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Effect of maturation on internal load response in chronological and bio-banded training groups in elite youth football players.

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Effect of maturation on internal load response in chronological and bio-banded training groups in elite youth football players.

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This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

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Abstract

The aim of this study was to investigate the effects of relative maturation within training groups on internal load response to matched training sessions. Additionally, training groups were arranged by biological development (bio-banded) to investigate the effects of manipulating the training environment on internal load response. 58 elite academy footballers from the youth development phase (U13, U14, U15, U16), completed 6 chronological and 6 biological age grouped technical training sessions lasting between 75 and 90 minutes at a moderate intensity (RPE ~ 4). Participants were split into quartiles based upon their maturity status, with external and internal load responses collected and analysed for each session. One-way and a repeated measures ANOVA were used to evaluate the difference between quartile of maturity status and relative RPE and sRPE response (z-score), and between RPE and sRPE response in chronological vs bio-banded grouped sessions respectively. All training sessions used in the analysis were matched for a similar external load. There were no significant differences between maturity quartiles and relative RPE response (1^{st}:-0.15, 2^{nd}:0.13, 3^{rd}:0.09, 4^{th}:0.17; $p>0.05$). There was a significant reduction in RPE as a result of bio-banded training when players moved down (chronological: 4.5 ± 0.5 vs biological: 4.2 ± 0.5, $P < 0.05$), but not when players moved up age groups (chronological: 4.3 ± 0.6 vs biological: 4.1 ± 0.3, $P > 0.05$). The results of this study suggest relative maturation does not affect internal load response within a training group of elite academy footballers. Insofar as the development of physical capabilities do not differentiate the internal load response between players in age matched training groups, despite contrasting maturity levels. Further research into whether bio-banded training groups could act as a potentially novel means of modifying internal training load is warranted.

Key words: Bio-banding; training load; maturity; youth football

Chapter 1: Introduction

Background

One of the major factors that impact on the development of youth athletes into senior professionals is the process of growth and maturation. The study of maturation in relation to the development of physical qualities and its interaction with talent development has been widely studied in the literature (Vandendrieessche et al., 2012, Deprez, Fransen, Lenoir, Philippaerts, & Vaeyens, 2015). Maturation refers to the development of bodily tissues, organs and systems towards a mature state (Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015), with the assessment of current status, the timing, and the tempo of maturation being of particular interest. The period of peak height velocity (PHV) is frequently used as an indicator of progress towards maturation and the adolescent growth spurt, which is the onset of the maximum rate of growth in stature of the athlete (Malina et al., 2015). Longitudinal data from the Ghent Youth Soccer Project found an average age at PHV for European youth footballers of approximately 13.8 ± 0.8 years, with an average growth rate of 9.7 ± 1.7 cm per year (Philippaerts et al., 2006). Whilst a similar age at PHV has been found in related studies, it must be noted that this value is a sample size mean, with ranges of age at PHV from 12.9 to 15.4 years found in research focussing on elite youth football players (Van der Sluis et al., 2014, Van der Sluis, Elferink-Gemser, Brink, & Visscher, 2015). This suggests the potential for a wide variance in the timing of maturation between individual players of the same chronological age. Importantly, this wide range of ages that player's may go through PHV spans the whole youth development phase of an academy structure, from which successful schoolboys enters the professional development phase and professional contracts.

Longitudinal research has been carried out tracking the development of physical qualities in youth soccer players throughout adolescence, and during PHV in particular

