Spor ve Performans Araştırmaları Dergisi,
Journal of Sports and Performance Researches

e-ISSN: 1309-8543 Spor ve Performans Araştırmaları Dergisi,
Nisan 2025, 16(1): 107-120

The Effects of Vertical and Horizontal Static Core Strength Exercises on Athletic Performance in Young Female Handball Players

Genç Kadın Hentbol Sporcularında Dikey ve Yatay Statik Core Kuvvet Egzersizlerinin Sportif Performans Üzerindeki Etkileri

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Makale Bilgisi/Article Information

Makale Türü/Article Types: Araştırma Makalesi/Research Article
Geliş Tarihi/Received: 27 Aralık/December 2024
Kabul Tarihi/Accepted: 16 Mart/March 2025
Yıl/Year: 2025 | **Cilt – Volume:** 16 | **Sayı – Issue:** 1 | **Sayfa/Pages:** 107-120

Atıf/Cite as: Edis, Ç., Bayrakdaroğlu, S., Ceylan, H.İ. "The Effects of Vertical and Horizontal Static Core Strength Exercises on Athletic Performance in Young Female Handball Players" Ondokuz Mayıs University Journal of Sports and Performance Researches, 16(1), April 2025: 107-120.

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Etik Kurul Beyanı/Ethics Committee Approval: “For the research, ethics committee permission was obtained from Trabzon University Social and Human Sciences Scientific Research and Publication Ethics Committee with the decision number 2023-3/2.4 dated 27/03/2023.”

https://doi.org/10.17155/omuspd.1608412

THE EFFECTS OF VERTICAL AND HORIZONTAL STATIC CORE STRENGTH EXERCISES ON ATHLETIC PERFORMANCE IN YOUNG FEMALE HANDBALL PLAYERS

ABSTRACT

Core exercises are typically performed in the horizontal plane, whereas athletic activities such as running, jumping, and change of direction (COD) occur in both vertical and horizontal planes. This study aimed to investigate the effects of static core exercises performed in the vertical and horizontal planes on physical performance. Twenty-four female handball players voluntarily participated in the study and were randomly assigned to either a vertical static core (VSC) exercise group (n=12; age: 17,75±0,99 years, height: 171,00±8,66 cm, weight: 66,08±5,97 kg) or a horizontal static core (HSC) exercise group (n=12; age: 17,75±0,75 years, height: 166,75±13,71 cm, weight: 63,33±6,74 kg). A two-group experimental design with a pretest-posttest model was employed. The core exercise protocol consisted of prone plank, side plank (right and left), supine bridge, and bird dog exercises, performed three times per week for eight weeks. Before and after the intervention, participants were evaluated for isometric core strength, 5-20 meter linear sprint performance, vertical jump height, and three different COD performance tests. Data were analyzed using the Shapiro-Wilk test to assess the normality of the distribution. Paired samples t-tests were used to analyze differences between the groups' pretest and posttest results based on normality assumptions. For between-group comparisons, independent samples t-test was used. The results revealed no statistically significant differences between the VSC and HSC groups in terms of post-exercise performance improvements ($p>0.05$). However, significant improvements in physical performance parameters were observed within both groups from pre- to post-intervention ($p<0.05$). In conclusion, while the exercise plane (vertical or horizontal) does not appear to be a determinant factor in enhancing physical performance, static core exercises can be considered an effective method for improving athletic performance.

Keywords: Athletic Performance, Core Strength, Handball, Plantar Training.

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GENÇ KADIN HENTBOL SPORCULARINDA DİKEY VE YATAY STATİK CORE KUVVET EGZERSİZLERİNİN SPORTİF PERFORMANS ÜZERİNDEKİ ETKİLERİ

