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ABSTRACT

This study examined the effects of an 8-week horizontal speed deceleration training (HSDT) program in combination with regular handball-specific training as compared with handball-specific training only in measures of physical fitness in male youth handball players. Thirty-nine players were randomly assigned to either an HSDT group (n=18; 15.55±0.24 years) or an active-control group (CG; n=21; 14.59±0.23 years). The results showed significant and large between-group differences at post-test in countermovement jump, change-of-direction speed, and repeated sprint ability (RSA) (all $p<0.01$; $d=2.04$ and 1.37, 1.39, 1.53, and 1.53 for the CMJ, 505 CoD, RSA_{best}, $RSA_{average}$, and RSA_{total} performances, respectively). The post-hoc-analysis demonstrated significant and large improvements in all measures of physical fitness in the HSDT group (Δ2.49% to 16,25%; d=1.01 to 1,70; all p<0,01). The CG, however, failed to reach any significant difference in all measures of physical fitness ((Δ0.31% to 1.98%; d=0.15 to 0.22; p=0.379; p>0.05). To summarize, an 8-week in-season HSDT program alongside regular handball-specific training yielded positive effects on various performance measures including jumping ability, CoD speed, and RSA, when compared to handball-specific training alone. These results highlight the potential benefits of integrating HSDT into the training regimen of youth handball athletes during the competitive season.

Keywords: team sports, Eccentric muscle action, adolescence, athletic performance

INTRODUCTION

Handball is a team sport characterized by intermittent periods of low and high intensity (41). It requires the execution of rapid offensive and defensive actions, involving frequent body contacts, duels between opponents, and a wide range of technical and tactical elements aimed at outplaying the opposing team and scoring more goals (30, 46). As a result, handball players need to be physically prepared to produce fast and forceful actions, surpass their opponents, and sustain the game's pace and intensity throughout successive matches and competitions (24). Additionally, crucial moments in a match are mainly characterized by short-duration high-intensity actions (e.g., quick offensive and defensive actions including sprinting, jumping, and change of direction speed), necessitating well-developed fitness capabilities (8, 16, 25, 29).

Athletic qualities such as linear sprint speed, change-of-direction (CoD) speed, jumping ability, and repeated sprint ability (RSA) are vital factors influencing the performance of handball players (32, 33, 41). Elite handball players have demonstrated higher power performances and related attributes (i.e., linear sprint speed, CoD, jumping ability) compared to amateur players (17, 41). Therefore, it is imperative to develop and implement well-structured training interventions that address the specific fitness demands of male handball players in competition to achieve sporting success in their future career.

There is strong evidence supporting the systematic integration of eccentric resistance training in young athletes to improve multiple measures of physical fitness such as muscle strength, jump, sprint, and CoD speed performance (6). Recently, the available eccentric resistance training techniques primarily revolve around the Nordic hamstring exercise (NHE) and flywheel inertial training (6). While these methods have demonstrated their effectiveness (6, 34), it is important to expand the range of eccentric resistance training exercises to offer practitioners a wider selection of options. In this sense, horizontal sprint deceleration training (HSDT) has gained recognition as a promising training method that specifically targets the eccentric action of the knee extensors (17, 27). It refers to the ability to effectively reduce the momentum of the entire body while efficiently attenuating and distributing the braking forces within the given constraints and objectives of the task (17). Notably, horizontal sprint deceleration exhibits a unique ground reaction force profile characterized by high-impact peak forces and loading rates (17). Importantly, the highest level of these forces occurs during the early stance phase (<50 ms) and they can be up to 2.7 times greater than those experienced during the initial steps of maximal horizontal sprint acceleration (17). These distinctive characteristics make the stimulus provided by horizontal sprint deceleration quite unique. In this context, researchers have proposed HSDT as a method to enhance various aspects of physical fitness in team sport athletes (30). Indeed, to the best of our knowledge, there is only one study available that has investigated the effects of a training intervention incorporating elements of speed and CoD training, with a specific focus on eccentric muscle action during rapid horizontal sprint deceleration, in recreationally trained young male and female team sport athletes (27). The findings of that study revealed large improvements in CoD and acceleration test performance (effect size [ES]=1.31) following six weeks of enforced stopping speed and CoD training compared to traditional sprint and agility training. The same authors reported moderate improvements in CoD (T-test: [ES=0.52]) and linear sprint speed performance (10-m [ES=0.44]) after training.

