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 ($30\text{-}15_{IFT}$). 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 $30\text{-}15_{IFT}$ (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., lactate accumulation) (Dellal, et al., 2010), allowing a reduced accumulation during effort bouts and faster rate of metabolite clearance during recovery periods (Iaia, et al., 2015).

Basketball competition requires frequent actions involving COD (Marcelino, et al., 2016). Inclusion of COD during HIT (HIT-COD) may allow a greater training specificity (Attene, et al., 2015; Brughelli, Cronin, Levin, & Chaouachi, 2008; Buchheit, Bishop, Haydar, Nakamura, & Ahmaidi, 2010). Moreover, HIT-COD may allow greater performance-related physiological demands (Dellal, et al., 2010), neuromuscular activation (Hader, et al., 2014), and deceleration-acceleration actions requiring eccentric and concentric muscle efforts (Attene, et al., 2015). However, limited evidence exist regarding how basketball players performance may be affected by HIT-COD with a different number of COD actions (Attene, et al., 2014, 2015, 2016). Although HIT-COD with one COD may be a minimum effective dose (Attene, et al., 2015), a greater number of COD would implicate a greater number of acceleration and deceleration efforts, potentially inducing greater neuromuscular (Padulo, et al., 2016) and metabolic adaptations (i.e., buffer capacity) (Glaister, 2005; Mendez-Villanueva, Hamer, & Bishop, 2008). In fact, a recent study involving female futsal players showed that increasing the number of COD during HIT optimized gains in peak velocity achieved during the incremental test, repeated-sprint ability and running economy (Teixeira, et al., 2017). Therefore, the aim of this study was to compare the effects of HIT-COD with one versus three COD on young female basketball players' performance, hypothesizing that both training strategies would improve court-based performance, with additional effects when three COD are incorporated into HIT.

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 ($30\text{-}15_{IFT}$).

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-containing beverages 24 h before testing and to be well rested, hydrated and fed before measurements. A standard warm-up was used before testing, including a 5-minute continuous run, 5-minute dynamic stretching, and three submaximal 30-m sprints. Measurements were scheduled in three non-consecutive days: Monday (TS-D, TS-ND and V-cut tests), Wednesday (TS-COD-D, TS-COD-ND, MAT and RSA tests) and Friday ($30\text{-}15_{IFT}$).

Jumping tests – TS-D, TS-ND, TS-D-COD and TS-ND-COD, followed previous recommendations (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 landing 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 perform triple unilateral horizontal jumping in a ~45º zigzag pattern (marked on the floor).

V-cut testing followed previous recommendations (Gonzalo-Skok, et al., 2015). Athletes were instructed to cover as fast as possible a circuit of 25 m with four 45° 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 timing 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 recommendations (Sassi, et al., 2009). Athletes performed two valid maximal trials of the MAT, with two minutes of recovery between trials. The best performance result was used for analyses. A timing

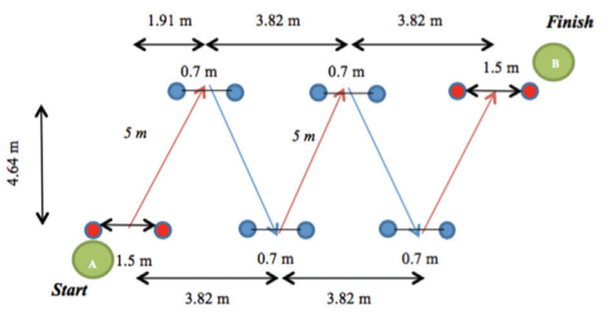

Figure 1. V-cut test.

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 verbal 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 (RSA_b) and the mean time of all sprints (RSA_m) were retained for analyses.