ÖZ

Core egzersizleri genellikle yatay düzlemde gerçekleştirilmekle birlikte, koşu, sıçrama ve yön değiştirmeli koşu (YDK) gibi spor aktiviteleri hem dikey hem de yatay düzlemde meydana gelmektedir. Bu çalışmanın amacı, dikey ve yatay düzlemde uygulanan statik core egzersizlerinin fiziksel performans üzerindeki etkilerini incelemektir. Çalışmaya gönüllü olarak katılan 24 kadın hentbol oyuncusu, dikey statik core (DSC) (n=12; yaş: 17,75±0,99 yıl, boy: 171,00±8,66 cm, ağırlık: 66,08±5,97 kg) ve yatay statik core (YSC) (n=12; yaş: 17,75±0,75 yıl, boy: 166,75±13,71 cm, ağırlık: 63,33±6,74 kg) egzersiz gruplarına rastgele atanmıştır. Çalışmada ön test-son test tasarımına dayalı iki gruplu deneysel model kullanılmıştır. Core egzersizleri, prone plank, side plank (sağ ve sol), supine bridge ve bird dog egzersizlerinden oluşmuş ve 8 hafta boyunca haftada 3 gün uygulanmıştır. Egzersiz öncesinde ve sonrasında katılımcıların izometrik core kuvveti, 5-20 metre doğrusal sprint, dikey sıçrama ve üç farklı yön değiştirmeli koşu performansları değerlendirilmiştir. Veriler, dağılımın normalliğini belirlemek için Shapiro-Wilk testi kullanılarak analiz edilmiştir. Normal dağılım varsayımlarına dayanarak grupların ön test ve son test sonuçları arasındaki farklar, eşleştirilmiş örneklem t-testi (paired sample t-test) ile değerlendirilmiştir. Gruplar arasındaki karşılaştırmalar için bağımsız örneklem t-testi (independent samples t-test). Çalışma sonucunda, DSC ve YSC grupları arasında egzersiz sonrası performans değişiminde istatistiksel açıdan anlamlı bir fark tespit edilmemiştir ($p>0.05$). Ancak her iki grupta da egzersiz öncesi ve sonrası fiziksel performans parametrelerinde anlamlı iyileşmeler gözlenmiştir ($p<0.05$). Sonuç olarak, core egzersizlerinin yapıldığı düzlem, fiziksel performans artışı açısından belirleyici bir faktör olmamakla birlikte, statik core egzersizleri sporcuların performansını geliştirmek için etkili bir yöntem olarak değerlendirilebilir.

Anahtar Kelimeler: Atletik Performans, Core Kuvveti, Hentbol, Düzlemsel Antrenman.

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INTRODUCTION

Handball is an Olympic sport and is a team sport that requires fast defence and offence. Handball athletes coordinate their movements in a competition and continuously repeat running, change of direction, opponent pushing and jumping type movements (Wagner et al., 2014). At this point, it is very important for athletes to be at physically appropriate levels in terms of competition performance. In this respect, core exercises can help athletes to perform more positive running, jumping or change of direction running acskills in the transfer of power features to be sent to the arms and legs (Willardson, 2007).

The core region, anatomically defined as the area extending from the knee joint to the shoulders, is critical for achieving optimal athletic performance (Hibbs et al., 2008). This region not only serves as a central hub for generating and transmitting power but also plays a pivotal role in enhancing the output of that power (Willardson, 2007). Functionally, the core operates as a junction through which neural commands from the brain are relayed to the arms and legs. Simultaneously, it facilitates the feedback loop by transmitting information regarding speed, angle, and muscle tension changes back to the brain (Leetun et al., 2004; Willson et al., 2005; Kibler et al., 2006).

Considering the crucial role of bidirectional communication within the core, adequate strength is necessary to ensure efficient and rapid message exchange. To achieve optimal functionality, it is essential to identify the specific core muscles that should be targeted and the exercises that effectively develop them (Escamilla et al., 2010). Accordingly, exercise programs must be tailored to the unique characteristics and anatomical structure of the core muscles. The core consists of distinct muscle groups, generally categorized into local muscles situated in the deepest layers of the lumbo-pelvic structure and global muscles, which are more superficial (Johnson, 2002). While local muscles are best activated and strengthened through static and isometric exercises, dynamic exercises are more effective for engaging global muscles.

Research on core muscle development has yielded conflicting results. For example, Sever (2017) reported that an eight-week training program incorporating static and dynamic core exercises in the horizontal plane did not significantly enhance sprinting, change-of-direction running, or jumping performance in 14-year-old athletes. Conversely, other studies have found that core training interventions can lead to performance improvements (Silfies et al., 2015; Genç et al., 2019).

A substantial body of research has primarily examined core exercises performed parallel to the horizontal plane. For instance, Arokoski et al. (2001) found no significant differences in core muscle activation during electromyographic assessments of athletes performing exercises across various positions. Yet, other findings suggest that standing core exercises, which introduce moderate instability, enhance power output and are more effective for improving both upper and lower body strength (Kraemer et al., 2002; McCurdy et al., 2005; Baechle & Earle, 2008). This type of training structure is thought to provide a greater transfer of strength to sport-specific activities (Willardson, 2007). Supporting these results, studies have

https://doi.org/10.17155/omuspd.1608412

shown that vertical core exercises can yield superior performance improvements compared to horizontal exercises (Kraemer et al., 2002). However, it is seen that there are very few or even a single study examining the effects of vertical and horizontal core exercises on the performance of athletes (Tınkır & Uzun, 2022). At this point, it is clearly seen that there is a deficiency in the literature.

