Title

Movement characteristics, physiological and perceptual responses of elite standard youth football players to different high intensity running drills.

Running title

Responses to high intensity running of youth football players

Key words

Football, interval training, youth, acute responses

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ABSTRACT

Purpose: To examine responses to high intensity running drills in youth football players. **Methods:** Seventeen players completed the YoYo Intermittent Recovery test level one (YYIR1) and a 15 m maximal sprint to quantify target running speeds. Players performed three conditions on separate occasions comprising: 12 x 15 s high intensity runs at 100% of the final YYIRT1 speed, 12 x ~4 s repeated sprints with ~26 s recovery, and combination running using both modalities. Heart rate was monitored continuously with PlayerLoad^{TM} and movement characteristics using microtechnology. Ratings of perceived exertion and blood lactate responses were measured 2 min after the final repetition. The ratio of Flight:contraction time was calculated from a countermovement jump before and at 2 min and 14 hours after each condition. Data analysis used magnitude based inferences and effect sizes statistics. **Results:** Peak speed (1.1%; ES 0.23 ± 0.44) and mean speed over the initial 4s (6.3%; ES 0.45 ± 0.46) were *possibly* faster during combination compared to high intensity running with *unclear* differences when compared to repeated sprinting. This was despite *most likely* (21.6%; ES 7.65 ± 1.02) differences in prescribed speeds between conditions. There were *likely* reductions in F:C at 14 hours ratio after high intensity (-5.6%; ES –0.44 ± 0.32) and combination running (-6.8%; ES -0.53 ± 0.47). Changes in the repeated sprinting condition were *unclear.* **Conclusions:** Actual movement characteristics of high intensity running drills may not reflect those used to prescribe them whilst reductions in F:C ratio are still evident 14 hours after their completion.

INTRODUCTION

Physical qualities, including speed (Mendez-Villanueva et al. 2011), agility (Dellal and Wong del 2013) and aerobic capacity (Waldron and Murphy 2013), are associated with successful football performance. Better aerobic capacity is associated with improved running performance in matches (Castagna et al. 2010) and accelerated recovery during repeated sprinting (Meckel et al. 2009). When performed chronically, aerobic capacity can be improved using high intensity interval training scheduled as high intensity running (Faude et al. 2013) and repeated sprinting (Tonnessen et al. 2011) over specific distances and at prescribed speeds (Dupont et al. 2004; Ingebrigtsen et al. 2013; Haugen et al. 2014). Few studies, however, have reported data from individual training sessions making it difficult to assess the fidelity of this approach, i.e. the degree to which a training manipulation has been implemented as intended (Taylor et al. 2015).

When high intensity running is performed in the field, participants must use periods of acceleration, deceleration and constant speed running to cover the prescribed distance in the allotted time. A greater understanding of the responses to individual sessions may allow practitioners to periodise training load more effectively at the group and individual level (Akubat et al. 2012; Buchheit and Laursen 2013; Faude et al. 2013). This is especially pertinent amongst youth players given than, compared to adults, children are less able to interpret temporal cues which may compromise their ability to cover set distances in specific time periods (Chinnasamy et al. 2013)

During training interventions, high intensity running and repeated sprints have been scheduled in series. That is, repetitions of the same intensity, duration and type performed with uniform recovery in the same set (Dupont et al. 2004; Ferrari Bravo et al. 2008). Whilst this is an effective means of improving speed and aerobic fitness (Tonnessen et al. 2011; Iaia et al. 2015) it represents a uniform approach to training prescription that might not reflect the variety in locomotor activities that is representative of football specific training and match play (Buchheit et al. 2010; Harley et al. 2010). Using a training modality that alternates repeated sprints and high intensity running might be an equally effective way of prescribing training of this nature. However, to date, training prescription of this nature has not been reported in the literature.

The aim of the present study was to investigate the movement characteristics, physiological and perceptual responses of youth soccer players to three different high intensity running drills matched for total distance incorporating high intensity running, repeated sprinting or a combination of the two.