Based on the evidence presented above, the objective of the current study was to examine the effects of an 8-week HSDT program on various measures of physical fitness in adolescent male handball players. We hypothesized that integrating HSDT into standard handball training regimen, as opposed to regular handball training alone, would lead to larger improvements in measures of physical fitness in adolescent male handball players (6, 27, 31).

METHODS

Experimental approach to the problem

A two-group repeated measures experimental design was utilized to evaluate the effects of an 8-week bi-weekly in-season HSDT program on various measures of physical fitness in adolescent male handball players compared to their counterparts who maintained their regular in-season handball-specific training regimen. A team of youth handball players was quasi-randomly divided into a HSDT group and an active control group (CG).

Both groups underwent four to five handball training sessions per week. The HSDT group replaced 25 minutes of low-intensity handball drills (i.e., tackling technique, shooting technique, faking skills, and attacking, and defending positions) with HSDT drills, on Tuesdays and Thursdays. After the HDT portion of the session, players completed the remainder of their regular handball-specific training. Two weeks before baseline testing, two familiarization sessions were performed to get participants acquainted with the applied tests. A number of tests were used to track changes in physical fitness before and after the training program. These included tests for linear sprint speed (i.e., 10- and 20-m), CoD (i.e., 505 CoD), vertical jump performance (i.e., countermovement jump [CMJ]), and RSA. All tests were scheduled at least 48 hours after the last training session or match, at the same time of day (8:00-9:30 a.m.), and under the same environmental conditions (16-18°C, no wind).

Participants

Figure 1 displays a Consolidated Standards of Reporting Trials (CONSORT) diagram of the levels of reporting and participant flow for the study. We performed an a priori sample size calculation for the 505 CoD speed test, contrasting intervention and control groups. We set the type I error rate at 0.05 and the statistical power at 80%. The estimated effect size of Cohen's d = 1.12 is based on a recent randomized controlled trial by Negra et al. (38). The analysis indicated that 14 participants per group would represent a sufficient sample. Therefore, the required number of participants was determined to be 28. To address potential participant attrition, a total of thirty-nine pubertal male handball players were randomly allocated to either the HSDT group (n = 18; age =15.55±0.24 years; maturity offset = 2.35±0.48 years) or the active CG (n = 21; age =14.59±0.23 years; maturity offset = 1.30±0.38 years). All participants were considered experienced players with an average of 6.0 ± 1.3 years of systematic handball training, comprising three to four training sessions per week. Further, all participants were in good health and had been free of musculotendinous injuries over the six months preceding the start of the study. Table 1 presents the anthropometric data for both groups. The maturity offset method was used to assess the biological maturity of participants (35). The following prediction equation was applied: Maturity offset = -7.999994 + (0.0036124*age*height).

****Figure 1 near here****

All the experimental procedures and the associated potential risks were fully explained and written informed consent (parents/legal guardians) and assent (participants) were obtained before the commencement of the study. All procedures were approved by the local Institutional Review Committee of the ****blinded for review****, and conducted per the latest version of the Declaration of Helsinki.

****Table 1 near here****

The 505 change of direction test

The 505 CoD speed test was administered using the protocol previously outlined by Negra et al. (38) using an electronic timing system (Microgate, Bolzano, Italy). Players assumed a standing position 10-m from the start line, ran as quickly as possible through the start/finish line, pivoted 180° at the 15-m line indicated by a cone marker, and returned as fast as possible through the start/finish line. To ensure proper execution of the test, a researcher was positioned at the turning line and if the participant changed direction before reaching the turning point, or turned off the incorrect foot, the trial was disregarded and reattempted after the recovery period. A between-trial rest period of three minutes was provided. The best performance out of two trials was used for further analysis. The between-trials intraclass correlation coefficient ($ICC_{3,1}$), and the smallest worthwhile change ($SWC_{(0.2)}$) were 0.92 and 1.3%, respectively.

Countermovement jump

During the CMJ, participants started from a standing position and performed a fast downward movement by flexing the knees and hips before rapidly extending the legs and performing a maximal vertical jump. During the test, participants were instructed to maintain their arms akimbo. Jump height was recorded using an optoelectric system (Optojump, Microgate, SRL, Bolzano, Italy). A rest period of 1-min was allowed between trials. This was consistent across all trials for all jump-hop tests. The best out of two trials was retained for further analysis. The between-trials $ICC_{3,1}$ and the $SWC_{(0.2)}$ were 0.86 and 3.43%, respectively.