While existing evidence highlights the potential benefits of vertical core exercises, further research is required to clarify their impact on athletic performance. In this context, the present study aims to investigate the effects of horizontal and vertical static core strength exercises on sprint performance, isometric core strength, change-of-direction running, and vertical jumping. Our hypothesis posits that core exercises, particularly those performed in vertical planes, may have a positive impact on overall physical performance.

METHOD

Research Group

The study included 24 female handball players who trained regularly at least three days per week. The minimum sample size for this study was determined using G*Power software version 3.1.9.7 (Faul et al., 2007) from the University of Düsseldorf, Germany. Based on the study design, a power analysis was conducted using the paired-samples t-test model. The parameters used for the analysis were as follows: one group, alpha error probability (α) = 0.05, statistical power ($1-\beta$) = 0.80, and effect size = 0.55. The analysis indicated that a total of 22 participants would be required to achieve the desired statistical power of 80.24%. The inclusion criteria required participants to have been actively engaged in licensed sports for a minimum of four years, commit to regular participation in the exercises, and have no history of sports injuries that could affect test results. Exclusion criteria included performing any strength exercises outside the study's exercise protocol during the research period, using stimulants the day before the tests, or experiencing a sports injury that could influence test outcomes. All handball players were informed about the study's requirements and potential risks and signed a consent form indicating their voluntary participation. Additionally, participants were asked to monitor their sleep habits throughout the study period.

Experimental Design

The study utilized a two-group experimental design incorporating a pre-test and post-test model (Büyüköztürk et al., 2017). This approach enabled the evaluation of the intervention's effects by comparing the performance outcomes of the groups before (pre-test) and after (post-test) the static core training program. The details of all tests and exercises performed during the study are presented in Table 1. Athletes participated in performance assessments conducted both before and after the 8-week static core training intervention. One week prior to the training program and again after its conclusion, tests were administered over a span of five days. These assessments included core strength, 5-meter and 20-meter sprint, vertical jump, and change of direction tests, with the latter being conducted on the last two days of the testing week. During the testing and training weeks, the athletes engaged only in technical and tactical training, ensuring minimal interference with the intervention. Additionally, all tests and training sessions were conducted during the competition season. Prior to each testing session, a standardized 15-minute dynamic warm-up routine was performed to prepare the participants. The warm-up protocol began with 5 minutes of dynamic running, emphasizing active arm and leg movements. This was followed by 5 minutes of bodyweight exercises targeting strength, balance, and jumping. In the last five minutes of the warm-up phase, the athletes performed dynamic stretching movements and actively performed their rest for the test in the main phase of the test (Faigenbaum et al., 2006).

For all tests, 24 athletes were divided into three groups, each consisting of eight participants. This grouping ensured that the athletes could perform the tests without losing the physiological benefits of the warm-up. During the eight-week training intervention, all exercises were executed immediately following the warm-up phase. The rest intervals between sets varied throughout the program: in the first and second weeks, the rest duration was set at half of the load duration; in the third and fourth weeks, it was standardized at 20 seconds; and in the final weeks, it was increased to 30 seconds. The Vertical Static Core (VSC) group executed the exercises in a vertical plane, whereas the Horizontal Static Core (HSC) group performed the same movements in a horizontal plane. The horizontal-plane exercises were conducted on a mat, while the vertical-plane exercises were performed against a wall. The sprint, change-of-direction, and jumping tests were conducted on an indoor court with a synthetic surface. The exercises were conducted in the afternoon at specific times of the day, aligning with the athletes' physiological and biological rhythms.

In the prone plank exercise, athletes assumed a position on their toes, ensuring that their elbows were in full contact with the wall while applying maximum tension to the Achilles tendon. In the side plank, they positioned themselves laterally against the wall, with the palm and elbow joint of one arm completely in contact with the surface. During the supine bridge, athletes leaned their backs against the wall, supporting themselves through their heels while fully extending their arms to the sides. In the bird dog exercise, they stabilized themselves in a prone position by pressing one hand against the wall while balancing on the opposite leg.