METHODS

Experimental design

Players performed three running conditions in a randomised, repeated measures crossover design: 12 x 15 s high intensity running at the speed corresponding to their final stage in the YoYo Intermittent Recovery Test Level 1 (YYIR1) (Buchheit et al. 2015), interspersed by 15 s recovery, 12 x ~4 s repeated sprints with ~26 s recovery and combination running comprising two repeated sprints followed by two high intensity runs, as performed in their respective conditions; six repetitions of each running modality were completed. During each condition participants completed the same total running distance, achieved by allocating individual 'running tracks', identical in length for each condition and equal to the distance associated with high intensity running condition. During repeated sprinting participants were able to cover the remainder of the 'running track' after their sprint at an intensity that brought them to the opposite end in time to start the subsequent repetition. Each condition lasted six minutes and required players to start each new repetition at 30 s intervals. Sessions were performed at the same time and on the same night of the week, separated by six days and conducted on a synthetic pitch before normal squad training. Participants were asked to maintain their normal pre-training nutrition practices during the study period and ensure that these were the same before each visit. Rating of perceived exertion (RPE) was collected 2 min after the final repetition along with a fingertip blood sample to measure lactate concentration. Movement characteristics were measured using microtechnology and heart rate was recorded throughout to calculate training impulse (TRIMP; Stagno et al. 2007). Countermovement jumps (CMJ) were performed before, 2 min and 14 hours after each condition.

Participants

Seventeen players (age: 14.9 ± 0.6 y; maturity offset 1.4 ± 0.7 y; stature: 173.2 ± 5.7 cm; body mass: 64.1 ± 7.1 kg; maximum HR 207 ± 7 b·min^{-1}) from the same professional football academy in their country's top tier of competition took part in the investigation that received ethics approval from Heriot-Watt University, School of Life Sciences and conformed to the recommendations of the Declaration of Helsinki. All participants were accustomed to high intensity training and were engaged in approximately 9-12 hours of organised practice and one competitive fixture per week.

Assessment of physical capacities

Assessments of physical capacity were performed one week before the first experimental condition. All assessments were completed in the early evening before normal squad training on a synthetic surface. After a warm up at a self-selected speed, players performed three, 15 m maximal effort sprints from a standing start 0.5 m behind the first electronic timing gate (Smartspeed, Fusion Sport, Australia). The technical error of measurement (TEM) for the assessment was 0.03 s. Players then completed the YYIR1, the protocol for which has been described elsewhere (Krustrup et al. 2003). Players were afforded two warnings for either failing to arrive on the line at the time indicated by the audio signal or moving from the start line prematurely. The final stage completed and its corresponding speed was recorded and used as the criterion speed for the high intensity running condition.

Repeated sprint condition

Twelve maximal sprints were completed starting every 30 s. Participants were instructed to sprint maximally from a stationary position until they were in line with a marker placed 30 m from the start line. Upon reaching the marker participants were instructed to decelerate before making their way to a marker opposite the start line located at a distance equal to that in the high intensity running condition (Figure 1). Participants were able to select a locomotor activity they felt best allowed them to recover from the sprint whilst still being in place at the opposite end of the running track in time to start the next repetition; this involved a mix of jogging, walking and standing. A distance of 30 m sprint was chosen as it represented a distance that would allow the calculation of speed over the initial 4 s period of each repetition, a sprint duration used in previous studies (Buchheit et al. 2009). The mean 30 m sprint time for this group of participants was 4.71 ± 0.26 s. Participants were given verbal instruction to get ready 10 and 5 s before starting each repetition.

High intensity running condition

Each player completed 12 x 15 s repetitions and ran in their own allocated channel measured to within 0.5 m of the required distance, calculated by converting the speed corresponding to the final stage achieved in the YYIR1 to $km \cdot h^{-1}$. Repetitions started every 30 s and players were instructed to pace their running speed to arrive at the marker on, or as close as possible to the 15 s target. Passive rest was employed in the 15 s recovery period between intervals. During each shuttle players were given verbal feedback as to elapsed time at 5, 10 and 15 s and then 5 s before the start of the next repetition.

Combination running condition

This condition comprised two maximal sprints followed by two high intensity runs in an alternating pattern until 12 repetitions in total had been completed. Each subject ran in their own allocated channel with distances and associated feedback for sprint and high intensity running repetitions identical to that described above.

