (Chittibabu, 2014). Moreover, the average shooting score in the Handball Super League was 32.18, while it was an average of 31.20 for those in the 1st league (Emre et al., 2021). It is believed that the results reported in those studies are different because there are individual (functional and structural) and environmental (lighting, ground) restrictions in the training process of the athletes.

In the present study, no significant correlation was found between the upper extremity neuromuscular control and strength of the participants and the shooting accuracy. When the literature is examined, other studies support our findings. Chelly et al. (2010), for example, reported that the shooting accuracy rate of the handball players in the experimental and control groups did not increase due to training because the percentage of shooting accuracy was not based solely on strength. Ürer and Kılınç (2014), on the other hand, concluded that the shooting performances of handball players did not progress at significant levels depending on the plyometric training.

Çetin and Balcı (2015) reported that handball players' upper extremity strength levels did not significantly affect the shooting accuracy percentage. In parallel with our findings, another study revealed that strength training had no impact on the percentage of shooting accuracy (Pilça & Altun, 2019). Similarly, Ersoy (2016) examined the effect of strength training on the 7-meter throwing performance in handball, concluding that strength training did not affect shooting accuracy. In a study by Hermassi et al. (2011), handball players performed strength training for a period of 8 weeks, and a control group of handball players continued the existing training program during the same period. In line with the findings of our study, they reported that there was no statistically significant change in the 9-meter free throw performance between the experimental and control groups and that the 9-meter throw performance could be closely related to the player's technical abilities. In addition, the authors also stated that the fact that

neither the experimental nor the control group players had a special training program to improve their 9-meter throwing performance and technique was a valid factor for this result (Hermassi et al., 2011). The study's results indicated no direct connection between the percentage of handball throwing performance and the level of strength. Besides many factors affecting the skill level in handball, the shooting technique of each player might be different. Similar results reported in the relevant literature support that throwing performance depends on the training method and an athlete's technical skills and cognitive characteristics (Lon, 2014; Loffing & Hagemann, 2014; Marques et al., 2011). As another example, Marques et al., (2011) pointed out that an athlete's cognitive skills are essential to shooting performance.

By contrast, a study by Lust et al., (2009) investigated the effect of mixed training consisting of open and closed kinetic chains and body-centered exercises on baseball players' trunk stabilization and shooting percentage. While there was no difference between the sample groups after a six-week training period, the researchers found that the trunk stability values and shooting performance of the players in the study sample increased compared to those of the control group. It is considered that the difference between the results of the present study and those reported in the literature may be due to the differing shooting accuracy assessment techniques in the games of baseball and handball.

A high positive correlation was found between the participants' dominant and non-dominant hand grip strengths. The relevant literature review shows specific findings supporting the current study's results. Yıldırım et al. (2010), for example, stated that hand grip strength and upper extremity strength were related to physical activity. In the studies conducted by İncel et al. (2002) and Gencer et al. (2019), the researchers concluded a significant difference between the grip strengths of the dominant and non-dominant hands in favor of the dominant hand. Based on the results of the relevant literature, it can be argued that the significant differences in favor of the dominant hand according to the extremity dominance may be attributed to the use of the dominant hand in daily activities as well as to the fact that it is used more than the non-dominant hand in training and competitions. Moreover, no significant correlation was found in this study between the hand grip strength of the participants and their shooting accuracy. However, Visnapuu and Jürimae (2007) reported that hand grip strength is essential for shooting in sports. It is a fact that studies conducted in different branches of the literature contradict our findings. In this context, some significant differences were found in studies examining the relationship between basketball players' free throw performance and dominant hand grip strength measurements (Gencer et al., 2019; Kinnunen et al., 2001; Pizzigalli et al., 2016). Nikolay et al., (2005) reported in a study conducted with archery athletes that grip strength positively affected throwing performance in both the body's dominant and non-dominant upper extremities. Another study found that non-dominant limb length and dominant limb grip strength positively impacted shooting performance, yet stabilizing muscles significantly affected it (Develik, 2022). Similarly, another study on climbing performance concluded that arm and hand strength effectively predicted climbing performance (Baláš et al., 2012). Furthermore, a significant relationship was found between ball shooting power and grip strength in water polo players (Ferragut et al., 2011). Nevertheless, there are also studies in the literature on the effect of hand grip strength on performance in other types of sports, with conflicting findings (Bilgic et al., 2016).