This structured training protocol ensured consistency in exercise execution while addressing different movement planes to examine the effects of static core exercises on athletic performance.

Table 1. Performance tests and static core training**.**

<table>
<tr><th rowspan="2">Pre Test</th><th rowspan="2" colspan="2">Horizontal and Vertical Core Training</th><th colspan="4">Training Load</th><th rowspan="2">Post Test</th></tr>
<tr><th>1-2 Weeks</th><th>3-4 Weeks</th><th>5-6 Weeks</th><th>7-8 Weeks</th></tr>
<tr><td rowspan="5">Static Core strength, 5 and 20 m sprint, Vertical Jump, Illinois, T and 505 COD</td><td>1</td><td>Prone Plank</td><td rowspan="5">3x30 (sec)</td><td rowspan="5">3x45 (sec)</td><td rowspan="5">3x60 (sec)</td><td rowspan="5">3x90 (sec)</td><td rowspan="5">Static Core strength, 5 and 20 m sprint, Vertical Jump, Illinois, T and 505 COD</td></tr>
<tr><td>2</td><td>Side Plank (Right)</td></tr>
<tr><td>3</td><td>Side Plank (Left)</td></tr>
<tr><td>4</td><td>Supine Bridge</td></tr>
<tr><td>5</td><td>Bird Dog</td></tr>
</table>

Data Collection Tools

Anthropometric measurements: The height and body mass of the athletes were measured with a calibrated Seca brand stadiometer without shoes and with shorts - t-shirt clothing. The weight of the athletes was recorded with the help of a digital scale. Body mass index BMI was calculated as “mass (kg)/ height (m)2.

Core strength testing: The isometric strength of the athletes’ core region was assessed using a standardized protocol. The test consisted of four distinct movement applications, measuring the isometric strength of the anterior, right, left, and posterior core muscles through plank variations. The performance was quantified based on the maximum duration each position was held, with the longest time recorded for each movement included in the statistical analysis (McGill, S., 2015).

Sprint test: The 5-meter and 20-meter sprint times of the participants were assessed in the training field where the athletes regularly practiced. Each participant completed three repetitions of the 20-meter sprint, with a standardized 3-minute rest period between trials to minimize fatigue. Sprint times were recorded using infrared sensor gates (Newtest Oy, Oulu, Finland) positioned at the starting line, the 5-meter mark, and the 20-meter finish line. The use of precise timing equipment ensured accurate measurement of sprint performance at each distance (Gorostiaga et al., 2005).

The Countermovement Jump (CMJ): Test was conducted using a jumping platform (Newtest Oy, Oulu, Finland) to assess explosive lower-body power. The movement involved a rapid descent into a squat, immediately followed by an explosive upward motion to maximize jump height. This procedure ensured standardized conditions for all participants, facilitating reliable measurement of vertical jump performance (Gorostiaga et al., 2005). Each participant performed the test three times, and the highest recorded jump height was used for statistical analysis.

Change of Direction Running Tests: The athletes' change of direction (COD) running performances were assessed using three established COD tests: the Illinois, 505, and T-tests (Pauole et al., 2000). Each athlete completed three repetitions of each test, with a standardized 3-minute rest period between trials to minimize fatigue. In all tests, the athletes started with their feet in contact with the starting line drawn at least 1 metre behind the first passing gate. In this way, the test starting conditions were standardised for each athlete. These tests provided a comprehensive evaluation of the athletes' agility and COD ability under varying movement patterns and conditions.

Data analysis: Statistical analyses were conducted using IBM SPSS® software version 28.0.1.0. Data were presented as mean ± standard deviation (SD). The Shapiro-Wilk test was used to assess the normality of variable distributions. For within-group comparisons of pre-test and post-test results, dependent sample t-tests were applied, contingent on the normality of the data. For between-group comparisons of pre-test and post-test differences, independent sample t-tests were used based on the normal distribution levels. According to Cohen's (1988) classification, effect sizes are categorized as negligible ($d < 0.2$), small ($0.2 \leq d < 0.5$), medium ($0.5 \leq d < 0.8$), and large ($d \geq 0.8$). A significance level of $p < 0.05$ was adopted for all analyses.