Measurement of movement characteristics

Movement characteristics were measured using portable global positioning system (GPS) devices (Minimax X, Catapult Sports, Melbourne, Australia) integrated with an in-built 6 g tri-axial accelerometer (100 Hz). Players were fitted with an appropriately sized vest housing the portable GPS unit between the scapulae over which a standard training shirt was worn. A digital watch was synchronized with Greenwich Mean Time and used to record the start and end of each 30 s period. These times were then used to truncate the raw GPS data file. All data were downloaded to a computer and analysed using Catapult Sprint software (Catapult Sports, Melbourne, Australia). This method provides a valid and reliable measurement of movement characteristics (Waldron et al. 2014). Peak speed, mean speed during the first 4 s of each repetition, time at or above the speed corresponding to the final stage in the YYIR1 and maximal sprint speed were derived from GPS data along with PlayerLoad™, which is reliable during discrete sprints in a soccer specific protocol (Barreira et al. 2016).

Measurement of internal load

Players were fitted with a heart rate monitor positioned around the chest (Polar, Oy, Finland) to record heart rate for the quantification of TRIMP as described elsewhere (Stagno et al. 2007). RPE using a modified Borg CR10 scale (Foster et al. 2001) and capillary blood samples to measure blood lactate concentration were collected 2 min after the final repetition. Blood samples were refrigerated and analysed within 30 min of collection (Biosen C Line, Germany; TEM = 0.42%).

Countermovement jump performance

Participants performed a CMJ for assessment of flight time:contraction time ratio (F:C ratio; s) using a portable force platform (Force Platform, Ergotest Innovation, Porsgrunn, Norway) connected to a laptop (Dell Inspiron 9100, Dell, United Kingdom). Participants performed two practice jumps before a third from which data were collected using commercially available software (MuscleLab 4020e, Ergotest Innovation). Participants were instructed to flex their knees to approximately 120 degrees before jumping as high as possible with their hands remaining on their hips. The landing and takeoff positions for jumps were assumed to be the same, with any jumps that deviated from the stated procedure ignored and an additional jump completed. Measurements were recorded before, and at 2 min and 14 hours after the final repetition. The F:C ratio is a valid and reliable indicator of neuromuscular fatigue (McLellan and Lovell 2012).

Statistical analysis

Effect sizes (ES), ± confidence limits, relative change (in percentages) expressed as the transformed (natural logarithm) ± 90% confidence limits, and magnitude based inferences were calculated for all physiological and performance outcome measures. Threshold probabilities for a substantial effect based on the 90% confidence limits were <0.5% most unlikely, 0.5-5% very unlikely, 5-25% unlikely, 25-75% possibly, 75-95% likely, 95-99.5% very likely, and >99.5% most likely (Batterham and Hopkins 2006). Thresholds for the magnitude of the observed change for each variable were determined as the between participant SD x 0.2, 0.6 and 1.2 for a small, moderate and large effect, respectively (Batterham and Hopkins 2006). Effects with confidence limits across a likely small positive or negative change were classified as unclear.

RESULTS

Assessments of physical capacity

The mean speed during the maximal 15 s sprint assessment (6.28 ± 0.2 $m \cdot s^{-1}$) was *most likely* (21.6%; ES 7.65 ± 1.02) faster than the speed associated with the final level completed during the YYIR1 (4.9 ± 0.4 $m \cdot s^{-1}$). Sprint speeds during the repeated sprint condition (6.4 ± 0.4 $m \cdot s^{-1}$) were *possibly* faster (2.5%; ES 0.31 ± 0.4) than those recorded in the assessment of physical capacity, suggesting that players were sprinting maximally.

