EFFECTS OF 4-WEEK FLYWHEEL SQUAT TRAINING ON SPEED, CHANGE OF DIRECTION AND VERTICAL JUMP PERFORMANCE AMONG YOUNG HANDBALL PLAYERS

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Abstract: *This study investigated the effects of a 4-week flywheel squat training program on speed, change of direction (COD), and vertical jump performance among young handball players. The total sample consisted of 18 handball players from RK "Dubočica" in Leskovac, Serbia, divided into an experimental group (n=9) and a control group (n=9). Speed was assessed using a 20-meter sprint test with split times recorded at 10 meters, agility was evaluated through the 505 COD Test, and vertical jump performance was measured using countermovement jump (CMJ) and squat jump (SJ) tests. The intervention involved progressive flywheel training, starting with medium inertia loads (0.025 kg·m²) and increasing weekly to larger loads (up to 0.070 kg·m²), performed twice weekly. Statistical analyses were conducted using MANCOVA/ANCOVA. Results revealed significant improvements in the experimental group following the 4-week kBox flywheel squat training program. Specifically, participants demonstrated enhanced performance in the 10- and 20-meter sprints and COD compared to the control group. These findings suggest that incorporating flywheel squat training into the regimen of young handball players can lead to significant improvements in speed and agility, which are crucial components for success in the sport. Therefore, coaches and trainers should consider integrating such training modalities to optimize the athletic capabilities of handball players, potentially improving their overall performance on the field.*
Key words: *eccentric training, leg strength, youth athletes, sprint, agility*

INTRODUCTION

In the dynamic and physically demanding sport of handball, speed, agility, and vertical jump performance are critical determinants of success. Athletes require advanced training strategies to optimize these attributes, enabling them to perform at peak levels during high-intensity match scenarios. Among the emerging methods in athletic training, flywheel resistance training has garnered significant interest for its ability to enhance eccentric muscle strength, a key factor in athletic performance (Maroto-Izquierdo et al., 2017).

Flywheel training utilizes inertial resistance to maximize force production during the eccentric phase of movement, which has been shown to improve not only muscle strength but also neuromuscular efficiency (Tesch et al., 2004). This method has demonstrated effectiveness in enhancing sprint speed, change of direction (COD) ability, and jumping capacity essential for handball players (Tous-Fajardo et al., 2006). Despite its potential, the application of flywheel training in youth athletes, especially in team sports like handball, remains underexplored.

One of the unique advantages of flywheel training lies in its adaptability to individual strength levels and its ability to provide consistent resistance throughout the movement range. This ensures optimal muscular engagement and minimizes the risk of injury, which is particularly important for youth athletes still undergoing physical development (Petré et al., 2018). Moreover, the focus on eccentric overload has been linked to improvements in tendon stiffness and elastic energy utilization, both of which are critical for explosive athletic movements such as jumping and sprinting (LaStayo et al., 2014). These benefits make flywheel training a promising tool for enhancing sports performance in young athletes.

Handball requires frequent accelerations, rapid COD movements, and explosive jumps, all of which demand superior lower-body strength and power. Traditional resistance training methods, while effective, may not fully capitalize on the benefits of eccentric overload, which is crucial for developing dynamic athletic abilities (Cormie et al., 2011). Research suggests that eccentric overload training can lead to improved rate of force development, reduced injury risk, and better athletic performance, making it an appealing option for youth athletes (de Hoyo et al., 2015).

The aim of this study is to examine the effects of a 4-week flywheel squat training program on speed, COD, and vertical jump performance in young handball players. By evaluating these effects, this research seeks to provide evidence-based recommendations for incorporating innovative training modalities into handball conditioning programs. Such insights could assist coaches and trainers in optimizing athletic capabilities, enhancing on-field performance, and contributing to the overall success of youth handball teams.

METHODS

Participants

Eighteen young male handball players from RK "Dubočica," Leskovac, Serbia, participated in this study. The participants were randomly assigned to an experimental group (n=9) and a control group (n=9). All participants were free from injuries and provided informed consent prior to participation. The study followed ethical guidelines in accordance with the Declaration of Helsinki. The sample characteristics are shown in Table 1.

Table 1 Sample characteristics

	Experimental Group (n = 9, Mean ± SD)	Control Group (n = 9, Mean ± SD)
Age	17.67 ± 1.32	16.89 ± 0.60
Body Height	181.02 ± 8.40	180.82 ± 7.78
Body Weight	76.80 ± 8.18	75.56 ± 14.72
BMI	23.58 ± 2.13	22.97 ± 3.32

Design

This study aimed to evaluate the effects of a 4-week flywheel squat training intervention on speed, change of direction (COD), and vertical jump performance. The design included a familiarization phase, pre- and post-intervention assessments, and a 4-week training program (Table 2).