Repeated sprint ability

The RSA test was assessed via the same photocell system used for the linear speed and 505 CoD tests (Microgate, Bolzano, Italy). Immediately after a standardised warm-up, participants completed a preliminary single shuttle-sprint test (20+20 m with 180° CoD). The first trial provided the criterion score for the actual shuttle-sprint test (43). Participants then rested for five minutes before starting the RSA test. During the first sprint, participants had to achieve at least 97.5% of their criterion score, otherwise, they rested for five minutes and then restarted the test (37, 39). We used such an approach to determine if participants adopted a coping strategy for performance. Of note, all participants attained their criterion score during the first sprint. All performed six 20-m shuttle sprints with 180º turns, separated by 25 seconds of passive recovery (37, 39). Three seconds prior to the commencement of each sprint, players were asked to adopt the ready position using a split stance, with their front foot 0.3 m behind the starting line, until the next start signal. From the starting line, they sprinted for 20-m and touched the second line with one foot before performing a 180° CoD and returning to the starting line as quickly as possible. Participants were instructed to complete all sprints as fast as possible. The RSA_{best} time, $RSA_{average}$ time, and RSA_{total} time were determined. Due to the fatigue induced by the test, only one maximal attempt was made i.e., no ICC was calculated. The $SWCs_{(0.2)}$ were 1.30%, 1.30%, and 1.37% for the RSA_{best}, $RSA_{average}$, and RSA_{total}, respectively.

The horizontal speed deceleration training program

The HSDT program was conducted during the second half of the in-season period (January-February, 2023). Prior to every HSDT session, a standardized 8-12-min warm-up was completed including low-intensity running, coordination exercises, dynamic movements (i.e., lunges, skips), sprints, and dynamic stretching for the lower-limb muscles. At the beginning of each training week, the first HSDT session was performed at least 48 hours after the last handball match that was scheduled on the weekend. The second HSDT session was completed 72-h after the first session (i.e., Tuesday and Thursday). The HSDT drills were performed at the beginning of the handball training session. The HSDT protocol is detailed in table 2. The total running distance (acceleration + deceleration) per week gradually increased from 300-m during the first week to 500-m during the last week of training. Each HSDT session included 20-m acceleration distance followed by 5-m deceleration distance. More specifically, participants were instructed to exert maximal acceleration effort during the 20-m distance and begin decelerating upon reaching the 20-m finish line. Subsequently, they were instructed to fully decelerate and come to a complete stop within a 5 m distance

****Table 2 near here****

Statistical analyses

Normal distribution was verified and confirmed using the Shapiro-Wilk test. Independent t-tests were conducted to examine between-group differences at baseline. Given that significant between-group differences were detected in certain measures of physical fitness at the pretest, training effects were further analyzed using the ANCOVA model, with pretest measurements, and MO entered as covariates. Effect sizes (d) were determined by converting partial eta-squared from the ANCOVA output to Cohen's d. To evaluate changes in performance from the pretest to the posttest within and between-group, paired sample t-tests were applied. The effect size was determined based on means, standard deviations, and correlation coefficients using the statistical software package G*Power (version 3.1.6). Effect size values were classified as small ($0.00 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), and large ($d \geq 0.80$) (12). Data are presented as group mean values and standard deviation for the pretest and adjusted means and standard deviation for the posttest. The SWC was calculated for both groups and converted to a percentage for each performance variable. The SWC was calculated as $0.2 * SD_{pooled}$ where SD represents the pooled standard deviation of pre-training scores. The level of significance was established at $p \leq 0.05$. SPSS 20.0 was used for statistical analyses (SPSS Inc., Chicago, IL, USA).

RESULTS

Only players who participated in 100% of the training sessions were included in the final analyses. The results presented in this section are included in Table 3. No injuries were documented during or following the conclusion of the intervention, indicating the safety of this training approach.

Countermovement jump height

Results indicated significant large between-group differences at posttest (d=1.39; p<0.01). The HSDT group demonstrated significant large pre- to post-training improvements (Δ16,25%; d=1,70; p<0,01;). However, no significant pre- to post-training changes were observed in the CG (Δ1.55%; d=0.22; p=0.379;). In terms of the individual responses, our statistical analysis indicated that 88% of the HSDT group (n=16) improved CMJ height performance to a level that was greater than the SWC with only 19% in the CG (n=4).