Movement characteristics

Movement characteristics for each condition are presented in Table 1 and Figures 2a and 2b. Peak speed achieved in combination running was *possibly faster* (1.1%; ES 0.23 ± 0.44) than the high intensity running. All other comparisons for peak speed were *unclear*. Mean speed over the initial 4 s of each repetition was *possibly higher* in repeated sprinting (6.2%; ES 0.44 ± 0.51) and combination running (6.3%; ES 0.45 ± 0.46) compared to high intensity running, respectively. Differences between the repeated sprint and combination running were *unclear*. Time at or above maximal sprint speed was *likely higher* in combination running when compared to the high intensity running (39.8%; ES 0.9 ± 0.7) and repeated sprinting (28.5%; ES 0.91 ± 0.83), respectively. Differences between repeated sprint and high intensity running conditions were *unclear*. Time at or above the speed associated with the final stage of the YYIR1 was *most likely higher* during high intensity running compared to repeated sprinting (51.8%; ES 3.6 ± 0.58) and combination running (25%; ES 1.38 ± 0.44). Time above the speed associated with the final stage of the YYIR1 was *most likely* higher in the combination running when compared to repeated sprinting (35.7%; ES 2.12 ± 0.4). Speeds associated with each repetition in the three conditions for one representative participant can be seen in Figure 3.

INSERT FIGURES 2a, 2b and 3 NEAR HERE

Speeds associated with repeated sprint and high intensity running repetitions performed in series and in an alternate pattern are presented in Figures 4 and 5. There were *likely trivial* (0.2%; ES 0.04 ± 0.32) differences in peak speed during maximal sprint repetitions within the repeated sprint condition (6.9 ± 0.3 $m \cdot s^{-1}$) and corresponding repetitions (1-2, 5-6, 9-10) in the combination running condition (7.0 ± 0.3 $m \cdot s^{-1}$). Mean speed over the first 4 s of each repetition was *very likely* slower (7.7%; ES 1.15 ± 0.82) in the repeated sprint (5.0 ± 0.4 $m \cdot s^{-1}$) compared to corresponding repetitions (1-2, 5-6, 9-10) in the combination running condition (5.3 ± 0.3 $m \cdot s^{-1}$).

Likely faster (4.6%; ES 0.76 ± 0.66) peak speeds were observed during high intensity running repetitions (3-4,7-8,11-12) in the combination (6.5 ± 0.4 $m \cdot s^{-1}$) compared to high intensity running condition (6.2 ± 0.3 $m \cdot s^{-1}$). Mean speed over the first 4 s of each repetition was *likely faster* (4.7%; ES -0.31 ± 0.44) during high intensity running (5.4 ± 0.5 $m \cdot s^{-1}$) compared to corresponding repetitions (3-4,7-8,11-12) in the combination running condition (4.9 ± 0.3 $m \cdot s^{-1}$).

INSERT FIGURES 4 AND 5 NEAR HERE

PlayerLoad™

PlayerLoad™ was *possibly higher* (4.8%; ES 0.62 ± 0.82) during repeated sprints compared to high intensity running and *likely higher* in the combination compared to the high intensity running condition (5.3%; 0.68 ± 0.9). Differences in PlayerLoad™ were *unclear* when repeated sprints were compared to combination running.

INSERT TABLE 1 NEAR HERE

Internal responses to high intensity running drills

RPE was *possibly* (-8.5%; ES 0.26 ± 0.48) lower after high intensity running compared to repeated sprinting; when compared to combination running differences were *likely trivial* (3.4%; ES 0.1 ± 0.35). All other comparisons were *unclear*. Differences in blood lactate after repeated sprinting compared to combination running were *likely trivial* (3.4%; ES 0.1 ± 0.32) whilst all other comparisons were *unclear*. TRIMP was *possibly higher* (49.4%; ES 0.27 ± 0.24) during repeated sprinting compared to high intensity running with *most likely trivial*

(9.4%; ES 0.06 ± 0.12) differences compared to combination running. TRIMP was *possibly* (36.3%; ES 0.21 ± 0.41) higher during combination compared to high intensity running. Internal response data are presented in Table 2.