Familiarization Phase

The first week was dedicated to familiarization, during which participants attended two sessions. These sessions focused on learning proper techniques for the field tests (Countermovement jump - CMJ, squat jump - SJ, COD 505, and 20-meter sprint) and for executing the squat exercise on a flywheel training device kBox (Exxentric AB, Sweden). This phase aimed to mitigate learning effects during subsequent testing and training sessions.

Field Tests

Field tests were conducted at baseline (week 0) and post-intervention (week 5) and included:

- 20-Meter Sprint with split times recorded at 10 meters using Microgate Witty photocells timing gates to evaluate linear sprint performance.
- COD 505 Test: Agility was assessed using Witty photocells (Microgate, Italy) where the participants are running from a 15-meter marker to build up speed, passing through the 5-meter markers, turning at the line, and running back through the 5-meter markers. The time is recorded as the participant passes the 5-meter marker on the way out and stops upon returning through the same marker, capturing the time to complete the 10-meter (5 m up and back) distance.
- Vertical Jump Tests: To perform CMJ and SJ tests using a Chronojump Boscosystem mat, For the CMJ, they start upright with hands on hips, perform a rapid downward movement, and immediately jump as high as possible without removing hands from hips. For the SJ, participants begin in a static squat position (knees at ~90°) and jump explosively without any preparatory movement. Each test is

performed two times with 2 minutes of rest between trials. Jump height is recorded using the Chronojump software. Reliability and validity are confirmed by Pueo et al. (2020).

Before testing, participants complete a 10-minute warm-up consisting of jogging and dynamic drills.

Flywheel Training Intervention

The experimental group participated in a 4-week progressive flywheel squat training program (Table 2), while the control group followed traditional resistance training protocols.

Table 2 Study flow across weeks

Week	Phase	Activity/Intervention
-1	Familiarization	Familiarization with field tests (CMJ, SJ, COD 505, 20 m sprint). Learning squat exercise technique using a flywheel device (kBox).
0	Baseline Testing	Initial performance testing (CMJ, SJ, COD 505, 20 m sprint).
1–2	Intervention Phase (Medium)	Flywheel training with medium (M) inertia load (0.025 kg·m^2). 3 sets of 7 all-out squat repetitions per session, two sessions per week.
3	Intervention Phase (Large)	Flywheel training with large (L) inertia load (0.050 kg·m^2). 4 sets of 7 all-out squat repetitions per session, two sessions per week.
4	Intervention Phase (Extra-Large)	Flywheel training with extra-large (XL) inertia load (0.070 kg·m^2). 4 sets of 7 all-out squat repetitions per session, two sessions per week.
5	Post-Testing	Final performance testing (CMJ, SJ, COD 505, 20 m sprint).

Each session included a standardized warm-up, and participants were given 2-minute rest intervals between sets to optimize recovery. Sessions were scheduled twice per week, ensuring a 48-hour rest period between them to allow for adequate recovery. All exercises emphasized eccentric overload, a critical aspect of flywheel resistance training. The kBox device was used for all flywheel sessions.

The control group performed traditional resistance training, focusing on free-weight front and back squats, which targeted similar muscle groups and movement patterns as the flywheel squat exercise, with matched intensity, volume, and progression to the experimental group.

Statistical Analysis

The Shapiro-Wilk test was used to assess the normality of the data. The effects of the intervention were evaluated using MANCOVA and ANCOVA to account for covariates from the initial measurements. MANCOVA was applied to examine the multivariate effects across dependent variables, while ANCOVA was employed for univariate analyses to determine the effects of the intervention on individual performance variables. Effect sizes were interpreted using partial eta squared (η^2), with values of 0.01, 0.06, and 0.14 indicating small, medium, and large effects, respectively, based on Cohen's benchmarks (Cohen, 1988). Statistical significance was set at $p < 0.05$. All analyses were conducted using SPSS software (version 27, IBM Corp.).

RESULTS

All participants from both the experimental and control groups successfully completed all training sessions without any missed sessions. The Shapiro-Wilk test confirmed that all variables were normally distributed.

The results from multivariate analysis of covariance (MANCOVA) showed in Table 3, revealed a significant overall effect of the intervention on the dependent variables, with Wilks' Lambda indicating a large effect size (partial eta squared = 0.788). This suggests that the flywheel squat training program had a significant effect on the combined measures of performance, accounting for approximately 78.8% of the variance in the results. This strong multivariate effect highlights the intervention's efficacy across multiple domains of physical performance.