505 CoD speed

Findings indicated significant large between-group differences at post-test (d=1.11; p<0.01). The HSDT group displayed significant large pre- to post-training enhancements (Δ9,90%; d=1.72 ; p<0.01) with no significant pre- to post changes in the CG (Δ1.98%; d= 0.50; and p>0.05). Our statistical calculation showed that 94% of the HSDT group (n=17) improved 505 CoD performance to a level that was greater than the SWC with only 42% in the CG (n=9).

Repeated sprint ability

Results pointed toward significant large between-group differences at posttest for the RSA_{best} (d=1.39; p<0.01), $RSA_{average}$ (d=1.04; p<0.01), and RSA_{total} (d=1.04; p<0.01) time (Table 3). The HSDT group demonstrated significant large pre- to post-training improvements in the RSA_{best} (Δ2.49%; d=1.01; p<0.01), $RSA_{average}$ (Δ2.67%; d=1.36; p<0.01), and RSA_{total} (Δ2.67%; d=1.36; p<0.01) time. The CG, however, failed to reach any significant changes (Δ0.49, 0.31, and 0.31%, d=0.22, 0.15, and 0.15, all p>0.05 for the RSA_{best}, $RSA_{average}$, and RSA_{total} time, respectively). The individual responses revealed that the HSDT group had the highest percentage of individual responses above the SWC for RSA_{best} (61%; n=11), $RSA_{average}$ (72%; n=13), and RSA_{total} (76%; n=13). Whereas only 19% (n=4), 9% (n=2), and 19% (n=4) of the CG showed improvement above the SWC in RSA_{best}, $RSA_{average}$, and RSA_{total}, respectively.

DISCUSSION

This study examined the effects of an 8-week HSDT program on various measures of physical fitness in adolescent male handball players. The main finding indicated that an in-season HSDT executed alongside regular handball-specific training resulted in positive effects on measures of CoD, jumping ability, and RSA performance in youth male handball players. Conversely, handball-specific specific training alone did not yield any significant changes on the same measures.

Jumping ability

A high level of jumping performance enables handball players to effectively cope with the physical demands of a handball match (32, 33). More specifically, jump performance is a valid marker of talent identification which can discriminate between potentially elite and non-elite youth male handball players (27). The current result suggest that HSDT induced a large improvement (Δ16,25%, d=1,70) in CMJ performance. However, no change was detected in the CG. Indeed 88 % of the HSDT group improved the level of CMJ performance to a level that exceeded the SWC compared to only 19% in the CG. This is consistent with the findings of a recent study by Abdelkader et al. (1), which found moderate (ES=0.84) and large (ES=1.39) improvements in standing long jump performance after an 8-week of one session of NHE vs. two sessions of NHE, respectively, in prepuberal male soccer players. Likewise, Chaabene et al. (10) showed a moderate (ES=0.85) improvement in countermovement jump performance after an 8-week of NHE training in postpubertal female handball players. Moran et al. (36) demonstrated a moderate (ES=1.04) improvement in standing long jump performance after an 8-week of NHE training in youth male soccer players. In elite male soccer players, Krommes et al. (24) revealed improvements in CMJ performance (Δ 4.8%) after 10-week of NHE training. In their systematic review with meta-analysis, Maroto-Izquierdo et al. (28) showed significance differences in training-induced adaptations favoring eccentric overload flywheel resistance training vs. control condition in vertical jumping performance (ES=0.46). While the exact mechanisms underlying the observed improvements in CMJ height in this study can only be speculated upon, it is likely that the positive adaptations primarily stem from enhanced neural drive to the active muscles (29). This is attributed to the relatively short duration of the intervention (i.e., 8 weeks), during which significant morphological adaptations would not be expected to occur (2,3). However, it cannot be discounted that the HSDT employed in this study may have also contributed to certain muscle hypertrophy (5). In fact, previous research suggests that eccentric exercises elicit greater increases in muscle hypertrophy compared to isometric and concentric exercises (16). In summary, the findings of this study indicate that in addition to

NHE and flywheel resistance training, HSDT is another effective eccentric exercise modality for enhancing jumping performance in young athletes.