(Philippaerts et al, 2006). The authors found that physical qualities experienced periods of accelerated development during different time periods, with speed and explosive actions developing quickest before PHV, endurance capability around the time of PHV, and strength and power shortly after PHV during peak weight velocity (PWV) (Malina et al., 2004, Philippaerts et al., 2006). Further research has found that in chronological age matched youth football players, players who were advanced in their biological development and therefore had a higher skeletal age, measured by hand-wrist radiographs, were found to be taller, heavier, and faster than players of a younger skeletal age (Malina et al., 2000, Iuliano-Burns, Mirwald, & Bailey, 2001, Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009, Carling, Le Gall, & Malina, 2012). The variance in the timing of maturation, and the associated development in muscle mass and stature during the period of an athlete's PHV, would likely create more extreme differences in physical stature and ability between players in the same chronological age group. Figueiredo, Coelho e Silva, Cumming, and Malina (2010) supported this notion, finding a range of 15 cm difference in height and 21 kg in weight between boys of the same chronological age group (13-14 years old), with a skeletal age difference of up to 3.7 years. These findings offer some explanation as to why there is a bias towards recruiting earlier maturing players in most youth football academies (Mujuka et al., 2009, Ostocij et al., 2014). With this being said, later maturing players in football, and other team sports, have been found to be more likely to achieve professional status in relation to their earlier maturing peers (Mujika et al., 2009, Ostocij et al., 2014). In a study tracking a Serbian football youth academy, over 60 % of the later maturing players, which constituted just 20 % of the squad composition at under-14 level, achieved the elite level of performance (Ostocij et al., 2014). Strategies to combat player disadvantages due to differences in physical development, including rotating the start date for year groups, 4th quarter birth date recruitment days, and bio-banded competitions are being introduced into elite academy football academies (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017, Sierra-Díaz, Gonzáles, Pastor-Vicendo, & Serra-Olivares, 2017). Therefore, consideration needs to be given to the training and development of the later maturing players within a training group, with particular focus on the challenges they may face as a result of their lesser advanced maturity status in comparison to their peers.

Monitoring training load is widely practiced in sports science as a means of objectifying the demands a given training session is placing on the athlete. Training load can be classified as either external or internal load (Impellizzeri, Rampinini, & Marcora, 2005). The external load is described as the training that has been prescribed to the athletes, for example 4x100m sprints, whereas the internal load is the physiological stress imposed on the athletes by the external load, which can be measured by various physiological markers including heart rate, blood lactate responses, and rate of perceived exertion (RPE) (Brink, Nederhof, Visscher, Schmikli, & Lemmink, 2010a). Research has shown that whilst external load information is useful, it can fail to highlight the individual internal response from athletes. Hill-Haas, Dawson, Coutts, and Rowsell (2009) highlighted this when analysing the external and internal loads elicited from various small sided games in football. The authors found that despite the players completing a lower external load, in terms of less distance covered in a 2 vs 2 small sided game, this game reported the highest internal load measures, including RPE response, in comparison to larger small sided games. It is this relative physiological stress imparted on the athlete which is the stimulus for adaptation to training (Viru & Viru, 2000).

The internal training load experienced by an athlete is highly affected by the external load placed upon them, however internal load also takes into consideration the readiness of the individual for the activity, for example previous training level, illness, and psychosocial factors (Impellizzeri, Rampinini, Coutts, Sasi, & Marcora, 2004). RPE responses as a measure of internal load has garnered attention in athlete monitoring research, especially related to the study of fatigue. Research has shown athletes reporting higher RPE values in response to a standardised exercise session when athletes were in a fatigued state (Snyder, Jeukendrup, Hesselink, Kuipers, & Foster, 1993). Further research also found athletes who experiencing overreaching reported higher RPE responses for a given heart rate (Martin & Anderson, 2000). This research suggests that monitoring RPE as a measure of internal load could be useful in detecting accumulated fatigue in athletes. Monitoring internal load has been suggested to be of particular importance for team sports in identifying differences in training response, where the external load prescribed is often fairly similar across a team of individuals due to group based training exercises, such as small sided-games (Bangsbo, 1994). Research analysing internal load responses to a football specific small sided game drill illustrated this point, when the authors found the subjects with the highest measured $\dot{V}O_{2max}$, measured from testing, operated at the lowest percentage of $\dot{V}O_{2max}$ during the matched training drill (Hoff, WislØff, Engen, Kemi, & Helgerund, 2002). Overall, the literature suggests that internal load monitoring is be able to highlight differences in individual workload from group training sessions; and as a result of the potential range in maturity, and therefore physical development, within the same chronological age group, it is fair to question whether the individual responses to a training session would vary amongst a training group.