FINDINGS

Table 2. Descriptive statistics of the players.

	n	Min.	Max.	$\bar{X}$	S.d
			VSC Group		
Age (years)	12	17.00	19.00	17.75	0.75
Height (cm)		144.00	182.00	166.75	13.71
Weight (kg)		52.00	76.00	63.33	6.74
BMI (kg.m^{-2})		19.32	26.56	22.80	2.13
			HSC Group		
Age (years)	12	17.00	20.00	18.58	0.99
Height (cm)		158.00	181.00	171.00	8.66
Weight (kg)		60.00	82.00	66.08	5.97
BMI (kg.m^{-2})		19.59	28.04	22.72	2.92

HSC: horizontal core training; VSC: vertical static core training.

Tables 3 and 4 show the performance tests after 8 weeks of HSC and VSC. After 8 weeks of static core exercises, it is seen that vertical and horizontal core exercises did not result in a statistical difference in the two groups.

Table 3. Statistical analysis of static core force values (Duration) between pre-test and post-test between HSC and VSC groups.

Core Strength Tests	Group	n	Pre-test X̄/S.d	Post-test X̄/S.d	t	p	Cohen d
Prone Plank (sec)	VSC	12	159.91±21.24	253.00±4.22	0.049	0.961	0.408, small effect
	HSC		160.33±21.33	252.91±4.05			
Supine Bridge (sec)	VSC		163.25±23.61	242.41±6.14	0.966	0.345	0.416, small effect
	HSC		161.00±24.67	259.25±5.27			
Side Plank (Right) (sec)	VSC		76.16±5.81	193.08±4.62	0.161	0.874	0.408, small effect
	HSC		75.91±5.55	193.41±5.48			
Side Plank (Left) (sec)	VSC		82.08±6.68	198.50±5.93	0.097	0.924	0.408, small effect
	HSC		82.25±6.83	198.75±6.70			

HSC: horizontal static core training; VSC: vertical static core training.

Table 4. Statistical results between pre and post-performance tests between HSC and VSC treated groups

Performance Measurements	Group	n	Pre-test X̄/S.d	Post-test X̄/S.d	t	p	Cohen d
5 m. Sprint (sec)	VSC	12	1.35±0.16	1.31±0.14	0.098	0.923	0.040, Negligible
	HSC		1.36±0.16	1.32±0.14			
20 m. Sprint (sec)	VSC		3.97±0.64	3.70±0.56	0.011	0.991	0.004, Negligible
	HSC		3.97±0.64	3.70±0.56			
Vertical Jump Height (cm)	VSC		36.58±8.37	43.00±9.48	0.021	0.984	0.009, Negligible
	HSC		36.33±8.27	42.91±10.08			
Illinois COD (sec)	VSC		17.73±1.33	17.75±1.14	0.004	0.997	0.001, Negligible
	HSC		17.72±1.33	17.75±1.14			
505 COD (sec)	VSC		4.25±0.50	4.05±0.45	0.022	0.982	0.009, Negligible
	HSC		4.25±0.49	4.06±0.45			
T COD (sec)	VSC		11.13±1.05	11.24±1.12	0.185	0.855	0.076, Negligible
	HSC		11.13±1.05	11.15±1.08			

COD: change of Directions Runs; HSC: horizontal core training; VSC: vertical core training.

Table 5. Statistical results between the pre and post-performance tests of the in-groups practicing HSC and VSC.

Performance Measurements	Group	n	Pre-test X̄/S.d	Post-test X̄/S.d	t	df	p
5 m. Sprint (sec)	VSC	12	1.35±0.16	1.31±0.14	1.977	11	0.074
	HSC		1.36±0.16	1.32±0.14	2.031	11	0.067
20 m. Sprint (sec)	VSC		3.97±0.64	3.70±0.56	4.046	11	0.002
	HSC		3.97±0.64	3.70±0.56	4.165	11	0.002
Vertical Jump Height (cm)	VSC		36.58±8.37	43.00±9.48	-5.687	11	0.000
	HSC		36.33±8.27	42.91±10.08	6.544	11	0.002
Illinois COD (sec)	VSC		17.73±1.33	17.75±1.14	-.229	11	0,823
	HSC		17.72±1.33	17.75±1.14	-.186	11	0,856
505 COD (sec)	VSC		4.25±0.50	4.05±0.45	2.184	11	0.052
	HSC		4.25±0.49	4.06±0.45	2,187	11	0.051
T COD (sec)	VSC		11.13±1.05	11.24±1.12	-.128	11	0.900
	HSC		11.13±1.05	11.15±1.08	-.585	11	0.571

COD: change of Directions Runs; HSC: horizontal core training; VSC: vertical core training.