Change of direction speed

CoD ability is a distinctive feature of performance in youth male soccer players (36). Our results demonstrated a large (*d*=1.72, Δ9,90%,) pre-to-post CoD improvement after the HSDT program. However, no significant pre-to-post change was detected for the CG. Indeed, 94 % of the HSDT group improved the CoD speed performance to a level that exceeded the $SWC_{0.2}$ compared to only 42% in the CG. In youth male soccer players, Moran et al. (36) demonstrated a large (ES=1.04) improvement in 505 CoD performance after an 8-week of NHE integrated into regular soccer training compared with regular soccer training only. Chaabene et al. (10) showed large (ES=1.38) performance improvement in the T-test after an 8-week of NHE training intervention compared to the standardized handball training in youth female handball players. Dos' Santos et al (14) investigated the effects of 6 weeks CoD speed and technique modification training in multidirectional sport athletes. They reported significant improvements in measures of 180° turning performance (ES=-0.84 and -0.49 for the completion time and ground contact time, respectively) and kinetic (I.e., final foot contact mean horizontal propulsive force and penultimate foot contact horizontal to vertical mean braking force ratio) and kinematic (i.e., final foot contact trunk inclination) variables (ES= -0.74 to1.21). More recently, Chaabene et al. (11) conducted a systematic review with meta-analysis on the effects of flywheel resistance training vs traditional resistance training on CoD speed performance in male athletes. They revealed that both training methods are effective with flywheel resistance training resulting in larger effects (ES =0.64) compared to traditional resistance training. There is compelling evidence indicating that eccentric strength of knee extensors plays a key role in CoD performance, more specifically during the deceleration phase (9, 45). Therefore, the observed CoD speed improvement could mainly be attributed to the improvement of eccentric muscle strength of knee extensors. Increased eccentric strength could optimize the braking phase (i.e., horizontal deceleration ability) during a rapid CoD task. Fast deceleration is crucial for quick CoD speed movements in team sports (18, 19). This improvement can facilitate an earlier re-acceleration in a different direction (8), ultimately resulting in superior overall CoD speed performance (13).

Overall, HSDT seems to have induced greater eccentric strength which in turn facilitates faster CoD performance by improving the ability to handle greater braking forces associated with faster approach velocities, particularly during the penultimate and final foot contacts during movement (21, 22). Moreover, there are indications that higher eccentric strength increases joint stability and facilitates better force transfer through joints, all of which contribute to more efficient CoD abilities (42).

Repeated sprint ability

RSA is a key fitness component in team sports as short maximal sprints, interspersed with brief recovery periods, are frequent actions during match play (4). This study is the first to report the effect of HSDT on RSA in male youth handball players. The findings of this study revealed large improvements in all RSA parameters (i.e., RSA_{best}, $RSA_{average}$, and RSA_{total}) after an 8-week program of HSDT in youth male handball players, with no significant changes observed in the active CG. Furthermore, 64%, 70%, and 76% of the HSDT group improved the RSA_{best}, the $RSA_{average}$, and the RSA_{total} performance to a level that exceeded the SWSs compared to only 19%, 9.5%, and 19%, for the RSA_{best}, $RSA_{average}$, and the $RSA_{total,}$ respectively, in the CG.

Chaabene et al. (10) examined the effect of the eccentric NHE training compared with an active control group on RSA outcomes (i.e., RSA_{best} and RSA_{total}) in youth female handball players. These authors reported small improvements for RSA_{total} and RSA_{best} in the NHE training group only. Likewise, Ishoi et al. (20) reported improvements in RSA_{total} (Δ2%), and RSA_{best} (Δ2.6%) after 10 weeks of NHE training in male soccer players. Taken together, the current findings suggest that HSDT is effective in improving RSA outcomes in youth male handball players. Based on previous research (7, 10), the RSA performance improvement seen in this study could have been caused by the substantial enhancement of motor abilities underpinning high-intensity actions (i.e., jumping, and CoD) following the HSDT. More specifically, the factors underpinning high-intensity task performance improvements (e.g., higher number of recruited motor-unit and better motor-unit synchronization, increasing firing frequencies, better stretch-shortening-cycle efficiency, or increased musculotendinous stiffness) (4, 34) may explain the observed RSA performance enhancements. Moreover, HSDT may have induced metabolic adaptations in terms of increases in muscular enzymatic activity, phosphocreatine and glycogen stores, and improved lactate buffering capacity (42). These metabolic changes could have potentially contributed to better RSA performance in adolescent male soccer players. Overall, our findings corroborate the conclusions of the published study by Lakomy et al. (24), which advocated for the inclusion of deceleration training programs in general fitness training regimens for athletes engaged in multiple sprint sports.