Table 3 MANCOVA results

Wilks' Lambda	F (df1, df2)	p-value	Partial η^2
0.212	5.215 (5, 7)	0.026*	0.788

Legend: F(df1, df2) = F-ratio with degrees of freedom for numerator (df1) and denominator (df2); p – significance coefficient; * - significant at p < 0.05 level; Partial η^2= Partial Eta Squared (Effect size).

The univariate ANCOVA analyses (Table 4) further clarified the specific areas of improvement. The experimental group demonstrated significant reductions in sprint times for both the 10-meter ($p = 0.007$) and 20-meter ($p = 0.023$) distances compared to the control group, reflecting faster linear sprint performance. Similarly, change of direction (COD) speed, measured through the COD 505 test, significantly improved in the experimental group ($p = 0.006$), with faster times than the control group. Improvements in vertical jump performance, measured through countermovement jump (CMJ) and squat jump (SJ) tests, were also observed in the experimental group. However, these results did not reach statistical significance. When adjusted means were considered, CMJ height was higher in the experimental group (42.64 cm) compared to the control group (39.56 cm), approaching significance ($p = 0.052$). Similarly, squat jump performance was better in the experimental group (33.57 cm) than in the control group (31.77 cm), though the difference was not statistically significant ($p = 0.133$).

Table 4 Descriptive statistics and ANCOVA results

Variables	Group	Pre (Mean ± SD)	Post (Mean ± SD)	Adjusted Post Mean	p-value	Partial η^2
10 m (s)	Experimental	1.99 ± 0.17	1.95 ± 0.07	1.94	0.007	0.496
	Control	1.99 ± 0.16	2.02 ± 0.16	2.03		
20 m (s)	Experimental	3.36 ± 0.27	3.31 ± 0.15	3.30	0.023	0.388
	Control	3.35 ± 0.25	3.40 ± 0.21	3.41		
COD 505 (s)	Experimental	2.61 ± 0.29	2.52 ± 0.16	2.54	0.006	0.509
	Control	2.68 ± 0.19	2.78 ± 0.27	2.76		
CMJ (cm)	Experimental	39.94 ± 6.83	42.16 ± 6.29	42.64	0.052	0.302
	Control	40.81 ± 6.75	40.04 ± 7.20	39.56		
SJ (cm)	Experimental	30.22 ± 4.74	33.71 ± 4.57	33.57	0.133	0.193
	Control	30.32 ± 7.16	31.63 ± 7.28	31.77		

Legend: CMJ – countermovement jump; SJ – squat jump; COD – change of direction; SD – standard deviation; p – significance coefficient; * - significant at p < 0.05 level; Partial η^2= Partial Eta Squared (Effect size).

DISCUSSION

This study evaluated the effects of a 4-week flywheel squat training program on the speed, change of direction (COD), and vertical jump performance in young handball players. The main findings demonstrated significant improvements in sprint performance (10 m and 20 m) and COD speed (COD 505) in the experimental group, while trends of improvement in vertical jump performance (CMJ and SJ) were observed without reaching statistical significance. These results underline the potential of flywheel training to enhance critical physical attributes essential for handball performance.

The significant improvements in sprint and COD performance align with prior research emphasizing the effectiveness of flywheel training for developing neuromuscular performance.

Jarosz et al. (2023) reported significant enhancements in COD testing (505 test) following flywheel resistance training in soccer players. A recent study demonstrated improvements of up to 3.5% in COD-90 test performance following the first three weeks of flywheel single-leg Romanian deadlift training (Morencos et al., 2022). The eccentric overload provided by flywheel devices may explain these results, as it provides greater neuromuscular adaptation to explosive movements such as accelerations and change of direction. The significant improvements in COD performance observed in this study are consistent with systematic reviews and meta-analyses showing that flywheel resistance training produces better outcomes in agility and COD tasks compared to traditional resistance training (Chaabene et al., 2022). The ability of the flywheel devices to replicate sport-specific multidirectional movements at different joint angles makes it particularly suitable for improving COD performance in handball players. Furthermore, the enhanced neuromuscular adaptations from eccentric overload may have contributed to the observed gains in agility.

Similar findings regarding short-distance sprint performance have been reported in recent studies. Sagelv et al. (2020) showed significant improvements in 10-meter sprint performance among football players, while Maroto-Izquierdo et al. (2017) highlighted improvements in 20-meter sprint times in handball players. Additionally, Morencos et al. (2022) showed significant reductions in sprint times following three weeks of flywheel training, with a 1.6% improvement in the 10-meter sprint and a 1.4% decrease in the 30-meter sprint, underscoring the efficacy of eccentric-overload training for short-distance sprints.