CONCLUSION

As a result, no significant relationship was found between hand grip strength, upper extremity neuromuscular control and strength, and shooting accuracy in handball, and it was concluded that shooting performance was not only related to strength. A high positive correlation was found between dominant hand strength and non-dominant hand strength. The most important limitation of this study is that it was conducted with 26 handball players and did not identify causal relationships. To support the relevant literature and to obtain common results, it may be recommended to conduct further studies on other factors affecting the shooting accuracy of handball players.

Conflict of Interest: Any personal and financial conflicts of interest within the scope of the Study not available.

Authors' Contribution: Research design, Data collection, Statistical analysis, Preparation of the article, SA.

Ethical Approval
Committee: Erzurum Technical University, Scientific Research Ethic Committee
Date: 30.03.2023
Decision / Protocol number: 10/04

REFERENCES

Alp, M., Kılınç, F., & Suna, G. (2015). Investigation the training's effects applied to handball players in preparation season on some anthropometric and biomotorıc features. *Academic Journal of Sports Health and Medical Sciences, 17*(2), 24-33.

Baláš, J., Pecha, O., Martin, A.J., & Cochrane, D. (2012). Hand-arm strength and endurance as predictors of climbing performance. *European Journal of Sport Science*, *12*(1), 16-25. https://doi.org/10.1080/17461391.2010.546431

Bassey, E. J., & Harries, U. J. (1993). Normal values for handgrip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clinical Science, 84*(3), 331-337. https://doi.org/10.1042/cs0840331

Bilgiç, M., Biçer, M., & Özdal, M. (2016). Investigation of relation 2D:4D finger ratio and sportive performance of 11-13 aged children participated in different sports. *Gaziantep University Journal of Sport Sciences, 1*(1), 48-56.

Borms, D., & Cools, A. (2018). Upper-extremity functional performance tests: Reference values for overhead athletes. *International Journal of Sports Medicine, 39*(06), 433-441. https://doi.org/10.1055/a-0573-1388

Büyüköztürk, Ş., Çokluk, Ö., & Köklü, N. (2016). *Statistics for the social sciences (18st Edition).* Pegem Academy.

Cardoso-Marques, M.A., & González-Badillo, J.J. (2006). In-Season resistance training and detraining in professional team handball players. *The Journal of Strength and Conditioning Research, 20*(3), 563-571.

Çelikbilek, S., Polat Y., Çınar, V., & Şahin, M. (2011). Evaluation of contest analyses of the first league of turkish male handball teams. *Istanbul University Journal of Sports Science, 3*(1), 114-118.

Çetin, E., & Balcı, N. (2015). The effects of isokinetic performance on accurate throwing in team handball. *Procedia Social and Behavioral Sciences, 174*, 1872–1877. https://doi.org/10.1016/j.sbspro.2015.01.850

Cetin, E., & Özdol, Y. (2012). Jump shot performance and strength training in young team handball players. *Procedia-Social and Behavioral Sciences*, *46*, 3187-3190. https://doi.org/10.1016/j.sbspro.2012.06.034

Chelly, M.S., Ghenem, M.A., Abid, K., Hermassi, S., Tabka, Z,. & Shephard, R.J. (2010). Effects of in-season short-term plyometric training program on leg power, jump and sprint performance of soccer players. *Journal of Strength and Conditioning Research*, *24*(10), 2670–2676. https://doi.org/10.1519/JSC.0b013e3181e2728f

Chittibabu, B. (2014). Relationship of selected physical fitness components on shooting accuracy of women handball players. *International Journal for Life Sciences and Educational Research*, *2*(2), 49-51.

Demirdizen Taşkiran, A. (2012). *The correlation between physical and physiological fitness, and throwing velocity and accuracy among elite female handball players*, Doctoral Thesis, Health Sciences Institute, University of Kocaeli, Koceli.

Develik, B. (2022). *The investigation of stabilization and stabilization related parameters in archers on shooting performance according to cervical, lumbar and scapular level*, Master Thesis, Hacettepe University, Graduate School of Health Sciences, Sports Physiotherapy Programme, Ankara.

Ellenbecker, T.S., Manske, R., & Davies, G. J. (2000). Closed kinetic chain testing techniques of the upper extremities. *Orthopedic Physical Therapy Clinics of North America, 9*(2), 219-230.

Emre, M. (2022). *Comparison of speed, agility and technical skills of local and foreign players playing in the handball super league*. Master Thesis, Necmettin Erbakan University, Graduate School of Educational Sciences Department of Physical Education and Sports Physical Education and Sports Program, Konya.

Emre, M., Uzun, A., & Erkek, A. (2021). Comparison of speed, agility and technical skills of handball super league and 1st league players. *Eurasian Journal of Sport Sciences and Education*, *3*(2), 141-155. https://doi.org/10.47778/ejsse.1024683

Ersoy, A. (2016). T*he effect of strength training on 7m throws in handball,* Master Thesis, Institute of Educational Sciences, Department of Physical and Sport Education, Sakarya.