The $30\text{-}15_{IFT}$ was applied to assess aerobic capacity 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 interval. Athletes were encouraged to achieve maximal effort. The test was ended when athletes were unable to maintain the required running speed. The velocity of the last interval completed (V_{IFT}) 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 recommendation (Attene, et al., 2014, 2015, 2016; Buchheit & Laursen, 2013a, 2013b; Glaister, 2005; Mendez-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), athletes completed two sets of a HIT-COD circuit composed of 10 s of running at 90% V_{IFT} 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 180° COD for the HIT-COD1 and HIT-COD3 groups, respectively (Figure 2).

Statistical analysis

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

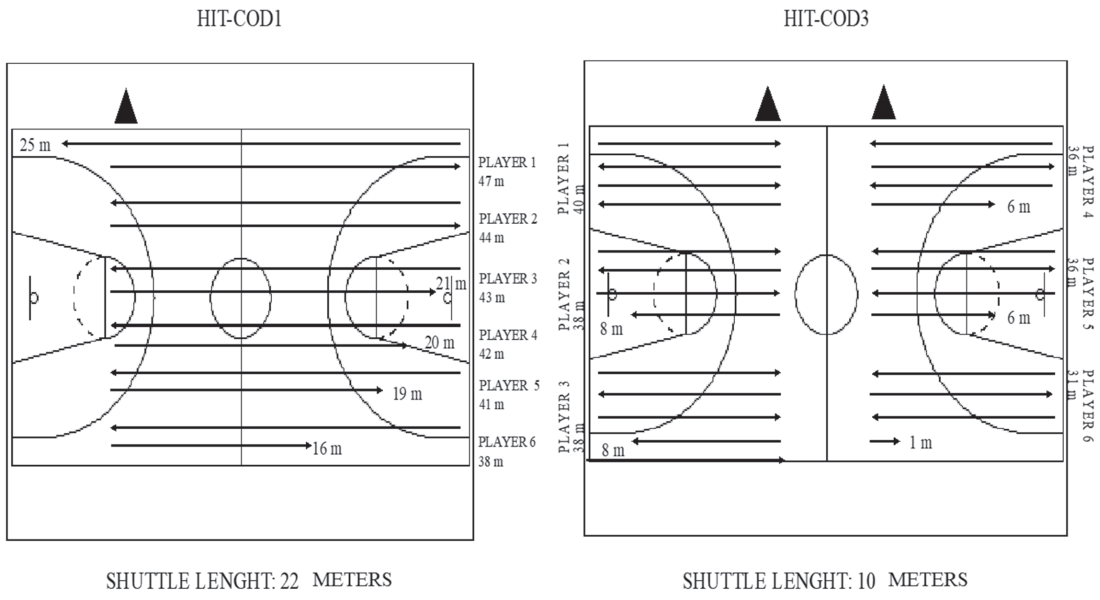

Figure 2. High intensity training circuits with one (HIT-COD1) or three (HIT-COD3) changes of direction.

Note. Athletes actively recover up to the next interval by walking toward near the starting point of the next run. Athletes were warned 5 seconds before the initiation of the next interval in order to be prepared. Note: each player completed different distances, according to her fitness level (V_{IFT}).

tics were >0.2 (small), >0.6 (moderate), and >1.2 (large) (Hopkins, Marshall, Batterham, & Hanin, 2009). For within/between-group comparisons, the chances that the differences in performance were better/greater (i.e., greater than the smallest worthwhile change, SWC [0.2 multiplied by the between-subject standard deviation, based on the Cohen's *d* principle]), similar or worse/smaller were calculated. Quantitative chances (QC) of beneficial/better, similar/trivial or detrimental/poorer effect were assessed qualitatively as follows: <1%, almost certainly not; >1-5%, very unlikely; >5-25%, unlikely; >25-75%, possible; >75-95%, likely; >95-99%, very likely; and >99%, most likely (Hopkins, et al., 2009). If the chance of having beneficial/better or detrimental/poorer performances was both >5%, the true difference was assessed as unclear. Otherwise, change was interpreted as the observed chance (Hopkins, et al., 2009).

