EFFECTS OF HIGH-INTENSITY TRAINING WITH ONE VERSUS THREE CHANGES OF DIRECTION ON YOUTH FEMALE BASKETBALL PLAYERS’ PERFORMANCE

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Abstract:
To compare the effects of high-intensity interval training (HIT) with one versus three changes of direction (COD) on young (age, 17.2±1.1 years) female basketball players’ performance, six weeks of regular basketball training (control period) was followed by six weeks of high-intensity training added to regular training, two times per week, with a random allocation of athletes to either HIT with one (HIT-COD1; n=6) or three COD (HIT-COD3; n=6). Before and after the control and HIT-COD training periods athletes performed repeated-sprint ability test (RSA), modified agility T-test (MAT), V-cut, triple standing dominant (TS-D) and non-dominant (TS-ND) jump, TS-D and TS-ND with COD tests, and 30-15 Intermittent Fitness Test (30-15 IFT). With the exception of a substantial improvement in V-cut in both groups, no substantial changes occurred during the control period. Both HIT-COD training programs improved V-cut, although only HIT-COD3 substantially improved RSA mean time (RSA m), MAT and the final speed reached in 30-15 IFT (V IFT). The between-group comparison revealed greater improvements in RSA m and V IFT in HIT-COD3 than in HIT-COD1. In conclusion, supplementation of basketball training with HIT-COD drills adds improvements to young female basketball player’s performance, especially when 3 COD are incorporated into HIT.

Key words: team sport, agility, fitness, women, maturation, explosive strength

Introduction
Optimization of strength and conditioning for basketball requires the consideration of a range of physical and physiological traits relevant to competition (Torres-Ronda, Ric, Llabres-Torres, de Las Heras, & Schelling, 2016). Basketball is an intermittent sport, in which high-intensity neuromuscular efforts alternate with brief partial-recovery rest periods (Ben Abdelkrim, El Fazaa, & El Ati, 2007). Performance of high-intensity actions such as jumping, accelerating, decelerating, sprinting with change of direction (COD) (Marcelino, et al., 2016) and the ability to repeat these actions during competition are key to success (Torres-Ronda, et al., 2016). To this aim athletes should strive to develop optimally their sport performance (Marcelino, et al., 2016), targeting adequate levels of aerobic and anaerobic power, strength, and agility (Schelling & Torres-Ronda, 2013).

High-intensity interval training (HIT) has been advocated as a sport-specific conditioning strategy for team-sport athletes due to its mimicking the specific demands of competition (Stone & Kilding, 2009), alternating between periods of high-intensity and low-intensity effort (Laursen & Jenkins, 2002). This pattern of neuromuscular recruitment activates both the aerobic and anaerobic metabolism (Buchheit & Laursen, 2013b). Moreover, HIT allows the accumulation of substantial volumes of intense training with reduced fatigue-related effects (e.g.,
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Methods

Subjects and experimental design

To compare the effects of HIT-COD with one versus three COD on young female basketball players’ performance, after 6 weeks of regular basketball training (control period) athletes were randomly allocated to either HIT with one (HIT-COD1; n=6) or three COD (HIT-COD3; n=6). HIT-COD sessions were conducted two times per week as an addition to the regular training schedule during a 6-week period. As in previous studies (Ramirez-Campillo, et al., 2013), we devised an experimental design using the same participants as their controls to reduce the bias related to typical inter-individual variability responses to training, especially observed among youth (Moran, et al., 2017a, 2017b, 2017c; Radnor, Lloyd, & Oliver, 2017). This experimental design may reduce limitations compared to previous studies that did not consider the inclusion of a control group (Attene, et al., 2015, 2016) and may help to control for differences in total training load and training experience, among other potential confounders that may be more problematic when control and experimental groups are formed with different athletes. In addition, in the current study participants were instructed to keep their training habits, daily routines and nutritional habits the same during the control and experimental periods.

Before and after the control and HIT-COD training periods (i.e., baseline, pre, and post-test, respectively), athletes completed assessment tests of their repeated-sprint ability (RSA), modified agility T-test (MAT), V-cut test, triple standing dominant (TS-D) and non-dominant (TS-ND) jump test, TS-D and TS-ND with COD (TS-COD-D and TS-COD-ND, respectively), and the 30-15 Intermittent Fitness Test (30-15IFT).