Table 6. Statistical analysis of static core strength values (Duration) of the in-groups performing HSC and VSC between the pre-test and post-test.

Core Strength Tests	Group	n	Pre-test X̄/S.d	Post-test X̄/S.d	t	df	p
Prone Plank (sec)	VSC	12	159.91±21.24	253.00±4.22	-285.880	11	0.000
	HSC		160.33±21.33	252.91±4.05	-242.671	11	0.000
Supine Bridge (sec)	VSC		163.25±23.61	242.41±6.14	-226.899	11	0.000
	HSC		161.00±24.67	259.25±5.27	-220.314	11	0.000
Side Plank (Right) (sec)	VSC		76.16±5.81	193.08±4.62	-33.135	11	0.000
	HSC		75.91±5.55	193.41±5.48	-34.049	11	0.000
Side Plank (Left) (sec)	VSC		82.08±6.68	198.50±5.93	-30.447	11	0.000
	HSC		82.25±6.83	198.75±6.70	-9.891	11	0.000

HSC: horizontal core training; VSC: vertical core training.

DISCUSSION

The findings of this study align with the existing literature on the effects of core exercises on physical performance. An eight-week static core training program was observed to significantly enhance sprint and vertical jump performance, regardless of whether the exercises were performed in the vertical or horizontal plane. However, no substantial improvements were noted in change-of-direction tests. This suggests that while core training enhances overall physical performance, it may not directly improve movement patterns related to agility.

Core training plays a fundamental role in enhancing athletic performance by improving stability, force transmission, and overall neuromuscular control (Sharma & Geovinson, 2012; Boyacı et al., 2018; Bora & Dağlıoğlu, 2022). Studies have demonstrated that core strength positively influences explosive power, running efficiency, and injury prevention.

Previous research in the context of handball highlights the role of core stability in throwing performance and overall athletic efficiency. For instance, Saeterbakken et al. (2011) reported that closed kinetic chain core exercises performed on unstable surfaces increased maximal throwing velocity by 4.9% in female handball players, attributing this improvement to enhanced rotational stability and force transfer across multiple segments. Similarly, Manchado et al. (2017) found that a 10-week progressive core training program increased throwing velocity by 4.5% in male handball players, emphasizing the crucial role of lumbopelvic stability in optimizing kinetic chain efficiency. These findings indicate that core training significantly contributes to force production and transfer, particularly in sports like handball.

However, not all studies have reported a direct relationship between core strength and sport-specific performance outcomes. Kuhn et al. (2019) found that although a six-week core stability training program significantly improved core strength and endurance, it did not lead to a meaningful increase in throwing velocity among female handball players. This suggests that while core training enhances fundamental strength, its direct transfer to sport-specific skills may require longer training durations or higher-intensity interventions. The findings of the present study are consistent with this perspective, as no significant improvements were observed in change-of-direction performance. This further implies that core training alone may not be sufficient to enhance agility performance.

Additionally, various studies have reported that core exercises can improve multiple fitness components. Bora & Dağlıoğlu (2022) indicated that core strength training enhances speed, anaerobic power, and static balance, while Boyacı et al. (2018) demonstrated its contribution to lower-extremity strength development. Similarly, Sharma & Geovinson (2012) reported that core stability training significantly improves vertical jump height and postural control. Tınkır & Uzun (2022) analyzed the effects of vertical and horizontal core exercises on agility and speed, concluding that core training enhances running performance, with vertical core exercises exerting a more pronounced impact on agility.

The specific core exercises selected for this study, including plank and side plank, were chosen due to their effectiveness in activating the transverse abdominis, rectus abdominis, and oblique muscles. These muscles play a critical role in maintaining posture, stabilizing movements, and generating force during dynamic handball actions such as throwing, sprinting, and rapid changes in direction. Given that handball requires explosive power generation, incorporating static core exercises aimed to enhance stability and power output. This approach is supported by previous research, which suggests that core stability enhances energy transfer and biomechanical efficiency (Lee & McGill, 2017).

The findings of this study are also consistent with research comparing dynamic and static core training. Lee & McGill (2017) reported that while static core exercises improve force production, dynamic core exercises are more effective in increasing impact velocity. This distinction aligns with the present study's results, as improvements in sprint and jump performance following static core training reinforce the holistic benefits of core strength development in athletic performance.