Ferragut, C., Vila, H., Abraldes, J.A., Argudo, F., Rodriguez, N., & Alcaraz, P.E. (2011). Relationship among maximal grip, throwing velocity and anthropometric parameters in elite water polo players. *Journal of Sports Medicine and Physical Fitnes*s, *51*(1), 26-32.

Fess, E.E., & Moran, C.A. (1981). *Clinical assessment recommendations.* American Society of Hand Therapists.

García, J.A., Sabido, R., Barbado, D., & Moreno, F.J. (2013). Analysis of the relation between throwing speed *and throwing accuracy in team handball according to instruction. European Journal of Sport Science, 13*(2), 149-154. https://doi.org/10.1080/17461391.2011.606835

Gąsior, J.S, Pawłowski, M., Williams, C.A., Dąbrowski, M.J., & Rameckers, E.A. (2018). Assessment of maximal isometric hand grip strength in school-aged children, *Open Medicine*, *13(*1), 22-8. https://doi.org/10.1515/med-2018-0004

Gencer, Y.G., Iğdır, E. C., Temur, H.B., Sarikaya, M., & Seyhan, S. (2019). Does hand grip strength affect shot hit rates? *Electronic Turkish Studies, 14*(1), 371-380. http://dx.doi.org/10.7827/TurkishStudies.13432

Gündüz, N., Sevim, Y., & Eler, S. (2002). Hentbolde performans ve testler. *Dinamik Spor Bilimleri Dergisi*, *1*(4), 13-20.

Hermassi, S., Chelly, M. S., Tabka, Z., Shephard, R.J., & Chamari, K. (2011). Effects of 8-week in-season upper and lower limb heavy resistance training on the peak power, throwing velocity, and sprint performance of elite male handball players. *Journal of Strength and Conditioning Research, 25*(9), 2424–2433. https://doi.org/10.1519/JSC.0b013e3182030edb

İnal, H.S. (2013). *Body biomechanics in sport and exercise (1st Edition).* Hipokrat Bookshop.

İncel, N.A., Ceceli, E., Durukan, P.B., Erdem, H.R., & Yorgancioglu, Z.R. (2002). Grip strength: Effect of hand dominance. *Singapore Medical Journal, 43*(5), 234-237.

Karadenizli, A.İ., & Karacabey, K. (2002). Comparison of physical acceptable degrees between girl and boy players who play handball in school teams. *Atatürk University Journal of Physical Education and Sport Sciences, 4*(2), 17-22.

Karasar, N. (2011). *Scientific research methods.* Nobel Publications.

Kawamura, K., Shinya, M., Kobayashi, H., Obata, H., Kuwata, M., Hagio, K., & Nakazawa, K. (2016). Development of throwing accuracy in elementary school handball players. *Paper presented at the ISBS-Conference Proceedings* Archive.

Kinnunen, D.A., Colon G., Espinoza, D., Overby, L.Y., & Lewis, D.K. (2001). Anthropometric correlates of basketball free-throw shootings by young girls. *Perceptual and Motor Skills*, *93*(1), 105-108. https://doi.org/10.2466/pms.2001.93.1.105

Kovacs, P. (2011). Shots from 6 meters–fast break, pivot/wing shots and breakthrough shots. https://activitiesarchive.eurohandball.com/web-periodicals/page-17.

Lepley, L.K., Lepley, A.S., Onate, J.A., & Grooms, D.R. (2017). Eccentric exercise to enhance neuromuscular control. *Sports Health, 9*(4), 333-340. https://doi.org/10.1177/1941738117710913

Loffing, F., & Hagemann, N. (2014). Skill differences in visual anticipation of type of throw in team-handball penalties. *Psychology of Sport and Exercise, 15*(3), 260–267. https://doi.org/10.1016/j.psychsport.2014.01.006

Lon, M. (2014). Technical training methods for increasing the junior handball teams. *Procedia - Social and Behavioral Sciences, 116*, 2004–2009. https://doi.org/10.1016/j.sbspro.2014.01.511

Lust, K.R., Sandrey, M.A., Bulger, S.M., & Wilder, N. (2009). The effects of 6-week training programs on throwing accuracy, proprioception, and core endurance in baseball, *Journal of Sport Rehabilitation, 18*(3), 407-426. https://doi.org/10.1123/jsr.18.3.407

Marques, M., Saavedra, F., Abrantes, C., & Aidar, F. (2011). Associations between rate of force development metrics and throwing velocity in elite team handball players: A Short research report. *Journal of Human Kinetics, 29A*, Issue Special, 53–57. https://doi.org/10.2478/v10078-011-0059-0

Müller, C., & Brandes, M. (2015). Effect of kinesiotape applications on ball velocity and accuracy in amateur soccer and handball. *Journal of Human Kinetics, 49*(1), 119-129. https://doi.org/10.1515/hukin-2015-0114

Neumann, D.A. (2002). *Kinesiology of the musculoskeletal system: Foundations for physical rehabilitation (1st Edition*). Mosby Elsevier.