Results

None of the players were injured during the HIT-COD sessions and positive feelings were re-

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

	HIT COD3 (n = 6)				HIT COD1 (n = 6)			
	%	ES	Chances	Outcome	%	ES	Chances	Outcome
RSAb (s)	2.8 (-2.7; 8.0)	0.32 (-0.30; 0.94)	64/28/8%	Unclear	1.3 (-1.6; 4.2)	0.26 (-0.32; 0.85)	58/33/8%	Unclear
RSAm (s)	0.5 (-4.4; 5.1)	0.05 (-0.44; 0.54)	28/54/18%	Unclear	-1.1 (-4.2; 1.9)	-0.22 (-0.82; 0.39)	11/36/52%	Unclear
V-cut (s)	2.4 (-0.4; 5.3)	0.30 (-0.05; 0.66)	71/27/2%	Possibly	4.8 (0.9; 8.4)	0.93 (0.18; 1.68)	95/4/1%	Likely
MAT (s)	1.8 (-2.0; 5.5)	0.30 (-0.33; 0.94)	62/29/9%	Unclear	-0.5 (-5.7; 4.5)	-0.07 (-0.84; 0.69)	25/37/38%	Unclear
TS-D (m)	-2.0 (-6.1; 2.1)	-0.12 (-0.35; 0.12)	2/72/25%	Possibly trivial	-3.6 (-6.9; -0.1)	-0.36 (-0.72; -0.01)	1/19/80%	Likely poorer
TS-ND (m)	-0.2 (-3.3; 2.9)2	-0.01 (-0.19; 0.16)	3/93/4%	Likely trivial	-1.9 (-6.1; 2.5)	-0.09 (-0.31; 0.12)	2/80/19%	Likely trivial
TS-COD-D (m)	-22.2 (-30.7; -12.6)	-1.44 (-2.10; -0.77)	0/0/99%	Very likely poorer	-17.5 (-28.3; -5.2)	-0.88 (-1.51; -0.24)	1/3/96%	Very likely poorer
TS-COD-ND (m)	-19.1 (-26.4; -11.0)	-1.25 (-1.81; -0.69)	0/0/99%	Very likely poorer	-14.7 (-27.2; 0.1)	-0.56 (-1.12; 0.00)	2/11/87%	Likely poorer
V_{IFT} (km/h)	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	33/33/33%	Unclear	-0.9 (-3.2; 1.4)	-0.11 (-0.41; 0.18)	4/67/29%	Possibly trivial

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_{IFT}: final velocity in the 30-15 Intermittent Fitness Test; ES: effect size.

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

	HIT COD3 (n = 6)				HIT COD1 (n = 6)			
	%	ES	Chances	Outcome	%	ES	Chances	Outcome
RSAb (s)	2.1 (-3.5; 7.4)	0.20 (-0.33; 0.73)	50/41/10%	Unclear	0.4 (-1.3; 2.1)	0.06 (-0.18; 0.31)	15/81/4%	Likely trivial
RSAm (s)	3.3 (-2.5; 8.8)	0.29 (-0.21; 0.79)	63/31/5%	Possibly	-1.0 (-2.2; 0.1)	-0.15 (-0.31; 0.01)	0/72/28%	Possibly trivial
V-cut (s)	5.4 (1.4; 9.2)	0.65 (0.17; 1.13)	94/5/1%	Likely	6.2 (0.3; 11.8)	2.62 (0.11; 5.12)	95/2/4%	Likely
MAT (s)	3.1 (2.3; 3.8)	0.39 (0.30; 0.49)	100/0/0%	Most Likely	2.5 (-1.4; 6.3)	0.45 (-0.25; 1.14)	75/19/6%	Unclear
TS-D (m)	-3.0 (-10.3; 4.9)	-0.15 (-0.54; 0.24)	40/53/6%	Unclear	-2.6 (-0.1; 5.2)	0.25 (-0.01; 0.51)	1/34/65%	Possibly poorer
TS-ND (m)	-0.7 (-4.9; 3.7)	-0.03 (-0.25; 0.18)	9/87/4%	Likely trivial	-3.6 (-12.0; 5.5)	-0.24 (-0.82; 0.35)	10/36/55%	Unclear
TS-COD-D (m)	-5.7 (-14.2; 3.6)	-0.27 (-0.71; 0.17)	4/34/62%	Possibly poorer	-1.4 (-5.8; 3.1)	-0.15 (-0.63; 0.32)	10/48/42%	Unclear
TS-COD-ND (m)	-3.1 (-8.1; 2.2)	-0.20 (-0.55; 0.14)	3/46/50%	Possibly poorer	-0.8 (-3.2; 1.6)	-0.06 (-0.24; 0.12)	2/89/9%	Likely trivial
V_{IFT} (km.h^{-1})	2.3 (1.4; 3.3)	0.22 (0.13; 0.31)	67/33/0%	Possibly	-0.5 (-3.2; 2.3)	-0.06 (-0.44; 0.31)	11/64/25%	Unclear