This study comes with some limitations that the reader should be aware of. First, although the overall exposure to training was similar between the HSDT and the CG, it would have been useful monitoring training load throughout the 8 weeks period by using external (i.e., total distance covered) and/or internal (i.e., rate of perceived exertion, heart rate) measures. Second, the eccentric muscle strength of knee extensors was not directly measured such as using an isokinetic device. This should be considered in the upcoming studies. Third, we did not include any direct physiological (e.g., electromyography) or biomechanical (e.g., vertical ground reaction force) measure in the study. These limitations make the statements concerning the mechanisms of adaptations purely speculative. Future research should aim to include both performance and physiological/biomechanical measures to provide a more comprehensive understanding of the mechanisms underlying training-related adaptations following HSDT. Third, the actual horizontal deceleration of players was not measured, therefore it is not clear if this specific training approach actually enhanced horizontal deceleration ability. Fourth, quasi- instead of pure randomization process was conducted. In fact, quasi-random methods are more susceptible to selection bias and may result in systematic differences between groups at baseline. This could, indeed, be the reason of the different baseline values observed between the two groups. However, we tried to account for the baseline difference by using the appropriate statistical approach, which is ANCOVA instead of ANOVA. Nevertheless, future studies should prioritize random over quasi-random allocation of participants to help minimize selection bias.

Conclusions

In conclusion, the incorporation of a short-duration (8 weeks) HSDT program during the in-season period, in combination with regular handball-specific training, yielded positive effects on various physical fitness measures. These included improvements in jumping ability, CoD speed, and RSA, surpassing the results achieved with handball-specific training alone. Notably, no injuries were reported during or after the intervention, indicating the safety of this training approach. These findings emphasize the advantages and safety of integrating HSDT into the training regimen of handball athletes during the competitive season.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, YN, upon request.

Disclosure statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Table 1. Anthropometric characteristics of the included participants.

	HSDT group (n= 18)	CG (n= 21)
Age (years)	15.55±0.24	14.59±0.23
Height (m)	184.28±8.01	176.57±6.80
Body mass (kg)	79.37±14.09	72.11±16.07
Maturity offset (years)*	2.35±0.48	1.30±0.38

Notes: Data are presented as means and standard deviations; HSDT= horizontal speed deceleration training; CG = control group; *: as years from peak height velocity.

Table 2. Horizontal speed deceleration training program.

Week 1	2× 20 × 5×6×90×4*
Week 2	2× 20 × 5×8×90×4*
Week 3	2× 20 × 5×10×90×4*
Week 4	2× 20 × 5×8×90×4*
Week 5	2× 20 × 5×10×90×4*
Week 6	2× 20 × 5×12×90×4*
Week 7	2× 20 × 5×14×90×4*
Week 8	2× 20 × 5×10×90×4*

*: denotes sets × acceleration distance (m) × deceleration distance (m)× repetitions × rest between repetitions (seconds) × rest between sets (minutes).

Table 3: Group-specific baseline and post-test performances after 8- weeks of in-season horizontal speed deceleration training on components of physical fitness in youth male handball players.

	Pre-test					Post-test						
	HSDT		CG		**Absolute Difference (95% CI)**		HSDT		CG			
	M	**SD**	**M**	**SD**		***Independent sample t-test* *p*-value**	**M**	**SD**	**M**	**SD**	**Absolute Difference (95% CI)**	***ANCOVA* *p*-value (ES)**
Muscle power												
CMJ (cm)	30.11	5.23	28.61	4.68	1.50 (4.7 to 1.7)	0.35	34.45	0.87	28.64	0.78	5.81 (2.93 to 8.68)	<0.001 (1.39)
Change of direction												
505 CoD (s)	2.62	0.16	2.83	0.13	0.22 (0.12 to 0.31)	<0.0001	2.42	0.05	2.71	0.04	0.29 (0.11 to 0.41)	<0.01 (1.11)
Repeated sprint ability												
RSA_{best}	7.23	0.29	7.58	0.52	0.35 (0.06 to 0.63)	0.01	7.22	0.06	7.47	0.05	0.25 (0.05 to 0.45)	<0.01 (1.39)
$RSA_{average}$	7.50	0.28	7.59	0.58	0.15 (0.08 to 0.69)	0.013	7.49	0.05	7.76	0.05	0.28 (0.09 to 0.46)	<0.01(1.04)
RSA_{total}	45.03	1.67	47.36	3.45	2.33 (0.52 to 4.14)	0.013	44.91	0.33	46.57	0.30	1.60 (0.56 to 2.76)	<0.01 (1.04)

Notes: M: mean; SD: standard deviation; d: Cohen's d (effect size); HSDT = horizontal speed deceleration training group; CG = control group; CMJ: countermovement jump; CoD= change of direction; ES: effect size.