It is important for a technical coach to be able to accurately prescribe the intensity of training drills to ensure optimal physical development through periodised plans (Little & Williams, 2007), however, a range of maturity levels within a training group could make this task problematic. Prescribing appropriate workloads could be particularly important for biologically younger players within an age group, as research has shown that repeatedly performing repetitively hard and intense training results in an increased susceptibility to injury and illness (Nieman & Pederson, 1999, Brink et al., 2010b). Brink et al. (2010b) monitored stress and recovery in elite youth soccer players aged between 15 and 18 across two seasons, finding that the occurrence of illnesses and traumatic injuries was related to higher levels of physical stress from training in the week preceding the injury or infection. Further studies in other sports, such as basketball and rugby league, have supported the negative effect of a consistently high training load on the occurrence of injuries and illnesses, with reductions in training loads in pre-season linked with reduced injury rates (Anderson, Triplett-McBride, Forster, Doberstein, & Brice, 2003, Gabbett & Domrow, 2007, Colby, Dawson, Heasman, Rogalski, & Gabbett, 2014, Gabbett, 2016). Osgood-Schlatter's disease (OSG) has been shown to be prevalent amongst youth athletes, particularly between the under 13 and under 14 age groups, where players are likely to be experiencing rapid growth or PHV (Price, Hawkins, Hulse & Hodson, 2004). OSG can be caused from mechanical stresses exceeding the tolerance limits of rapidly developing physis (Caine, DiFiori, & Mafulli, 2006), with further research showing that reducing training workloads in youth athletes can reduce days lost due through injury (Horobeanu, Jones, & Johnson, 2017). Further longitudinal tracking research has found that later maturing players with a lower biological age, experienced significantly more overuse injuries, such as Osgood Schlatter's disease, than earlier maturing players (Van der Sluis et al., 2014). This may in part be explained by inappropriate load prescription from the technical coach, negatively affecting lesser biologically developed players within a varied biological age group, therefore, it is vital that coaches understand the training loads they are placing upon youth football players; as research suggests that consistently high training loads, in a high-intensity sport such as football, could be a factor in increasing days lost to injury due to overloading vulnerable joints as a result of growth and maturation (DiFiori, 2010).

Research Question

There is a growing body of research suggesting that the chronological age groups used in youth soccer academies are not conducive for talent development (Malina, Cumming, Morano, Barron, & Miller, 2005). This is thought to be due to differences in the rates of physical development during the period of adolescence, resulting in a wide range of physical and functional capabilities within a chronological age group. However, research has not yet investigated whether there is a difference in physiological response to training, between players who are more advanced and players who are less advanced in maturity (Van der Sluis et al., 2015). There is a body of literature suggesting that youth athletes can be sensitive to the training load imparted on them, with literature highlighting the negative effects of repeatedly high physical stresses on athletes, including the development of overuse injuries. The aim of this study therefore is to investigate how players with differing levels of maturity within a chronological age group respond to a similar external load being placed on them through technical on field soccer training. It is hypothesized that the players who are less biologically mature will report a higher internal training load in comparison to their biologically advanced peers when a similar external load is placed upon them. Further to this, this study will investigate how manipulating the training environment to lower the biological age variance in a training group affect the players internal training load response.

Chapter 2: Methods

Participants

Data were collected from elite youth football players (n = 57), split across the youth development phase age groups (U13 = 13, U14 = 18, U15 = 13, U16 = 13), from a Premier League football academy. Descriptive data for participants can be found in Table 1. Data were collected from the same weekly technical training session, 48 hours after a competitive fixture, across 12 weeks of uninterrupted training. Participants were exposed to the same volume of training and match play as their age group peers, which ranged from between 7.5 to 10 hours of technical training and one competitive fixture per week. Participants were required to be injury free for the past month of training for data to be analysed, in order minimise the effect of any detraining due missed training. Training load data was only collected and analysed for outfield field players in this study, due to the differing physical activity that goalkeeper's undertake (Salvo, Benito, Calderon, Di Salvo, & Pigozzi, 2008). Written informed consent and parental assent was obtained from the participants. The study was approved by the St. Mary's University ethics committee.

Table 1. Descriptive data of the participants (mean ± SD).