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_{IFT}: final velocity in the 30-15 Intermittent Fitness Test; ES: effect size.

corded from players and coaches about the intervention.

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, RSA_m and V_{IFT} (Table 2).

Between-group changes

Improvements in RSA_m (4.5% [CL90%: -1.5; 10.9]; QC = 79/17/4%) and V_{IFT} (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).

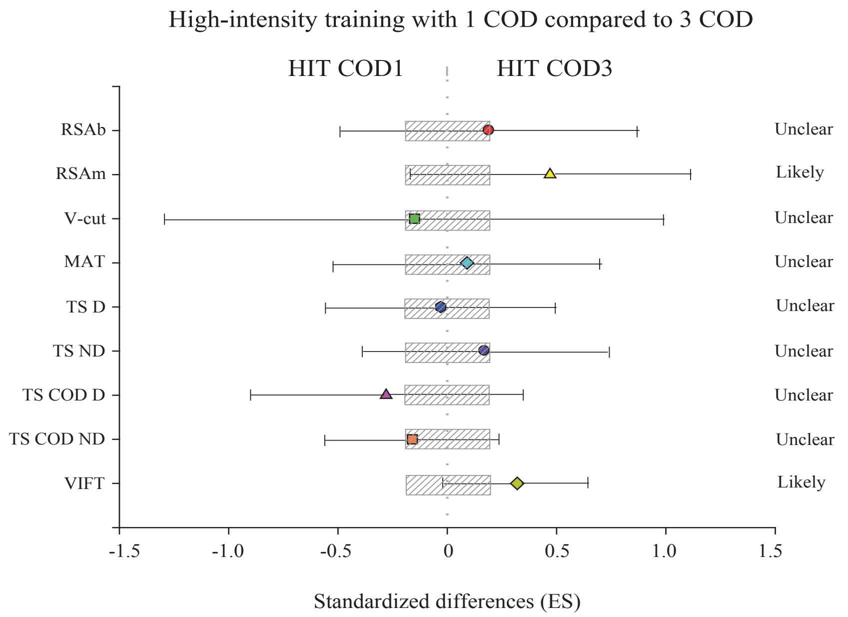

Figure 3. Between-group changes in fitness tests.

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; V_{IFT}: 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_m and V_{IFT}, with greater improvements in the latter two tests compared to HIT-COD1.

RSA_m 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_m improved without changes in RSA_b, 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.