The positive trends observed in vertical jump performance (CMJ and SJ) support findings from previous studies that suggest flywheel training enhances jumping ability by improving eccentric strength and the stretch-shortening cycle (Sabido et al., 2017; Jarosz et al. 2023). Similarly, Morencos et al. (2022) reported improvement of 7.3% in CMJ height after three weeks of flywheel training, reflecting enhanced lower-limb power and the impact of eccentric overload on explosive strength. However, the lack of statistical significance in the present study may be attributed to the relatively short duration of the intervention and the small sample size, as longer training durations have been shown to produce more pronounced effects on jumping performance (Buonsenso et al., 2023).

These findings underscore the practical relevance of flywheel training for sports like handball, where sprinting, agility, and jumping are critical determinants of performance. Coaches and practitioners should consider incorporating flywheel devices into conditioning programs to target these attributes effectively. However, the relatively high cost of flywheel devices and their limited capacity for group training may pose practical challenges (Buonsenso et al., 2023).

Several limitations of this study warrant consideration. The small sample size and short intervention period may have limited the ability to detect statistically significant improvements in vertical jump performance. Future research should employ longer interventions with larger participant groups to explore the long-term benefits of flywheel training.

CONCLUSION

This study demonstrated that a 4-week flywheel squat training program significantly improved sprint performance (10 m and 20 m) and change of direction (COD 505) speed in young handball players compared to traditional resistance training. While vertical jump performance (CMJ and SJ) showed trends of improvement in the experimental group, these changes did not reach statistical significance. These findings highlight the potential of eccentric-overload training, using flywheel devices, to enhance critical athletic attributes that are essential for success in handball.

Given the practical implications, coaches and practitioners are encouraged to incorporate flywheel resistance training into athletic conditioning programs to optimize sprinting and agility. However, further research with longer intervention durations and larger sample sizes is needed to fully explore its impact on explosive power and to establish best practices for integrating this innovative training modality into sports programs.

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EFEKTI 4-NEDELJNOG PROGRAMA EKSCENTRIČNOG TRENINGA ČUČNJEVA NA BRZINU, PROMENU PRAVCA KRETANJA I VISINU VERTIKALNIH SKOKOVA KOD MLADIH RUKOMETAŠA

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Sažetak: *Ovo istraživanje je sprovedeno sa ciljem da se utvrde efekti 4-nedeljnog programa ekscentričnog treninga čučnjeva na brzinu, promenu pravca kretanja (eng. change of direction - COD) i performanse vertikalnog skoka među mladim rukometašima. Ukupan uzorak činilo je 18 rukometaša RK „Dubočica“ iz Leskovca, podeljenih u eksperimentalnu (n = 9) i kontrolnu grupu (n = 9). Brzina je procenjena korišćenjem testa sprinta na 20 metara sa prolaznim vremenima na 10 metara, agilnost je procenjena kroz 505 COD test, a performanse vertikalnog skoka merene su pomoću testova skoka iz čučnja sa pripremom (CMJ) i skoka iz čučnja (SJ). Ekscentrični trenažni program* *je obuhvatao progresivne treninge, počevši sa srednjim inercijalnim opterećenjem (0,025 kg*m²) i nedeljnim povećanjem do većih opterećenja (do 0,070 kg*m²), koji su izvođeni dva puta nedeljno. Statističke analize su sprovedene korišćenjem MANCOVA/ANCOVA metoda. Rezultati su pokazali značajna poboljšanja u eksperimentalnoj grupi nakon četvoronedeljnog treninga čučnjeva sa uređajem kBox flywheel. Konkretno, učesnici su ostvarili bolje rezultate u sprintu na 10 i 20 metara, kao i u testu promene pravca (COD), u poređenju sa kontrolnom grupom. Ovi nalazi sugerišu da uključivanje ekscentričnog treninga čučnjeva u trenažni režim mladih rukometaša može dovesti do značajnih poboljšanja u brzini i agilnosti, koji su ključne komponente za uspeh u ovom sportu. Stoga, treneri i sportski stručnjaci treba da razmotre integraciju takvih modaliteta treninga kako bi optimizovali atletske sposobnosti rukometaša, potencijalno poboljšajući njihov ukupni učinak na terenu.*

Ključne reči: *ekscentrični trening, snaga nogu, mladi sportisti, agilnost, sprint*