INSERT TABLE 2 NEAR HERE

Countermovement jump performance

Possible increases were observed in F:C at 2 min after the high intensity (2.6%; ES -0.19 ± 0.46) and combination running (2.5%; ES -0.27 ± 0.29) conditions compared to baseline. Repeated sprinting resulted in *likely trivial* (-2.0%; ES -0.15 ± 0.33) reductions at the same time point. At 14 hours there were *likely* reductions in F:C ratio after high intensity (-5.6%; ES –0.44 ± 0.32) and combination running (-6.8%; ES -0.53 ± 0.47) compared to baseline. Changes in the repeated sprinting condition were *unclear.*

For between condition comparisons at 2 min post there were *likely trivial* differences in the F: C ratio after repeated sprint and high intensity running (1.5%; ES 0.07 ± 0.33) whilst F:C ratio was *possibly lower* (-4.5%; ES 0.21 ± 0.41) after combination running. The F:C ratio after combination running was possibly lower than high intensity running (-6.7%; ES 0.3 ± 0.38). At 14 hours post the F:C ratio was *possibly lower* (-3.7%; ES 0.23 ± 0.41) after high intensity running and combination running (-4.7%; ES 0.3 ± 0.58) compared to repeated sprinting. There were *unclear* differences between high intensity running and combination running.

DISCUSSION

When performed in series, the movement characteristics, physiological and perceptual responses associated with high intensity and repeated sprint running were similar with differences ranging in magnitude from *unclear* to *possible*. Given *most likely* differences in the speeds used to prescribe high intensity runs and sprints, these data question the fidelity of this approach to training prescription. When runs were scheduled in an alternate pattern during the combination trial, more time was spent above maximum sprint speed and participants altered their movement characteristics resulting in higher peak speeds and mean speeds over the initial 4 s were during high intensity runs and sprints, respectively.

In the combination condition peak speeds in the high intensity running repetitions were *likely* faster whilst mean speed during the initial 4 s of sprint repetitions were *very likely* faster than when each were performed in series. These data, combined with more time spent above maximum sprint speed during the combination trial, support its use when the intention is to maintain or increase intensity without a concomitant increase in volume. The differences in running speed during the combination condition might be explained by a potentiating stimulus of preceding high intensity runs with repeated sprints. Indeed, prior dynamic activity can improve sprint speed in football players when incorporated into warm up routines (Gelen 2010). Further research is required to assess whether alternating runs of varying intensity within the same session is a useful means of using high intensity interval training to enhance performance (Tonnessen et al. 2011).

Higher peak speeds achieved in combination compared to high intensity running may explain why PlayerLoad™ values were *likely higher* in the former whilst only *possible* differences existed compared to repeated sprinting. Indeed, higher PlayerLoad™ has been reported during striding compared to sprinting during a soccer simulation protocol (Barreira et al. 2016). Although the validity of whole body loading assessed using microtechnology has been questioned (Nedergaard et al. 2017), the metric may be useful when prescribing training for youths at different stages of their physical development. The increased mechanical load associated with combination running may be an unwanted outcome, especially given the paucity of information surrounding appropriate loading patterns for young athletes (Gabbett et al. 2014; van der Sluis et al. 2014).

Repeated sprinting had *possibly* higher individualised TRIMP values than high intensity running. Although the duration of high intensity activity was less during repeated sprinting compared to high intensity running (4 s vs. 15 s) participants were required to cover the same total distance using locomotor activities that ensured they arrived at the opposite end of the running track in time to start the next repetition. Active recovery of this nature can enhance the rate at which metabolic waste products are removed (Dupont and Berthoin 2004) which may explain the similarity in response in the present study. Despite reducing specific metabolites produced during exercise, active recovery interspersing high intensity running can increase heart rate (Buchheit et al. 2009) because of a greater exercise intensity. Whilst this may be beneficial in maximising time at $\dot{V}O_{2\,\mathrm{max}}$, it could be detrimental during repeated sprinting where the aim is to maintain speed (Thevenet et al. 2007) and could explain higher TRIMP values during repeated sprinting. Furthermore, given the relationship between RPE and the physiological response to intermittent exercise

(Foster et al. 2001; Impellizzeri et al. 2004), a higher TRIMP during repeated sprinting might explain the *possible* increase reported in RPE after this condition compared to high intensity running.