V_{IFT} 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 V_{IFT} (Viano-Santasmarinas, Rey, Carballeira, & Padron-Cabo, 2017) through increases in peripheral oxidative capacity (Gibala, et al., 2006) and VO_2max (Taylor, et al., 2015), the fact that only HIT-COD3 improved V_{IFT} suggests that the addition of COD may have increased neuromuscular and metabolic adaptations required for V_{IFT} improvements (Taylor, et al., 2015), especially considering the stretch-shortening cycle (SSC) needs for both the COD actions and $30\text{-}15_{IFT}$ 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

Attene, G., Laffaye, G., Chaouachi, A., Pizzolato, F., Migliaccio, G.M., & Padulo, J. (2015). Repeated sprint ability in young basketball players: One vs. two changes of direction (Part 2). *Journal of Sports Sciences*, *33*(15), 1553-1563. doi: 10.1080/02640414.2014.996182

Attene, G., Nikolaidis, P.T., Bragazzi, N.L., Dello Iacono, A., Pizzolato, F., Zagatto, A.M., . . . Padulo, J. (2016). Repeated sprint ability in young basketball players (Part 2): The chronic effects of multidirection and of one change of direction are comparable in terms of physiological and performance responses. *Frontiers in Physiology*, *7*, 262. doi: 10.3389/fphys.2016.00262

Attene, G., Pizzolato, F., Calcagno, G., Ibba, G., Pinna, M., Salernitano, G., & Padulo, J. (2014). Sprint vs. intermittent training in young female basketball players. *Journal of Sports Medicine and Physical Fitness*, *54*(2), 154-161.

Aziz, A.R., Mukherjee, S., Chia, M.Y., & Teh, K.C. (2007). Relationship between measured maximal oxygen uptake and aerobic endurance performance with running repeated sprint ability in young elite soccer players. *Journal of Sports Medicine and Physical Fitness*, *47*(4), 401-407.

Ben Abdelkrim, N., El Fazaa, S., & El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine*, *41*(2), 69-75. doi: 10.1136/bjsm.2006.032318

Brughelli, M., Cronin, J., Levin, G., & Chaouachi, A. (2008). Understanding change of direction ability in sport: A review of resistance training studies. *Sports Medicine*, *38*(12), 1045-1063. doi: 10.2165/00007256-200838120-00007

Buchheit, M. (2008). The 30-15 intermittent fitness test: Accuracy for individualizing interval training of young intermittent sport players. *Journal of Strength and Conditioning Research*, *22*(2), 365-374. doi: 10.1519/JSC.0b013e3181635b2e

Buchheit, M., Bishop, D., Haydar, B., Nakamura, F.Y., & Ahmaidi, S. (2010). Physiological responses to shuttle repeated-sprint running. *International Journal of Sports Medicine*, *31*(6), 402-409. doi: 10.1055/s-0030-1249620

Buchheit, M., & Laursen, P.B. (2013a). High-intensity interval training, solutions to the programming puzzle. Part II: Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine*, *43*(10), 927-954. doi: 10.1007/s40279-013-0066-5

Buchheit, M., & Laursen, P. B. (2013b). High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. *Sports Medicine*, *43*(5), 313-338. doi: 10.1007/s40279-013-0029-x

Castagna, C., Manzi, V., D'Ottavio, S., Annino, G., Padua, E., & Bishop, D. (2007). Relation between maximal aerobic power and the ability to repeat sprints in young basketball players. *Journal of Strength and Conditioning Research*, *21*(4), 1172-1176. doi: 10.1519/R-20376.1

Chaouachi, A., Chtara, M., Hammami, R., Chtara, H., Turki, O., & Castagna, C. (2014). Multidirectional sprints and small-sided games training effect on agility and change of direction abilities in youth soccer. *Journal of Strength and Conditioning Research*, *28*(11), 3121-3127. doi: 10.1519/JSC.0000000000000505

Chaouachi, A., Manzi, V., Wong del, P., Chaalali, A., Laurencelle, L., Chamari, K., & Castagna, C. (2010). Intermittent endurance and repeated sprint ability in soccer players. *Journal of Strength and Conditioning Research*, *24*(10), 2663-2669. doi: 10.1519/JSC.0b013e3181e347f4

Dellal, A., Keller, D., Carling, C., Chaouachi, A., Wong del, P., & Chamari, K. (2010). Physiologic effects of directional changes in intermittent exercise in soccer players. *Journal of Strength and Conditioning Research, 24*(12), 3219-3226. doi: 10.1519/JSC.0b013e3181b94a63

Gibala, M.J., Little, J.P., van Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., . . .& Tarnopolsky, M.A. (2006). Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *Journal of Physiology*, *575*(Pt 3), 901-911. doi: 10.1113/jphysiol.2006.112094

Glaister, M. (2005). Multiple sprint work: Physiological responses, mechanisms of fatigue and the influence of aerobic fitness. *Sports Medicine*, *35*(9), 757-777.