	Age Group			
	U13 (n = 13)	U14 (n = 18)	U15 (n = 13)	U16 (n = 13)
Age (yrs)	13.0 ± 0.3	13.9 ± 0.4	14.9 ± 0.3	15.9 ± 0.3
Height (cm)	157.0 ± 6.6	162.8 ± 6.6	169.9 ± 7.0	179.3 ± 5.2
Weight (kg)	47.8 ± 7.8	50.4 ± 6.3	58.4 ± 9.0	68.6 ± 5.4
Maturity (%PAH)	87.2 ± 2.5	91.4 ± 2.7	95.4 ± 1.7	98.4 ± 0.8

Research Design

Internal and external training load data was collected and analysed across 12 standardised technical training sessions for each age group studied, with players grouped in normal chronological age groupings (CHRON) for 6 sessions, then grouped in biologically matched training groups (BIO) for 6 sessions. Technical sessions were standardised in accordance with the club philosophy on session structure, with a breakdown as follows: 20 minutes of general warm up; 20 minutes of technical practice, (ball manipulation or passing practice); 30 minutes of a skill practice (possession or phase of play based drill); followed by 20 minutes of small-sided games (even numbered game with goalkeepers). Specific drill content and variables, for example pitch sizes, were at the discretion of the technical coach to prescribe as appropriate for their age group, but were directed to elicit a moderate (RPE ~ 4) physical load in their sessions. All technical coaches were highly qualified and experienced working with elite youth football players.

Quantifying Workload

External training load was collected as a means of comparing training session's volume and intensity to ensure all players were being prescribed a similar external load. GPS units (Viper V.2, StatSports, Ireland), sampling at 10 Hz and the accelerometers at 100 Hz, were used to quantify external workload. The data collected from these units was downloaded and analysed using specialist software (Viper, V.2.1.3.0). Work rate (m/min) and metabolic power (W/kg) were selected metrics for use in this study due to their relevance to running loads (Gaudino et al., 2014, Bowen, Gross, Gimpel, & Li, 2016). For sessions when the GPS data was not available for a participant (n=27 of 435, 6 %), because the unit failed to download the data or the data was interrupted due to intermittent satellite signal, the training load data was removed from further analysis. Internal training load was quantified using the RPE (Rate of Perceived Exertion) and session-RPE method (sRPE) method, which have been extensively used in research as a valid and reliable measure of internal load monitoring in football (Foster, 1998, Foster et al., 2001, Impellizzeri et al., 2004, Little & Williams, 2007). Heart rate measures of internal load were not utilised in this study as research has questioned its ability to explain variance in RPE response following high intensity activity, with authors suggesting it take into consideration repeated muscular efforts contributing to perception of fatigue (Coutts, Rampinini, Marcora, Castagna, & Impellizzeri, 2009, Gil-Rey, Lezaun, & Los Arcos, 2015). Furthermore, many football academies do not have access to heart rate monitors for the youth teams reducing the ecological validity of the study. RPE score was collected approximately 30 mins after the completion of the training session using Borg's category ratio score scale (CR10-scale) (Borg, Hassmen, & Lagerstrom, 1987, Brink et al., 2010b). The lapse in time before data collection is to ensure the RPE given will reflect the whole training session and not the most recent activity (Impellizzeri, et al., 2004). The RPE score was combined with the duration of the session to give a session-RPE (sRPE) score (arbitrary units, AU) (Impellizzeri et al., 2004). The session-RPE method was included to as a comparison measure of internal load, and to investigate whether it offered increased sensitivity to changes in internal load response. All participants had been familiarised with the scale prior to the commencement of this study.