Initially, 14 young (U19) national league-level athletes volunteered to participate. Two athletes missed ≥90% of HIT-COD training sessions and were excluded from the final analyses. Thus 12 athletes (age, 17.2±1.1 years; body height, 171.1±6.3 cm; body weight, 64.1±7.9 kg) completed the intervention. Athletes had ≥8 years of basketball training experience. During the control and experimental periods, participants regularly trained 90 min/session four times/week, with an official match every Saturday. From the total training session time, 70% was devoted to technical-tactical drills with offensive and defensive system games, in addition to individualized technique refinement. Further, 20% of the total time was dedicated to strength and conditioning, using small-sided games, plyometric and specific endurance drills; and 10% to injury prevention, using circuit training with eccentric, core, proprioception, and coordination drills. Athletes had ≥2 months of regular training (i.e., no injuries or illness) and a medical clearance to participate in intense physical activity. Although athletes had experience with HIT-COD drills, they reported no systematic experience with this type of training. The technical department of the basketball club, athletes and their parents/guardians gave their assent and written consent (respectively) after a thorough description of the general purpose of the study, the experimental procedures involved, and all potential risks and benefits. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the responsible department.

Testing procedures

Measurements were completed while athletes wore their habitual basketball outfits, during regular training hours (17-19 p.m.), in an indoor facility (temperature, 20-22°C; humidity, 45-48%) where athletes usually train and compete. Athletes were instructed to avoid consumption of caffeine-con-
taining beverages 24 h before testing and to be well
rested, hydrated and fed before measurements. A
standard warm-up was used before testing, includ-
ing a 5-minute continuous run, 5-minute dynam-
ic stretching, and three submaximal 30-m sprints.
Measurements were scheduled in three non-consec-
utive days: Monday (TS-D, TS-ND and V-cut tests),
Wednesday (TS-COD-D, TS-COD-ND, MAT and
RSA tests) and Friday (30-15IFT).

Jumping tests – TS-D, TS-ND, TS-D-COD and
TS-ND-COD, followed previous recommenda-
tions (Maulder & Cronin, 2005; Rosch, et al.,
2000), using a triple unipodal horizontal jump with
either dominant (TS-D) or non-dominant (TS-ND)
leg, with the aim of reaching maximal horizontal
distance (m). Valid jumps required that athletes
jumped with arms akimbo, maintaining the land-
ing position after the third jump for two seconds
without losing balance or touching the ground with
the free lower limb. Three valid maximal trials were
allowed, using the best result for analyses. Three
minutes of recovery were allowed between trials.
During TS-D-COD and TS-ND-COD testing the
same protocol was followed, but athletes had to per-
form triple unilateral horizontal jumping in a ~45º
zigzag pattern (marked on the floor).

V-cut testing followed previous recommenda-
tions (Gonzalo-Skok, et al., 2015). Athletes were in-
structed to cover as fast as possible a circuit of 25
m with four 45º COD. Athlete’s displacement from
one imaginary line to another (delimited by 0.7 m
height cones) in the circuit requires that at least one
of the foot touch that line before moving to the next
(Figure 1). The time needed to complete the test
was measured with a double beam photocell tim-
ing gates system (Witty, Microgate®, Italy), with
gates at the start and finish line. To avoid activation
errors, athletes initiated the test 0.5 m behind the
first gate. Two valid maximal trials were allowed,
using the best result for analyses. Two minutes of
recovery were allowed between trials.

Modified agility T testing followed previous rec-
ommendations (Sassi, et al., 2009). Athletes per-
formed two valid maximal trials of the MAT, with
two minutes of recovery between trials. The best
performance result was used for analyses. A timing
gate (Witty, Microgate®, Italy) located at the start/
finish line (the same line for this test) was used to
record time, while athletes initiated the test 0.5 m
behind the gate. The total distance covered was 20
m for each trial.

Repeated sprint ability (RSA) testing included
six 20 m sprints, with 20 s of passive recovery
between sprints (Aziz, Mukherjee, Chia, & Teh,
2007). Times were recorded with timing gates
(Witty, Microgate®, Italy). Athletes received ver-
bal motivation during testing and were verbally and
visually informed to assume the starting position
0.5 m behind the starting line 6 s before each sprint
(Chaouachi, et al., 2010). A countdown of 3 s was
then visually provided to athletes with a light panel
(Microgate®, Italy). The fastest sprint (RSAb) and
the mean time of all sprints (RSAm) were retained
for analyses.