Gonzalo-Skok, O., Tous-Fajardo, J., Suarez-Arrones, L., Arjol-Serrano, J.L., Casajus, J.A., & Mendez-Villanueva, A. (2015). Validity of the V-cut test for young basketball players. *International Journal of Sports Medicine*, *36*(11), 893-899. doi: 10.1055/s-0035-1554635

Hader, K., Mendez-Villanueva, A., Ahmaidi, S., Williams, B.K., & Buchheit, M. (2014). Changes of direction during high-intensity intermittent runs: Neuromuscular and metabolic responses. *BMC Sports Science, Medicine and Rehabilitation*, *6*(1), 2. doi: 10.1186/2052-1847-6-2

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., . . .& Hoff, J. (2007). Aerobic high-intensity intervals improve VO_2max more than moderate training. *Medicine and Science in Sports and Exercise, 39*(4), 665-671. doi: 10.1249/mss.0b013e3180304570

Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-13. doi: 10.1249/MSS.0b013e31818cb278

Iaia, F.M., Fiorenza, M., Perri, E., Alberti, G., Millet, G.P., & Bangsbo, J. (2015). The effect of two speed endurance training regimes on performance of soccer players. *PLoS One*, *10*(9), e0138096. doi: 10.1371/journal.pone.0138096

Ikutomo, A., Kasai, N., & Goto, K. (2017). Impact of inserted long rest periods during repeated sprint exercise on performance adaptation. *European Journal of Sport Science*, 1-7. doi: 10.1080/17461391.2017.1383515

Laursen, P.B., & Jenkins, D.G. (2002). The scientific basis for high-intensity interval training: Optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Medicine*, *32*(1), 53-73.

Marcelino, P.R., Aoki, M.S., Arruda, A., Freitas, C.G., Mendez-Villanueva, A., & Moreira, A. (2016). Does small-sided-games' court area influence metabolic, perceptual, and physical performance parameters of young elite basketball players? *Biology of Sport*, *33*(1), 37-42. doi: 10.5604/20831862.1180174

Maulder, P., & Cronin, J. (2005). Horizontal and vertical assessment: Reliability, symmetry, discriminative and predictive ability. *Physical Therapy and Sport*, *6*, 74-82.

Mendez-Villanueva, A., Hamer, P., & Bishop, D. (2008). Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. *European Journal of Applied Physiology*, *103*(4), 411-419. doi: 10.1007/s00421-008-0723-9

Moran, J., Sandercock, G.R., Ramirez-Campillo, R., Meylan, C., Collison, J., & Parry, D.A. (2017a). A meta-analysis of maturation-related variation in adolescent boy athletes' adaptations to short-term resistance training. *Journal of Sports Sciences*, *35*(11), 1041-1051. doi: 10.1080/02640414.2016.1209306

Moran, J., Sandercock, G.R.H., Ramirez-Campillo, R., Todd, O., Collison, J., & Parry, D.A. (2017b). Maturation-related effect of low-dose plyometric training on performance in youth hockey players. *Pediatric Exercise Sciences*, *29*(2), 194-202. doi: 10.1123/pes.2016-0151

Moran, J.J., Sandercock, G.R., Ramirez-Campillo, R., Meylan, C.M., Collison, J.A., & Parry, D.A. (2017c). Age-related variation in male youth athletes' countermovement jump after plyometric training: A meta-analysis of controlled trials. *Journal of Strength and Conditioning Research*, *31*(2), 552-565. doi: 10.1519/JSC.0000000000001444