The volume of high intensity running players undertake during a season is dependent on the number of matches they contest, with fringe players performing less than regular starters (Anderson et al. 2016). This is perhaps the result of fringe players following a similar loading pattern as starters yet without the stimulus of high intensity running achieved in matches. Likely reductions in F:C from pre to 14 hours after high intensity and combination running were detected, whilst changes after repeated sprinting at the same time point were *unclear.* These data suggest that high intensity training in the form or repeated sprinting and high intensity running, if performed the day before, might impair neuromuscular function during match play. This is especially pertinent since changes in running efficiency have been linked to the F:C ratio (Cormack et al. 2013). Practitioners should consider alternative forms of conditioning for players who are likely to play the following day.

PRACTICAL APPLICATIONS

Youth soccer players engage in both high intensity running and repeated sprints during competitive match play (Harley et al. 2010) and, as such, should train both qualities. When physiological responses and movement characteristics are considered, however, both modalities elicit similar acute responses. Performing repeated sprinting and high intensity running in an alternate pattern, rather than in series, facilitates faster speeds during the latter and as such could be a useful stimulus for developing this physical component. In instances where the aim is to limit mechanical load, for example during periods of rapid growth or when returning from injury, high intensity running performed in series yielded the lowest values for PlayerLoad^{TM}.

CONCLUSION

High intensity running and repeated sprinting achieve similar acute physiological and perceptual responses in youth football players despite being prescribed using different target speeds. Youth players appear to alter their approach to high intensity running and repeated sprints when they are alternated within the same set resulting in faster running speeds and more time above the maximal sprint speed.

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Figures

Figure 1: Individual running channel for high intensity, repeated sprint and combination running conditions.

Figure 2: Movement characteristics associated with each repetition of high intensity running, repeated sprinting and combination running for a) peak speed and b) mean speed over the initial 4s.

Figure 2: Speeds associated with a) high intensity b) repeated sprinting and c) combination running for one subject. Lower dashed line denotes the individual final speed attained in the YYIR1, upper dashed line denotes maximal sprint speed.

Figure 3: Comparison of mean speeds over the initial 4s of each repetition in the combination running condition and corresponding repetition in the repeated sprint and high intensity running conditions. High intensity running repetitions are denoted by the dashed box.

Figure 4: Comparison of peak speeds during each repetition in the combination running condition and corresponding repetition in the repeated sprint and high intensity running conditions. High intensity running repetitions are denoted by the dashed box.

Table 1. Peak speed, mean speed during the initial 4 s of each repetition and time above maximal sprint speed and the final YYIR1 speed during high intensity running, repeated sprints and combination running conditions. Target exercise time was calculated as the number of repetitions multiplied by either 15 s or 4 s for high intensity running and repeated sprints, respectively.

	High intensity running	Repeated sprinting	Combination running
Peak speed ($m \cdot s^{-1}$)	7.6 ± 0.34	7.63 ± 0.34	7.68 ± 0.5
Mean speed over initial 4 s ($m \cdot s^{-1}$)	4.9 ± 0.59	5.22 ± 0.74	5.19 ± 0.4
Time above final YYIR1 speed (s)	38.43 ± 7.2	18.5 ± 3.1	28.7 ± 4.3
Time above maximal sprint speed (s)	10.33 ± 5.06	9.55 ± 2.88	14.2 ± 6.26
Target exercise time (s)	180	~48	~114

Table 2. Rating of perceived exertion, blood lactate, PlayerLoad™, modified TRIMP and flight:contraction time after high intensity running, repeated sprinting and combination running conditions.

	High Intensity running	Repeated sprints	Combination running
RPE	5.9 ± 1.7	6.3 ± 1.4	6.1 ± 1.3
Blood lactate ($mmol \cdot l^{-1}$)	10 ± 2.8	9.6 ± 1.9	9.3 ± 2.5
Modified TRIMP (AU)	43.2 ± 16.2	48.6 ± 12.7	44.2 ± 10.8
PlayerLoad™ (AU)	279.2 ± 39.1	291.6 ± 21.4	293 ± 23.1
Flight:Contraction time (s)			
Baseline	0.76 ± 0.01	0.77 ± 0.1	0.75 ± 0.1
2 min post	0.79 ± 0.12	0.78 ± 0.15	0.74 ± 0.12
14 hours post	0.73 ± 0.13	0.75 ± 0.12	0.72 ± 0.14