A notable limitation of this study is the lack of significant correlations between agility tests (Illinois, 505, T-Test) and sprint and jump performance. This highlights the need for more comprehensive core training programs that encompass functional movement mechanics across different movement tasks. Additionally, the study sample was limited to female handball players, which is another constraint. Future studies incorporating different age groups and professional male handball players could expand the scope of the findings. Lastly, the study focused exclusively on core exercises. Future research should examine the effects of both static and dynamic exercises, as well as training performed in different planes, to provide a more detailed understanding of core training's impact.

Practical Implications

From a practical perspective, incorporating core exercises across both vertical and horizontal planes can provide athletes with a well-rounded and comprehensive training approach. Coaches and athletes can integrate core training to enhance sprint and jump performance. Handball-specific training should emphasize core exercises that support explosive power production, rotational stability, and agility-related movements. A combination of static and dynamic core exercises may optimize agility and power-oriented movements. These findings underscore the need to tailor core training to sport-specific demands, emphasizing that training programs should be structured accordingly to maximize performance efficiency in team sports such as handball.

CONCLUSION

In conclusion, static core exercises performed in both vertical and horizontal planes have similar effects on performance outcomes. Static core training positively impacts sprint, jump, and core strength development. Further research is needed to assess the effectiveness of static core exercises performed in different movement planes. In female handball players who do not engage in regular structured training, static core exercises may serve as an effective means of improving performance. Integrating both static and dynamic core training may further optimize performance in sport-specific demands such as rotational stability and rapid directional changes.

These findings highlight that core training is a fundamental component for sports requiring explosive movements and postural control, particularly in team sports such as handball.

Acknowledgements

We thank the participants for their participation in this study.

Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contribution Rates

Design of Study: ÇE(%100)

Data Acquisition: ÇE(%100)

Data Analysis: HİC(%100)

Writing Up: ÇE(%30), SB(%40), HİC(%30)

Submission and Revision: SB(%100)

REFERENCES

Arokoski, J. P., Valta, T., Airaksinen, O., & Kankaanpää, M. (2001). Back and abdominal muscle function during stabilization exercises. *Archives of Physical Medicine and Rehabilitation, 82*(8), 1089-1098. https://doi: 10.1053/apmr.2001.23819.

Atlı, A. (2021). The effect of a core training program applied on football players on some performance parameters. *Journal of Educational Issues, 7*(1), 337-350. doi:10.5296/jei.v7i1.18493.

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength training and conditioning*. Human kinetics.

Bayrakdar, A., Boz, H. K., & Işıldar, Ö. (2020). The investigation of the effect of static and dynamic core training on performance on football players. *Turkish Journal of Sport and Exercise, 22*(1), 87-95. doi: 10.15314/tsed.689994.

Bora, H., & Dağlıoğlu, Ö. (2022). Effect of core strength training program on anaerobic power, speed and static balance in volleyball players. *European Journal of Physical Education and Sport Science, 8*(5) 72-80. https://doi:10.46827/ejpe.v8i5.4355.

Boyacı, A., Tutar, M., & Bıyıklı, T. (2018). The Effect of Dynamic and static core exercises on physical performance in children. *Online Submission, 4*(7), 50-61. https://doi:10.5281/zenodo.1283743.

Büyüköztürk, Ş., Çakmak, E. K., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2017). *Bilimsel araştırma yöntemleri.* Ankara: Pegem Akademi.

Escamilla, R. F., Lewis, C., Bell, D., Bramblet, G., Daffron, J., Lambert, S., ... et al. (2010). Core muscle activation during Swiss ball and traditional abdominal exercises. *Journal of Orthopaedic & Sports Physical Therapy, 40*(5), 265-276. https://doi:10.2519/jospt.2010.3073.

Faigenbaum, A. D., McFarland, J. E., Schwerdtman, J. A., Ratamess, N. A., Kang, J., & Hoffman, J. R. (2006). Dynamic warm-up protocols, with and without a weighted vest, and fitness performance in high school female athletes. *Journal of Athletic Training*, *41*(4), 357.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.

Genc, H., Cigerci, A. E., & Sever, O. (2019). Effect of 8-week core training exercises on physical and physiological parameters of female handball players. *Physical Education of Students, 23*(6), 297-305. https://doi: 10.15561/20755279.2019.0604.