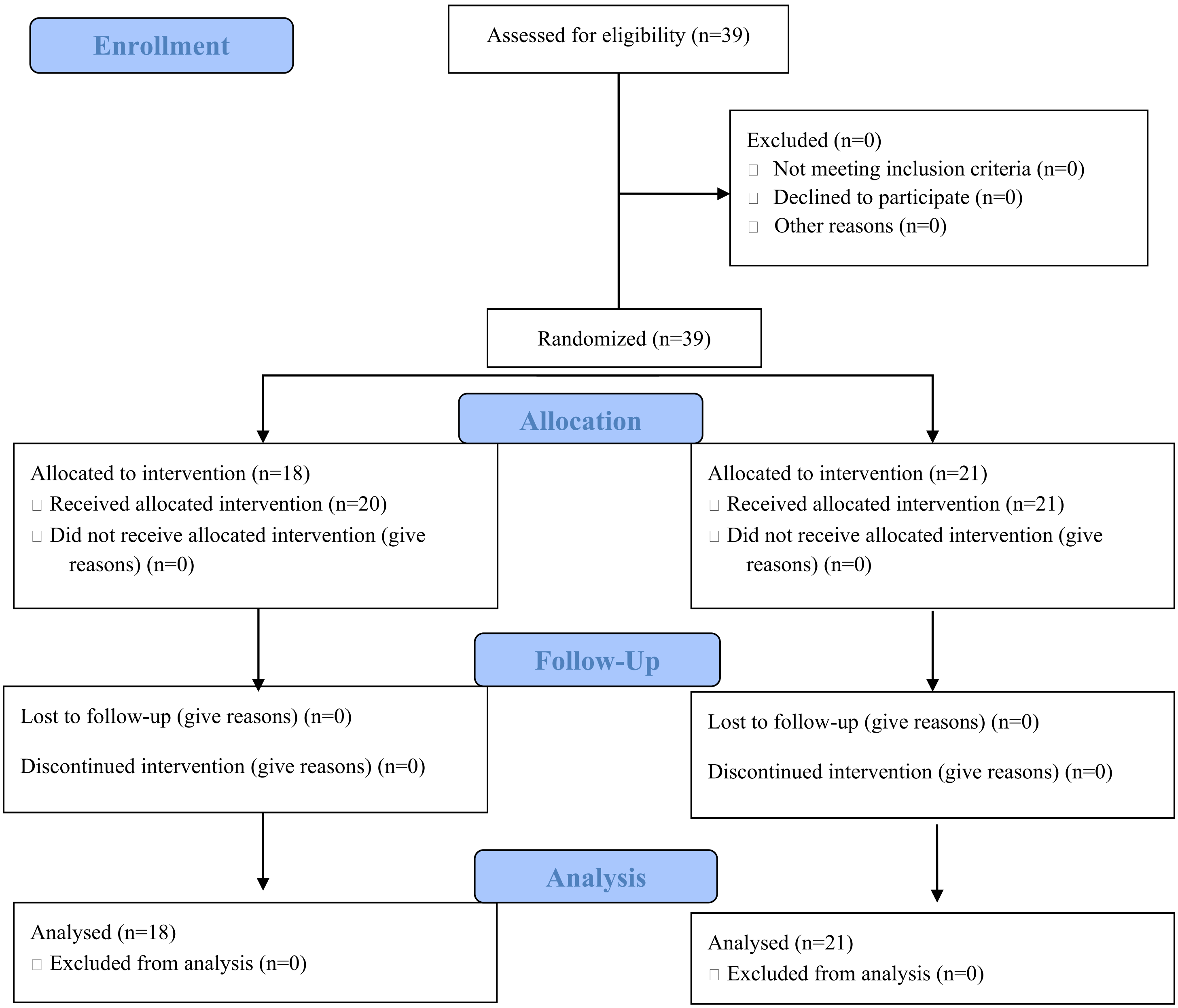

Figure 1. The diagram (The CONSORT: Consolidated Standards of Reporting Trials) includes detailed information on the interventions received.