Özer-Kaya, D. (2017). Lower extremity rehabilitation: Neuromuscular training in athletes. *Turkiye Klinikleri J. Physiother Rehabil-Special Topic, 3*(2), 69-79.

Pekmez, G.S. (2019). *The investigation of the relationship between the physical properties of the upper extremity, grip force, reaction time and wrist proprioception in handball players at the elite and substructure level*. Master Thesis, Pamukkale University, Denizli.

Pilça, O. (2017). *The effect of different types of training on the rate of shooting precision for male handballs between the ages of 19 and 24*. Master Thesis, Dokuz Eylul University. Izmir.

Pilça, O., & Altun, M. (2019). Evaluation of the effects of 12-week handball technical and strength training on shooting and power performance. *CBU Journal of Physical Education and Sport Sciences, 14*(1), 66-78. https://doi.org/10.33459/cbubesbd.533581

Pizzigalli L., Cremasco, M.M., Torre, AL., Rainoldi, A., & Benis, R. (2016**).** Hand grip strength and anthropometric characteristics in italian female national basketball teams. *The Journal of Sports Medicine and Physical Fitness, 57*(5), 521-528. https://doi.org/10.23736/S0022-4707.16.06272-1

Rannou, F., Prioux J., Zouhal, H., & Gratas- Delamarche, P. (2001). Physiological profile of handball players. *The Journal of Sports Medicine and Physical Fitness, 41*(3), 349-353.

Silfies, S. P., Ebaugh, D., Pontillo, M., & Butowicz, C. M. (2015). Critical review of the impact of core stability on upper extremity athletic injury and performance. *Brazilian journal of physical therapy, 19*(5), 360-368. https:/doi.org/10.1590/bjpt-rbf.2014.0108

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics*. Pearson Education.

Taborsky, F. (2007). Playing performance in team handball (summary descriptive analysis). *Res Yearbook, 13*(1), 156-159.

Tucci, H.T., Martins, J., Sposito, G.D.C., Camarini, P.M.F., & De Oliveira, A.S. (2014). Closed kinetic chain upper extremity stability test (CKCUES test): A reliability study in persons with and without shoulder impingement syndrome. *BMC Musculoskeletal Disorders, 15,* 1-9. https://doi.org/10.1186/1471-2474-15-1

Ürer, S., & Kılınç, F. (2014). Investıgate the effect of applied plyometric training for upper and lower extremities on the vertical jump performance and ratio of shoot accuracy over the block of aged 15-17 male handball players. *Inonu University, Journal of Physical Education and Sport Sciences, 1*(2), 16-38.

Ustasaraç-Camcıoğlu, N. (2018). *The Effects of stabilization exercises on performance in amputee football players.* Master Thesis, Hasan Kalyoncu University, Institute of Health Sciences, Gaziantep.

Visnapuu, M., & Jürimäe, T. (2007). Handgrip strength and hand dimensions in young handball and basketball players. *The Journal of Strength & Conditioning Research, 21*(3), 923-929. https://doi.org/10.1519/1533-4287(2007)21[923:HSAHDI]2.0.CO;2

Wit, A., & Eliasz, J. (1998). A three-dimensional kinematic analysis of handball throws. Riehle, H. J., & Vieten M. M. (Eds). *16 International Symposium on Biomechanics in Sport.* In ISBS-Conference Proceedings Archive. Konstanz: Germany.

Wu, G., Van der Helm, F.C., Veeger, H.D., Makhsous, M., Van Roy, P., Anglin, C., & Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion-Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics*, *38*(5), 981-992. https://doi.org/10.1016/j.jbiomech.2004.05.042

Yıldırım, İ., Baş, O., Kabadayı, M., Taşmektepligil, M.Y., Ocak, Y., & Karagöz, Ş. (2010). Examination of the correlation of hand grip strength with upper extremity physical characteristics in the male players of handball super league. *Mustafa Kemal University Journal of Physical Education and Sport Sciences*, *1*(1), 9-15.