Gorostiaga, E. M., Granados, C., Ibanez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine, 26*(03), 225-232. https://doi:10.1055/s-2004-820974

Hibbs, A. E., Thompson, K. G., French, D., Wrigley, A., & Spears, I. (2008). Optimizing performance by improving core stability and core strength. *Sports Medicine, 38*(12), 995-1008. https://doi: 10.2165/00007256-200838120-00004.

Johnson, P. (2002). Training the trunk in the athlete. *Strength & Conditioning Journal, 24*(1), 52-59. https://doi: 10.1519/00126548-200202000-00016.

Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine, 36*(3), 189-198. https://doi: 10.2165/00007256-200636030-00001.

Kraemer, W. J., Adams, K., Cafarelli, E., Dudley, G. A., Dooly, C., Feigenbaum, M. S., ... et al. (2002). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine aAnd Science iİn Sports aAnd Exercise, 34*(2), 364-380. https://doi: 10.1097/00005768-200202000-00027.

Kuhn, L., Weberruß, H., & Horstmann, T. (2019). Effects of core stability training on throwing velocity and core strength in female handball players. *The Journal of Sports The Journal of Sports Medicine and Physical Fitness*, *59*(9), 1479-1486. https://doi:10.23736/S0022-4707.18.09295-2

Lee, B., & McGill, S. (2017). The effect of core training on distal limb performance during ballistic strike manoeuvres. *Journal of Sports Sciences, 35*(18), 1768-1780. https://doi: 10.1080/02640414.2016.1236207.

Leetun, D. T., Ireland, M. L., Willson, J. D., Ballantyne, B. T., & Davis, I. M. (2004). Core stability measures as risk factors for lower extremity injury in athletes. *Medicine & Science in Sports & Exercise, 36*(6), 926-934. https://doi: 10.1249/01.mss.0000128145.75199.c3.

Manchado, C., García-Ruiz, J., Cortell-Tormo, J. M., & Tortosa-Martínez, J. (2017). Effect of core training on male handball players' throwing velocity. *Journal of Human Kinetics, 56*, 177-185. https://doi:10.1515/hukin-2017-0035

McCurdy, K. W., Langford, G. A., Doscher, M. W., Wiley, L. P., & Mallard, K. G. (2005). The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *The Journal of Strength & Conditioning Research, 19*(1), 9-15. https://doi: 10.1519/14173.1.

McGill, S. (2015). *Low back disorders: evidence-based prevention and rehabilitation*. Human Kinetics.

Pauole, K., Madole, K., Garhammer, J., Lacourse, M., & Rozenek, R. (2000). Reliability and validity of the T-test as a measure of agility, leg power, and leg speed in college-aged men and women. *The Journal of Strength & Conditioning Research, 14*(4), 443-450. https://doi: 10.1519/00124278-200011000-00012.

Saeterbakken, A. H., Van den Tillaar, R., & Seiler, S. (2011). Effect of core stability training on throwing velocity in female handball players. *The Journal of Strength & Conditioning Research, 25*(3), 712-718. https://doi: 10.1519/JSC.0b013e3181cc227e

Sever, O. (2017). Comparison of static and dynamic core exercises' effects on stork balance test in soccer players futbolcularda statik ve dinamik core egzersizlerin stork denge testine etkisi. *Journal of Human Sciences, 14*(2), 1781-1791. https://doi: 10.14687/jhs.v14i2.4440.

Sharma, A., & Geovinson, S. G. (2012). Effects of a nine-week core strengthening exercise program on vertical jump performances and static balance in volleyball players with trunk instability. *The Journal of Sports Medicine and Physical Fitness, 52*(6), 606-615.

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: 10.1590/bjpt-rbf.2014.0108.

Tınkır, D. A., & Uzun, A. (2022). The effect of vertical and horizontal core trainings on core strength, agility and speed. *Turkish Journal of Sport and Exercise, 24*(3), 238-245. https://doi: 10.15314/tsed.1199209.

Wagner, H., Finkenzeller, T., Würth, S., & Von Duvillard, S. P. (2014). Individual and team performance in team-handball: A review. *Journal of Sports Science & Medicine, 13*(4), 808.

Willardson, J. M. (2007). Core stability training: applications to sports conditioning programs. *The Journal of Strength & Conditioning Research, 21*(3), 979-985. https://doi: 10.1519/R-20255.1.

Willson, J. D., Dougherty, C. P., Ireland, M. L., & Davis, I. M. (2005). Core stability and its relationship to lower extremity function and injury. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons, 13*(5), 316-325. https://doi: 10.5435/00124635-200509000-00005.