Full title: Contrasting effects of a mixed-methods high-intensity interval training intervention in girl football players

Running title: Mixed methods HIIT in girls' football.

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Abstract

Little is known about responses of girl athletes to training interventions throughout maturation. This study evaluated group and individual responses to an eight-week, mixed-methods, high-intensity interval training (HIIT) programme in girl football players. Thirty-seven players (age 13.4 ± 1.5 years) were tested for 20 m speed, repeated-sprint ability, change-of-direction speed and yo-yo level 1 recovery (YYIR). Players were subcategorised into before-, at- and after- peak height velocity (PHV) based on maturity offset. *Very likely* moderate (25%; ±90% confidence limits = 9.2) improvements occurred in YYIR, but data were unclear in players before-PHV with moderate individual differences in response. Decrements in repeated-sprint ability were *most likely* very large (6.5%; ±3.2) before-PHV, and *likely* moderate (1.7%; ±1.0) at-PHV. Data were unclear after-PHV. A *very likely* moderate (2.7%; ±1.0) decrement occurred in change-of-direction speed at-PHV while there was a *very likely* increase (-2.4%; ±1.3) in after-PHV players. *Possibly* small (-1.1%; ±1.4) improvements in 20 m speed occurred before-PHV but the effect was otherwise unclear with moderate-to-large individual differences. These data reflect specific responses to training interventions in girls of different biological maturity, while highlighting individual responses to HIIT interventions. This can assist practitioners in providing effective training prescription.

Introduction

Long-term athlete development models are designed to accelerate a "windows of opportunity" to enhance specific physical attributes in youth athletes (Balyi & Hamilton., 2004; Philippaerts et al., 2006). There is however, a lack of physiological evidence to support this concept (Ford et al., 2011; Lloyd et al., 2013). Furthermore, the development of physical attributes in girls is not well understood, which is noteworthy, given that sex-based differences occur both in maximal-intensity and endurance exercise (Catley & Tomkinson, 2013; Mujika, Santisteban, Impellizzeri, & Castagna, 2009; Papaiakovou et al., 2009). These differences increase during adolescence, where boys demonstrate marked improvements in performance. Conversely, a plateau often occurs in girls (Catley & Tomkinson, 2013; Malina, Sławinska, Ignasiak, & Rożek, 2010). Neuromuscular training might attenuate this neuromuscular deficit, while simultaneously reducing risk factors for injury (Hewett, Myer, Ford, & Slauterbeck, 2006; Sugimoto, Myer, Foss, & Hewett, 2015). However, few studies have quantified effects of training interventions throughout maturation on sport-specific physical attributes in females.

Participation in women football has increased rapidly (Datson et al., 2014; Fahmy, 2011) and similar to men football, success is often determined by tactical and technical qualities. Nevertheless, physical attributes such as high-intensity running performance, repeated-sprint ability and speed are important determinants of successful performance (Gabbett & Mulvey, 2008; Gabbett, Wiig, & Spencer, 2013; Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008). Match high-intensity running performance is closely related to performance on the yo-yo level 1 recovery (YYIR) (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005) while maximal-intensity actions, such as sprinting, occur in close proximity to key moments in football competition (Faude, Koch, & Myer, 2012). Thus, high-intensity running capability and sprint performance are of great importance in football (Datson et al., 2014).

Girl football players have less football-specific fitness than boys (Bradley et al., 2012; Mujika et al., 2009). However, these data are limited to players in late adolescence e.g. 17.3 ± 1.6 (Mujika et al., 2009) and 19 ± 1 years of age (Bradley et al., 2012). Small-sided games and high-intensity interval training (HIIT) have been recommended as an effective means for physical development for male players throughout maturation (Harrison, Gill, Kinugasa, & Kilding, 2015) but, it is not known how girl players respond to such training interventions. Hence, studies of physical performance of girl football players and their response to training interventions are warranted.

The application of various modes of HIIT in the development of fitness in team sport players has been investigated (Buchheit & Laursen, 2013; Taylor, Macpherson, Spears, & Weston, 2015; Weston, Taylor, Batterham, & Hopkins, 2014). The majority of studies have focused on the inclusion of one mode of HIIT in an overall training program as either additional, or replacement training. Considering that these modes of training are often used concurrently, it is more appropriate to investigate the use of concurrent HIIT strategies (Bishop, Girard, & Mendez-Villaneva, 2011). Buchheit and Laursen (2013), detailed physiological responses to different modes of HIIT, with primarily central responses arising from engagement in long duration "aerobic" intervals, and peripheral responses from sprint-based intervals; making it intuitive to use both ends of this spectrum to achieve a variety of adaptations. While long-term athlete development models attempt to identify when aerobic and anaerobic oriented conditioning should be foci relative to maturation (Balyi & Hamilton 2004; Lloyd & Oliver, 2012), children do not lack trainability for an array of physiological variables (i.e. aerobic to anaerobic or central to peripheral), and this is independent of maturation status (McNarry & Jones, 2011).