The 30-15IFT was applied to assess aerobic ca-
pacity following previous instructions (Buchheit,
2008). Athletes run for 30 s interspersed with 15 s
of passive recovery. Initial run velocity was set at
8 km/h, increasing by 0.5 km/h after each inter-
val. Athletes were encouraged to achieve maximal
effort. The test was ended when athletes were un-
able to maintain the required running speed. The
velocity of the last interval completed (VIFT) was
considered for analysis.

**HIT-COD training**

After 6 weeks of regular basketball training (control period) athletes completed 6 weeks of
HIT-COD1 or HIT-COD3, two times per week (on
Tuesday and Thursday), in addition to their regular
training schedule. According to previous recom-
mandation (Attene, et al., 2014, 2015, 2016; Buch-
heit & Laursen, 2013a, 2013b; Glaister, 2005; Men-
dez-Villanueva, et al., 2008; Padulo, et al., 2016),
after a warm-up (5 min low-intensity running, 5
min dynamic stretching, and 5 min skipping), ath-
letes completed two sets of a HIT-COD circuit com-
posed of 10 s of running at 90% VIFT and 10 s of
active recovery (walking), repeating this pattern
during 6 minutes for each set, with a 3-minute of
passive recovery between sets. HIT-COD circuits
had one or three 180º COD for the HIT-COD1 and
HIT-COD3 groups, respectively (Figure 2).

**Statistical analysis**

Data are presented as mean ± standard devia-
tion (SD). All data were first log-transformed to
reduce bias arising from non-uniformity error. An
ANCOVA was conducted to determine the be-
tween-group differences using the pre-test as a co-
variate. The standardized difference or effect size
(ES, 90% confidence limits [CL]) in the selected
variables was calculated using the pooled pre-train-
ing SD. Threshold values for Cohen’s ES statis-

![Figure 1. V-cut test.](image)
The effects of high-intensity training (HIT) were explored in a study by Sanchez-Sanchez et al. (2018). The study involved players performing different HIT-COD sessions, with one (HIT-COD1) or three (HIT-COD3) changes of direction. The players were observed for changes in athletic performance, especially in repeated sprint ability tests, modified agility tests, and other specific activities.

### Results

None of the players were injured during the HIT-COD sessions, and positive feelings were reported. Athletes were actively recovering up to the next interval by walking toward the starting point of the next run. Athletes were warned 5 seconds before the initiation of the next interval in order to be prepared. Each player completed different distances, according to her fitness level (V_{fr}).

The chances of having beneficial/better or detrimental/poorer performances were both >5%, the true difference was assessed as unclear. Otherwise, change was interpreted as the observed chance (Hopkins et al., 2009).

### Table 1: Mean changes (with 90% confidence limits) in athletic performance in high-intensity running with 3 (HIT COD3) or 1 change of direction (HIT COD1) groups during the control period

<table>
<thead>
<tr>
<th></th>
<th>HIT COD3 (n = 6)</th>
<th></th>
<th>HIT COD1 (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>ES</td>
<td>Chances</td>
</tr>
<tr>
<td>RSAb (s)</td>
<td>2.9 (-2.7; 8.0)</td>
<td>0.32 (-0.30; 0.94)</td>
<td>64/28/8%</td>
</tr>
<tr>
<td>RSAm (s)</td>
<td>0.5 (-4.4; 5.1)</td>
<td>0.05 (-0.44; 0.54)</td>
<td>26/54/18%</td>
</tr>
<tr>
<td>V-cut (s)</td>
<td>2.4 (-0.4; 5.3)</td>
<td>0.30 (-0.05; 0.66)</td>
<td>71/27/2%</td>
</tr>
<tr>
<td>MAT (s)</td>
<td>1.0 (-2.0; 5.5)</td>
<td>0.30 (-0.33; 0.94)</td>
<td>62/29/9%</td>
</tr>
<tr>
<td>TS-D (m)</td>
<td>-2.0 (-6.1; 2.1)</td>
<td>-0.12 (-0.35; 0.12)</td>
<td>2/72/25%</td>
</tr>
<tr>
<td>TS-ND (m)</td>
<td>-0.2 (-3.3; 2.9)</td>
<td>-0.01 (-0.19; 0.16)</td>
<td>3/93/4%</td>
</tr>
<tr>
<td>TS-COD-D (m)</td>
<td>-22.2 (-30.7; -12.6)</td>
<td>-1.44 (-2.10; -0.77)</td>
<td>0/0/99%</td>
</tr>
<tr>
<td>TS-COD-ND (m)</td>
<td>-19.1 (-26.4; -11.0)</td>
<td>-1.25 (-1.81; -0.69)</td>
<td>0/0/99%</td>
</tr>
<tr>
<td>V_{fr} (km/h)</td>
<td>0.0 (0.0; 0.0)</td>
<td>0.0 (0.0; 0.0)</td>
<td>33/33/33%</td>
</tr>
</tbody>
</table>