Padulo, J., Bragazzi, N.L., Nikolaidis, P.T., Dello Iacono, A., Attene, G., Pizzolato, F., . . .& Migliaccio, G.M. (2016). Repeated sprint ability in young basketball players: Multi-direction vs. one-change of direction (Part 1). *Frontiers in Physiology*, *7*, 133. doi: 10.3389/fphys.2016.00133

Radnor, J.M., Lloyd, R.S., & Oliver, J.L. (2017). Individual response to different forms of resistance training in school-aged boys. *Journal of Strength and Conditioning Research*, *31*(3), 787-797. doi: 10.1519/JSC.0000000000001527

Ramirez-Campillo, R., Andrade, D.C., Campos-Jara, C., Henriquez-Olguin, C., Alvarez-Lepin, C., & Izquierdo, M. (2013). Regional fat changes induced by localized muscle endurance resistance training. *Journal of Strength and Conditioning Research*, *27*(8), 2219-2224. doi: 10.1519/JSC.0b013e31827e8681

Rosch, D., Hodgson, R., Peterson, T.L., Graf-Baumann, T., Junge, A., Chomiak, J., & Dvorak, J. (2000). Assessment and evaluation of football performance. *American Journal of Sports Medicine*, *28*(5 Suppl.), S29-39.

Sassi, R.H., Dardouri, W., Yahmed, M.H., Gmada, N., Mahfoudhi, M.E., & Gharbi, Z. (2009). Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *Journal of Strength and Conditioning Research*, *23*(6), 1644-1651. doi: 10.1519/JSC.0b013e3181b425d2

Schelling, X., & Torres-Ronda, L. (2013). Conditioning for basketball: Quality and quantity of training. *Strength and Conditioning Journal*, *35*, 89-94.

Shalfawi, S.A.I., Young, M., Tonnessen, E., Haugen, T., & Enoksen, E. (2013). The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. *Kinesiologia Slovenica*, *19*, 29-42.

Sheppard, J.M., & Young, W.B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, *24*(9), 919-932. doi: Doi 10.1080/02640410500457109

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities: Specific to field-based team sports. *Sports Medicine*, *35*(12), 1025-1044.

Stone, N.M., & Kilding, A.E. (2009). Aerobic conditioning for team sport athletes. *Sports Medicine*, *39*(8), 615-642. doi: 10.2165/00007256-200939080-00002

Taylor, J., Macpherson, T., Spears, I., & Weston, M. (2015). The effects of repeated-sprint training on field-based fitness measures: A meta-analysis of controlled and non-controlled trials. *Sports Medicine*, *45*(6), 881-891. doi: 10.1007/s40279-015-0324-9

Teixeira, A.S., Arins, F.B., De Lucas, R.D., Carminatti, L.J., Dittrich, N., Nakamura, F.Y., & Guglielmo, L.G.A. (2017). Comparative effects of two interval shuttle-run training modes on physiological and performance adaptations in female professional futsal players. *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000002186

Torres-Ronda, L., Ric, A., Llabres-Torres, I., de Las Heras, B., & Schelling, I.D.A.X. (2016). Position-dependent cardiovascular response and time-motion analysis during training drills and friendly matches in elite male basketball players. *Journal of Strength and Conditioning Research*, *30*(1), 60-70. doi: 10.1519/JSC.0000000000001043

Viano-Santasmarinas, J., Rey, E., Carballeira, S., & Padron-Cabo, A. (2017). Effects of high-intensity interval training with different interval durations on physical performance in handball players. *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000001847

Zagatto, A.M., Ardigo, L.P., Barbieri, F.A., Milioni, F., Iacono, A.D., Camargo, B.H., & Padulo, J. (2016). Performance and metabolic demand of a new repeated-sprint ability test in basketball players: Does the number of changes of direction matter? *Journal of Strength and Conditioning Research*. doi: 10.1519/JSC.0000000000001710

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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.

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