The extent to which sport science research informs applied practice has been questioned (Bishop, 2008; Drust & Green, 2013) and there remains a need for "effectiveness" research i.e. evaluations of projects that assess effects of an intervention under real-world conditions (Glasgow, Lichtenstein, & Marcus, 2003). Therefore, this applied study aimed to evaluate overall and individual responses to an eight-week, mixed-methods, high-intensity interval training program on measures of physical performance in girl football players. A secondary aim was to investigate effects of mediating factors such as maturation, baseline fitness or compliance, on responses to training.

METHODS

Participants

Fifty-one players registered to an FA Girls Centre of Excellence were recruited as part of pre-season training. Ethics approval was provided by Teesside University. Informed parental consent was gained for all participants, who were notified of their right to withdraw at any point without reason. Only players who completed testing before and after the intervention were included for analysis, while players diagnosed with any musculoskeletal injury throughout the study were excluded. Therefore, a total of 37 players (age 13.4 ± 1.5 years; stature 155.6 ± 8.9 cm; body mass 50.4 ± 13.4 kg; maturity offset 1.1 ± 1.5 years) across three age groups (u13s [n=13]; u15s [n=14] and u17s [n=10]) were included in the analysis. Biological maturity was estimated using a maturity offset in years from peak height velocity (PHV) derived from sitting height, stature, body mass and date of birth (Mirwald, Baxter-Jones, & Bailey, 2002; Sherar, Mirwald, Baxter-Jones, & Thomis, 2005) and players were categorised as being before-PHV (-0.5 years) at-PHV (-0.51 to 0.5 years) and after-PHV (≥0.51 years). Participant characteristics for each group are presented in table 1.

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

Procedures

A fitness testing battery was modified from previously published procedures (Taylor, Portas, Wright, Hurst & Weston, 2012) and included measures of change-of-direction speed (a modified T-test), speed (20 m sprint); repeated-sprint ability, and high-intensity running performance (the yo-yo intermittent recovery level 1 test (YYIR)). Photoelectric timing gates (Smartspeed, Fusion Sport, Australia) recorded sprint times. Players were habituated to the procedures before testing. Order of tests, time of day and venue were the same throughout to minimise effects of circadian and other similarly induced variations in performance. The modified T-test was included (Figure 1) to provide a measure of change-of-direction ability with the better time from two maximal efforts recorded for analysis. The T-test assesses physical mechanisms that underlie agility i.e. change-of-directional speed and not cognitive or perceptual decision-making processes that are required to represent true agility (Sheppard & Young, 2006).

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

Assessment of repeated-sprint ability consisted of three, 20 m straight-line maximal sprints interspersed by 15 s passive recovery. This is an ecologically valid test of repeated-sprint ability (Gabbett et al., 2013) and our previous work found no advantage in testing more than three sprints (Wright, Best, Hurst, Taylor, & Weston, 2014). A criterion sprint was performed before the repeated-sprint ability test as per Impellizzeri et al. (2008). The better score from two maximal sprints was taken as the players' 20 m time and the mean of the three repeated-sprints was recorded.

The YYIR is a valid and reliable measure of high-intensity running performance (Bangsbo, Iaia, & Krustrup, 2008) with high concurrent validity reported in female football (Krustrup et al., 2005). The YYIR also discriminates performance standard in senior and girl players (Bradley et al., 2012; Mujika et al., 2009).

Test-retest reliability was examined before the intervention in 36 players with each test being completed on two occasions, seven-days apart. There were trivial differences between testing sessions for all tests. Typical error was 3.0% (90%

confidence limits; 2.5 – 3.8%) for our T-test, 2.0% (1.7 – 2.5%) for 20 m sprint, 2.5% (2.1 – 3.1%) for repeated-sprint ability and 16.5% (13.3 – 21.8) for YYIR. Typical error presented here provides valuable information to help practitioners interpret changes in testing scores for girl football players on an individual level.

Training intervention

Pre-season training was divided into two, 4-week blocks. Block one focused on longer-duration HIIT and block two on sprint-based interval training (Buchheit & Laursen, 2013; Gist, Fedewa, Dishman, & Cureton, 2013; Macpherson & Weston, 2015) (See tables 2 and 3). The primary focus of this period was to improve football-specific fitness. During the intervention period each player undertook an individually prescribed strength and conditioning programme (1 x 70 minutes per week) targeting fundamental movement skill development and potential neuromuscular deficits (e.g. Sugimoto et al., 2015; Wright & Weston, 2014). The third week of each block was the most intense training week, with multi-terrain and sand surfaces used in an attempt to elicit a greater training response in one of the sessions. Training sessions followed a similar format, with a standardised warm-up, consisting of a modified FIFA11+ protocol (Soligard et al., 2008), the prescribed training sessions, football training and a short cool-down. Rating of perceived exertion was assessed at the end of each session to monitor training intensity using the centiMax (CR100) scale (Borg & Borg, 2002).