Note: RSAb and RSAm: best and mean time in the repeated sprint ability test, respectively; MAT: modified agility T test; TS-D and TS-ND: triple standing long jump with dominant and non-dominant leg, respectively; TS-COD-D and TS-COD-ND: triple standing long jump with change of direction with dominant and non-dominant leg, respectively; V_{fr}: final velocity in the 30-15 Intermittent Fitness Test; ES: effect size.
Within-group changes

With the exception of a substantial improvement in V-cut in both HIT-COD 3 and HIT-COD1, no other substantial changes were detected during the control period in any group (Table 1). After the HIT-COD training, substantial performance improvements were found in V-cut in both groups, while HIT-COD3 also substantially enhanced MAT, RSAm and VIFT (Table 2).

Between-group changes

Improvements in RSAm (4.5% [CL90%: -1.5; 10.9]; QC = 79/17/4%) and VIFT (2.7% [CL90%: 0.0; 5.4]; QC = 76/23/1%) were substantially greater in HIT-COD3 than in HIT-COD1. No substantial differences (unclear results) were found in the rest of variables (Figure 3).

Table 2. Mean changes (with 90% confidence limits) in athletic performance in high-intensity running with 3 (HIT COD3) or 1 change of direction (HIT COD1) groups after the intervention period

<table>
<thead>
<tr>
<th>HIT COD3 (n = 6)</th>
<th>HIT COD1 (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>ES</td>
</tr>
<tr>
<td>RSAb (s)</td>
<td>2.1 (-3.5; 7.4)</td>
</tr>
<tr>
<td>RSAm (s)</td>
<td>3.3 (-2.5; 8.8)</td>
</tr>
<tr>
<td>V-cut (s)</td>
<td>5.4 (1.4; 9.2)</td>
</tr>
<tr>
<td>MAT (s)</td>
<td>3.1 (2.3; 3.8)</td>
</tr>
<tr>
<td>TS-D (m)</td>
<td>-3.0 (-10.3; 4.9)</td>
</tr>
<tr>
<td>TS-ND (m)</td>
<td>-0.7 (-4.9; 3.7)</td>
</tr>
<tr>
<td>TS-COD-D (m)</td>
<td>-5.7 (-14.2; 3.6)</td>
</tr>
<tr>
<td>TS-COD-ND (m)</td>
<td>-3.1 (-8.1; 2.2)</td>
</tr>
<tr>
<td>VIFT (km.h⁻¹)</td>
<td>2.3 (1.4; 3.3)</td>
</tr>
</tbody>
</table>

Note. RSAb and RSAm: best and mean time in the repeated sprint ability test, respectively; MAT: modified agility T-test; TS-D and TS-ND: triple standing long jump with dominant and non-dominant leg, respectively; TS-COD-D and TS-COD-ND: triple standing long jump with change of direction with dominant and non-dominant leg, respectively; VIFT: final velocity reached in the 30-15 Intermittent Fitness Test; ES: effect size.

Figure 3. Between-group changes in fitness tests.

Note. RSAb and RSAm: best and mean time in the repeated sprint ability test, respectively; MAT: modified agility T-test; TS-D and TS-ND: triple standing long jump with dominant and non-dominant leg, respectively; TS-COD-D and TS-COD-ND: triple standing long jump with change of direction with dominant and non-dominant leg, respectively; VIFT: final velocity reached in the 30-15 Intermittent Fitness Test; ES: effect size. HIT-COD3 and HIT-COD1: high intensity training groups with 3 or 1 changes of direction.
Discussion and conclusions

The aim of this study was to compare the effects of HIT-COD with one versus three COD on young female basketball players’ performance. Main findings indicate that both training approaches improved V-cut test performance, but only HIT-COD3 allowed improvements in MAT, RSA and VT, with greater improvements in the latter two tests compared to HIT-COD1.