Estimating Maturity Status

The Khamis-Roche protocol was used to predict the mature adult height of the participants, which has been shown to be reliable as a non-invasive tool to predict adult height in youth soccer players (Khamis & Roche, 1994, Malina, Coelho e Silva, Figueiredo, Carling, & Beunen, 2012). The Khamis-Roche method was developed on the sample from the Fels Longitudinal Study, with a 2.2 cm median absolute deviation of between actual and predicted mature height at 18 years of age (Khamis & Roche, 1994). The protocol required the participant's height, weight, and date of birth and both parents' height to be collected; parents' heights were self-reported on the consent forms and adjusted using sex specific equations (Epstein, Valoski, Kalarchian, & McCurley, 1995, Malina, Cumming, Morano, Barron, & Miller, 2005) to adjust for the tendency to overestimate when self-reporting height (Cumming, Standage, & Malina, 2004). Participant's height was measured in a stretch stature using a wall mounted stadiometer to the nearest 0.1 cm (Tanita Leicester Portable Stadiometer, UK); participants stood erect without shoes, with their head in the Frankfurt plane and heels together (Van der Sluis et al., 2015). Participant's body weight was measured using digital scales, to the nearest 0.1 kg (Seca 803, Birmingham, UK). Measurements were collected by the same measurer to account for error in measurement (Stratton & Oliver, 2012). The participant's current height was represented as a percentage of their predicted adult height (% PAH), to the nearest 0.1 %, providing an estimate of biological maturity for comparison across participants (Beunen et al., 1997, Beunen, Rogol, & Malina, 2006, Malina, Dompier, Powell, Barron, & Moore, 2007). Bio-banded training squads were created by grouping players by current percentage of predicted adult height as opposed to normal chronological age groupings, with squad sizes determined by positional requirements of the squad for fixtures. This resulted in a two sub groups being formed, players who moved up from their normal chronological age group (n=4) and players who moved down from their normal chronological age group (n=9). Once established, participants trained in their biological groups for one of their weekly sessions and their competitive fixture, with the groupings remaining consistent across the 6 weeks.

Statistical Analysis

Data was analysed using Statistical package for the Social Sciences (SPSS v20.0, SPSS Inc, Chicago, Ill). A two-way repeated measures ANOVA (time x training group) was used to assess if significant differences in external load measures (work rate and metabolic power) were present in the 6 chronological and 6 bio-banded training sessions. Significant differences in external load highlighted a different physical stimulus being prescribed in comparison to the other training sessions, meaning any comparison of internal load would be unfair; therefore these sessions were removed from further analysis. Using percentage of predicted adult height data, players were assigned to quartiles relative to each individual training session; with the 1st

quartile representing the earlier maturers, the 2nd and 3rd quartiles representing the on-time maturers, and the 4th quartile representing the later maturers within that session (Iuliano-Burns et al., 2001, Aroso & Cumming, 2007). RPE and sRPE responses were then adjusted into z-scores relative to that session, to highlight the difference away from the session squad mean. A one-way ANOVA was used to investigate the effect of maturity quartiles on the relative RPE and sRPE z-scores across the 6 chronological training sessions for all age groups. To examine the effect of bio-banded training, paired samples t-tests were used to compare RPE and sRPE response across both training group conditions (chronological and biobanded). Participants had to attend at least four of each session condition for their data to be included in the analysis. Results were deemed significant if p was less than 0.05, with Greenhouse-Geisser correction factor applied when assumptions of sphericity were violated. Effect sizes were calculated using Cohen's d (0.2 = small, 0.5 = moderate, 0.8 = large effect) and partial eta squared (η_p^2) (0.01 = small, 0.06 = moderate, 0.14 = large effect) (Cohen, 1988), with 95 % confidence limits set for the analysis.