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

****Table 3 near here****

Statistical analysis:

Using a custom-made spreadsheet (Hopkins, 2006) all data were log transformed and back transformed to obtain percentage change for measures before and after pre-season tests. Uncertainty of the estimate was taken to be 90% confidence limits. Inferences were based on the disposition of the confidence limit for the mean difference to the smallest-worthwhile effect (0.2 between-participant SD). The probability that a change in testing scores was beneficial, harmful or trivial, was identified according to the magnitude-based inferences approach (Batterham & Hopkins, 2006). Descriptors were assigned using the following scales: 0.5-4.9%, very unlikely; 5-24.9%, unlikely; 25-74.9%, possibly; 75-94.9% likely; 95-99.49% very likely; >99.5% most likely (Hopkins, Marshall, Batterham, & Hanin, 2009). Magnitude-based inferences were categorised where the probabilities for declaring an effect beneficial were >25% for benefit with <0.5% for harm. Thus effects were deemed unclear if they were possibly beneficial (>25%) with an unacceptable risk of harm (>0.5%). The magnitude of responses was evaluated through standardised differences in the means as follows: <0.2 trivial, <0.6 small, <1.2 moderate, <2 large, <4, very large ≥4 extremely large (Hopkins et al., 2009). The effect of baseline test score, and compliance, defined as total RPE score from pre-season conditioning, were accounted for separately as covariates in the analysis. Data were analysed separately for each maturity group (before-, at- and after-PHV) while still controlling for baseline test score (Hopkins et al., 2009).

Individual responses to training should be evaluated when assessing the effectiveness of interventions, particularly in youth athletes where extraneous variables such as maturation status, baseline fitness and training compliance are mediating factors. Hence, individual responses with upper and lower confidence limits (90%) were calculated using the standard deviation of the change score (SD_{Ch}) after adjusting for measurement error as recommended by Hopkins (2015a). However, with no control group to anchor SD_{Ch} our analysis accounted for typical error. These data were converted to standardised units by dividing by the standard deviation at baseline and interpreted by halving the aforementioned thresholds for standardized difference in the mean change (e.g. <0.1, 0.3, 0.6, 1, ≥2). Magnitude-based inferences were also quantified on individual level using a separate custom made spreadsheet (Hopkins, 2004) and an odds ratio of 66% was used to define *likely* responders.

Results

Results are presented for each group in Table 4 and on an individual basis in Figure 2. Pre-season training elicited a small improvement in T-test performance. There were moderate decrements in players at-PHV and moderate improvements after-PHV. Effects on 20 m sprint time were trivial with moderate individual differences and a small homogenous improvement in players at-PHV. There were small decrements in repeated-sprint performance with moderate individual differences. These decrements were large before-PHV and moderate at-PHV. Moderate improvements in YYIR occurred overall, and in players at- and after-PHV. Effects were unclear in before-PHV players with moderate individual differences. The intervention was beneficial in two players, unclear in three and detrimental for one. All other effects were trivial or unclear, as was the effect of controlling for training compliance on these results.

****Table 4 near here****

****Figure 2 near here****

Discussion

The aim of this study was to quantify responses to a mixed-methods, high-intensity, interval-training programme on change-of-direction speed, 20 m speed, repeated-sprint ability and high-intensity running performance in girl football players. This is the first study to quantify individual responses to training in such players and so provides valuable data on effects of maturation status on training response. There were moderate beneficial effects on high-intensity running performance for the group overall; individual responses were less than the typical error. However, the benefit of this intervention before-PHV was unclear. Baseline mean YYIR performance was comparable to that reported in players after-PHV 814 ± 455 m versus 826 ± 160 m (Mujika et al., 2009) although, with much larger variation. A small harmful effect on repeated-sprint ability occurred, which was dependent upon maturation. The response was unclear in players after-PHV but we found a very large, harmful effect before-PHV where 83% of players were slower.

These findings suggest a mixed-methods interval training approach is not effective at enhancing components of football-specific fitness such as high-intensity running or repeated-sprint ability, in pre-pubescent girls. For players after-PHV, YYIR was improved without affecting repeated-sprint ability, suggesting that mechanisms underpinning adaptation on these tests differ. While moderate to large correlations between repeated-sprint time (7 x 35 m) and YYIR have been reported, they account for only 14% and 33% of the variance in YYIR at 20 and 35 m respectively (Ingebrigtsen et al., 2014). Repeated-sprint ability tests with small total sprint distances require a greater contribution from anaerobic means of energy delivery (Pyne, Saunders, Montgomery, Hewitt, & Sheehan, 2008) than YYIR, considered an aerobic-anaerobic, soccer-specific test (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006). Furthermore, children have a lower glycolytic capacity to supply ATP during high-intensity exercise (Boisseau & Delamarche, 2000), which could explain the decrement in repeated-sprint ability before-PHV.