RSA improved only after HIT-COD3. In addition, the improvement was likely greater compared to HIT-COD1. Although a previous study observed an improvement in RSA in soccer players after a HIT-COD intervention (Shalfawi, Young, Tonnessen, Haugen, & Enoksen, 2013), this is the first study to compare the effects of different COD number during HIT on linear RSA performance. RSA is required in competitive basketball, and is heavily dependent of both metabolic and neuromuscular factors (Glaister, 2005). These factors may be improved through HIT, especially if the specificity of training for basketball is maintained through the inclusion of COD (Attene, et al., 2015) to increase both metabolic and neuromuscular demands (Dellal, et al., 2010). As RSA improved without changes in RSA, improvement may have occurred through fatigue-resistance adaptation modulated by a greater number of COD during HIT-COD3. More COD actions require more acceleration and deceleration efforts, thus eliciting greater stimulus to improve neuromuscular (Padulo, et al., 2016; Teixeira, et al., 2017) and metabolic factors relevant to RSA (i.e., buffer capacity) (Glaister, 2005; Mendez-Villanueva, et al., 2008; Teixeira, et al., 2017). Given the relevance of RSA for basketball (Spencer, Bishop, Dawson, & Goodman, 2005), strength and conditioning professionals should take into consideration the inclusion of HIT with several COD as a part of the regular training schedules (Castagna, et al., 2007).

Performance in the V-cut test improved during both the control and intervention period in both training groups. Previous observations agree with our results, showing that a regular season basketball training improves V-cut test performance (Gonzalo-Skok, et al., 2015). The improvement (i.e., ES) in the V-cut test was greater during the intervention period compared to the control period in the HIT-COD1 than after HIT-COD3, which may be potentially related to a greater load induced by small-sided games in the former group (Chaouachi, et al., 2014), although this was not objectively controlled in our intervention. Future studies should aim to control this potentially confounding variable. Regarding MAT, this athletic performance proxy improved only after HIT-COD3. Given the relevance of MAT-related COD ability to basketball performance (Ben Abdelkrim et al., 2007; Brughelli, et al., 2008), these results may be of practical importance to practitioners, especially considering the potential of COD ability to improve other performance traits (Sheppard & Young, 2006) relevant for basketball.

VT was improved only after HIT-COD3. In addition, the improvement was likely greater compared to the HIT-COD1 group. Although the scarcity of studies (Attene et al., 2014, 2016) in this area make comparisons difficult, these results partially agree with the results obtained with young female soccer players (Shalfawi, et al., 2013). Although HIT alone may have positively affected VT (Viano-Santasmarinas, Rey, Carballeira, & Padron-Cabo, 2017) through increases in peripheral oxidative capacity (Gibala, et al., 2006) and VO2max (Taylor, et al., 2015), the fact that only HIT-COD3 improved VT suggests that the addition of COD may have increased neuromuscular and metabolic adaptations required for VT improvements (Taylor, et al., 2015), especially considering the stretch-shortening cycle (SSC) needs for both the COD actions and 30-15 performance.

Paradoxically, the TS-COD with both the dominant and non-dominant limbs were impaired after the experimental training period in HIT-COD3, whereas this trend was not observed in HIT-COD1. Although no obvious explanation of this finding can be raised, one can speculate that fatigue levels during HIT are higher when 3 COD are performed instead of 1 COD. Thus, even though HIT-COD3 are more exposed to COD maneuvers, performing it with less fatigue can optimize gains in tasks involving maximal levels of power output (Ikutomo, Kasai, & Goto, 2017). This aspect needs to be addressed in future studies.

Although COD training alone may improve performance, due to the nature of basketball, a training program that mimic the multimodal nature of the game may optimize training effectiveness (Padulo, et al., 2016). In this sense, integration of COD into HIT proved to be an effective strategy to improve young female basketball athletes’ performance, including both COD and RSA performance, which are considered key physical fitness traits for basketball. In the current intervention, HIT-COD incorporated 180° COD actions. Practitioners should consider specific angles for COD actions depending on the sport requirements (Attene, et al., 2015). Future studies may compare the effects of a mixture of COD angles executed during HIT, considering the multi-angle displacement requirements of some sports. Considering the limitations of this investigation, we also recommend the recruitment of larger sample sizes and the inclusion of a control group during the experimental training period for future studies.

In conclusion, supplementation of basketball training with HIT-COD drills seems to benefit performance improvements in young female basketball athletes, especially when 3 COD are incorporated into HIT.
References


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**Authors’ contributions**
JSS, OGS, RRC and FYN conceived the study design, participated in its design, coordination, helped to draft the manuscript and carried out the statistical analysis. MC, CP and MD applied the programs and assessments and critically reviewed the manuscript. All authors have read and approved the final version of the manuscript, and agreed with the order of presentation of the authors.

**Competing interests**
The authors declare that they have no conflict of interest.

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