Chapter 3: Results

External Loading

The external load results of the chronological and bio-banded training sessions are presented in Table 2. There was a significant interaction effect ($F_{(3.465,1246.934)}$= 18.770, $p < 0.05$, $\eta_p^2 = 0.254$) and main effect for time ($F_{(3.481, 419.074)}$= 7.852, $p < 0.05$, $\eta_p^2 = 0.125$), but not for training group ($F_{(1,434.411)}$= 2.170, $p > 0.05$, $\eta_p^2 = 0.038$) when analysing work rate across 12 training sessions; with analysis of metabolic power presenting a significant interaction effect ($F_{(3.988,11.766)}$= 19.413, $p < 0.05$, $\eta_p^2 = 0.261$) and group effects for time ($F_{(3.756, 1.717)}$= 3.130, $p < 0.05$, $\eta_p^2 = 0.54$) and training group ($F_{(1,6.384)}$= 3.755, $p < 0.05$, $\eta_p^2 = 0.64$), revealing that not all of the training sessions prescribed the same intensity and external load. *Post hoc* tests highlighted significant differences between training session 3 and the other trials, however a significant interaction effect was still found for work rate with session 3 removed from the analysis ($F_{(2.793,1480.520)}$= 21.269, $p < 0.05$, $\eta_p^2 = 0.279$). Following analysis of the profile plots, it was decided session 6 presented as outlier data, and was subsequently removed from further analysis. Following the removal of session 3 and session 6 from the analysis, no significant interaction effect was found for work rate ($F_{(2.654,24.195)}$= 0.644, $p > 0.05$, $\eta_p^2 = 0.12$) and metabolic power ($F_{(3,0.231)}$= 0.577, $p > 0.05$, $\eta_p^2 =0.010$) with no main effects in work rate for time ($F_{(3,37.392)}$= 1.374, $p > 0.05$, $\eta_p^2 =0.24$), or training group ($F_{(1,272.189)}$= 2.336, $p > 0.05$, $\eta_p^2 = 0.41$), and metabolic power for time ($F_{(3,0.102)}$= 0.310, $p > 0.05$, $\eta_p^2 =0.006$) and training group ($F_{(1,2.104)}$= 1.971, $p > 0.05$, $\eta_p^2 = 0.035$). Consequently, these 4 sessions were removed from further analysis.

Table 2. External load outputs from technical training sessions in chronological and biological groupings (mean ± SD).

External Load Metrics	Chronological						Biological					
	1	2	3	4	5	6	1	2	3	4	5	6
Work Rate (m/min)	51.1 ± 5.6¥	51.7 ± 7.5¥	45.5 ± 9.1	52.3 ± 7.0¥	53.2 ± 9.4¥	44.6 ± 10.6¥	50.5 ± 6.9¥	50.7 ± 9.7¥	49.4 ± 7.4	49.9 ± 6.5¥	51.0 ± 7.5¥	56.6 ± 13.2
Average Metabolic Power (W/kg)	4.8 ± 0.6[a]	4.9 ± 0.7	4.3 ± 0.9	4.9 ± 0.7[b]	5.0 ± 0.9	4.1 ± 1.0	4.8 ± 0.7[a]	4.7 ± 0.9	4.8 ± 0.8	4.7 ± 0.8[b]	4.8 ± 0.8	5.4 ± 1.2

¥ Significant difference between chronological and biological session 3 ($P < 0.05$)

Superscripted letters denote significant ($P < 0.05$) differences between: [a]Trial 1 vs Trial 3; [b]Trial 3 vs Trial 4.

Effect of Maturity on Internal Load Response

The average RPE response to chronological training was 4.4 ± 0.6, with a sRPE average of 382 ± 55au. Figure 1 shows the average relative RPE response when players were classified into within-session quartiles of maturity. There was no significant effect of maturity, classified by quartiles, on relative RPE score ($F_{(3,73)}$= 0.763, $p > 0.05$, $\eta_p^2 = 0.032$). There was also no significant difference in relative sRPE score for quartiles of within session maturity ($F_{(3,73)}$= 0.665, $p > 0.05$, $\eta_p^2 = 0.28$).

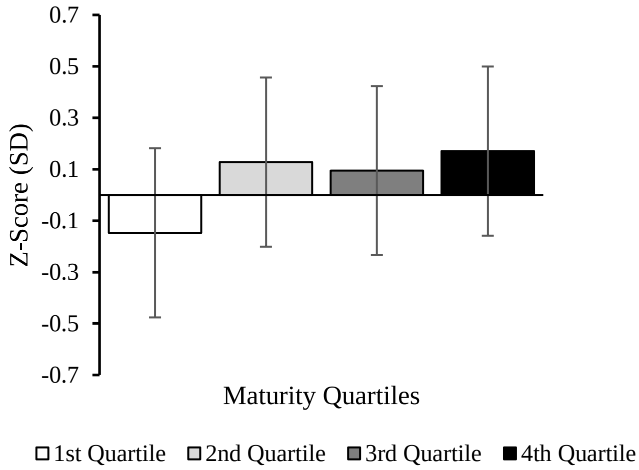

Figure 1. The effects of maturity quartile on relative RPE response to technical training sessions, where 1st quartile represents earlier maturers, 2nd and 3rd represent on time maturers, and 4th quartile represents.