Although research suggests aerobic and anaerobic fitness qualities are trainable throughout adolescence (McNarry & Jones, 2011), methods of eliciting a response should differ. These data provide some support for "windows of opportunity" and recommendations from the Youth Physical Development Model (Lloyd & Oliver, 2012) which, de-emphasises endurance and metabolic conditioning in pre-pubescent children. However, these findings do not support the recommendations to delay endurance and metabolic conditioning as a focus of training until late adolescence and early adulthood, or around 18 years of age. A beneficial effect of our training occurred in 83% of players' at-PHV, and in 78% after-PHV, while all players were under 17 years old. Therefore, it is advantageous to spend time focusing on endurance and metabolic conditioning in girl players, particularly given the demands of the sport to produce repeated high-intensity running.

There were small improvements in change-of-direction speed however, this appeared to be dependent on maturation status. The magnitude of the response was greatest in players after-PHV. This response is important as sex-based differences in agility after puberty in distance runners have been demonstrated, with a plateau occurring in girls (Eisenmann & Malina, 2003). Natural development of change-of-direction speed in pre-pubescent athletes is likely a result of neural mechanisms such as intramuscular co-ordination and improved motor control while improvements in boys after-PHV are related to hormone concentrations e.g. testosterone, growth hormone and insulin-like growth factors (Oliver, Lloyd, & Rumpf, 2013). Improvements in the players after-PHV suggest the training intervention elicited neural adaptations, which can attenuate a plateau in agility performance. This could be important both for physical performance and injury prevention given the role of neuromuscular control during cutting and landing in girls (Ford, Myer, Toms, & Hewett, 2005; Hewett et al., 2006).

There were moderate decrements in change-of-direction speed for players at-PHV. Sixty-seven percent of players decreased performance and moderate individual differences likely reflect differences in the magnitude of the decrement. A possible mechanism for this is adolescent awkwardness associated with accelerated growth, leading to a temporary reduction in motor performance and coordination, evidenced previously in boy football players (Philippaerts et al., 2006). This finding has practical implications, as players at-PHV could show a decline in performance in training tasks that are dependent on agility e.g. small-sided games. Further research should consider more appropriate training interventions for girl football players at this stage of maturation.

There are several limitations to this study, most notably the lack of a control group. However, this reflects a real-world setting where it is unethical, and impractical for practitioners to withhold training interventions from players, and difficult to find appropriately matched controls. The analysis performed on an individual level in this study takes into account potential noise by including typical error of the measurement. Ideally, typical error should be derived from test re-test data taken over the same time period as an intervention, e.g. eight weeks, and include more than two data points per player to reduce influences of order effects (Hopkins, 2015b), however this was not practical in this instance. Furthermore, differences between test and re-test scores were trivial for all measures, which suggests that order effects were not an issue in this study. Finally, the YYIR had poorer reliability in this group than that reported in senior players (Bradley et al., 2012), and might not be the most appropriate test. Despite this, the magnitude of response meant there was a beneficial effect in 68% of players. This study raises concerns over the YYIR in girl football players, perhaps because the initial running speed is too high (Castagna, Impellizzeri, Manzi, & Ditroilo, 2010) and practitioners should consider alternative tests such as the 30:15 intermittent fitness test (Buchheit & Laursen, 2013) or the multi-stage fitness test (Castagna et al., 2010). Despite these limitations this study provides additional data on girl football players and the design is sufficiently robust to provide important practical recommendations.

Conclusion

Practitioners who use mixed-methods high-intensity interval training programmes in girl football players should be cautious with younger players (before-PHV). There are clear benefits of this training in players after-PHV where there were moderate improvements in YYIR with small individual responses, and speed, agility or repeated-sprint performance were not compromised. Players at-PHV decreased T-test performance indicating training prescription at this stage should be carefully considered and monitored on an individual level. Maturation affected response to training, however, baseline fitness and total training load made no substantial difference. There were moderate to large individual differences in response to training for 20 m sprint, T-test and repeated-sprint ability, emphasising the importance of individuality in sport science support.

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Figures

Figure 1: Schematic of the set up for the modified T-test. Players were required to sprint through timing gates A around the cone and 2-m agility pole to line B, then back across to line C and around the cone before sprinting through timing gates A to complete the repetition. This was repeated with players instructed to run first to line C on the second repetition.

Figure 2: Distribution of individual responses to preseason training as a percentage of players within each maturation group for: A: 20 m Sprint, B: Repeated-Sprint Ability; C: T-Test and D: YYIR.