Effect of Player Movement on Internal Load Response

The change in the range of maturity status by biologically grouping players can be found in Table 3. There was a significant effect of downward player movement from their chronological age group into a bio-banded age group for RPE ($t_{(8)} = 2.312$, $p < 0.05$, $d = 0.71$), and for sRPE measures ($t_{(8)}$= 3.198, $p < 0.05$, $d = 0.99$). Whereby bio-banded training resulted in a statistically significant reduction in RPE response (mean difference: 0.36; 95 % likely range 0.001 - 0.710), and sRPE response (mean difference: 44.94, 95 % likely range 12.5 – 77.4). In contrast, no significant effects were observed when players moved up an age group into a bio-banded group from their chronological for RPE ($t_{(3)}$= 0.575, p < 0.05, d = 0.26), and sRPE ($t_{(3)}$= 1.413, p < 0.05, d = 0.54). The Cohen's effect size value suggested small to moderate practical significance of the results. The data showed no change in RPE response (mean difference: 0.13; 95 % likely range -0.567 - 0.817) and sRPE response (mean difference: 24.8, 95 % likely range -31.0 – 80.6) in bio-banded grouped sessions compared to chronological age grouped sessions.

Table 3. Ranges of maturity status of chronological age training groups and biological age training groups (minimum - maximum).

	Age Group			
	U13	U14	U15	U16
Chronological (%PAH)	84.9 – 92.1	87.1 – 95.7	91.4 – 97.6	96.7 – 99.7
Biological (%PAH)	84.9 – 89.1	89.4 – 94.7	95.0 – 97.6	96.7 – 99.7

Chapter 4: Discussion

The aim of this study was to examine whether relative maturity status within a training group affected the internal load response to a standardised football training session, in elite academy footballers. The results showed that relative maturity did not significantly affect the internal training load response of players from across the youth development phase of an elite academy. Furthermore, this study was the first of its kind to investigate the effect of player movement, biobanded training, on internal load response to training, with findings indicating a significant reduction in training load when players were moved to a younger age group. This study also demonstrated an effective means of reducing the biological age range within a training group (see Table 3). The findings from this present study provide insight on training workload and maturation in elite academy footballers, and novel findings on the effect manipulating the training environment by biologically grouping players on internal loading.

The training workload reported in the chronological and biological training sessions is comparable with values seen in the literature for football training sessions. Previous research using U18 players found similar RPE responses to those reported in this study, whilst Leiper Watson, Evans, and Dvorak (2008) used a 15 point Borg scale, the results translated to similar responses on the CR10-scale used in this study. Research investigating elite footballers found similar sRPE responses for in-season training (250-400au) (Jeong, Reilly, Morton, Sang-Won, & Drust, 2011), and external load outputs during in-season football training in comparison to this study (Malone, Di Michele, Morgans, Burgess, Morton, & Drust, 2015). In-season training has been shown to be have a higher emphasis on technical and tactical work and thus lower external load outputs than during pre-season training, in which the development of physiological capabilities is a higher priority and as such produces higher external loads than found in this study (Jeong et al., 2011). Interestingly, higher internal training load responses have been observed for elite academy footballers, with U14's reporting an average RPE of 6.2, and U16 training reporting 6.3 in response to on-field football training (Wrigley Drust, Stratton, Scott, & Gregson, 2012). Jeong and colleagues (2011) did find varying internal load responses for sessions focussed on technical/tactical outcomes (RPE = 4 ± 1) vs physical outcomes (RPE = 7 ± 1); highlighting that the objective of the training session can affect the physiological response elicited. Therefore, the results of this study suggest that the prescribed training may have been more technically and tactically focussed than physically taxing. This may have influenced the outcomes of the study, as any physical advantages earlier maturing players may have, due to advanced biological development of fitness, speed and strength qualities, would have had limited opportunities to present themselves in predominantly technical/tactical focussed sessions. Research examining data from U16 competitive matches show that earlier maturers perform more high intensity actions and repeated high intensity actions, as well as a higher maximal sprint speed than their less mature peers (Buchheit & Mendez-Villanueva, 2014). This research, alongside the findings of this study, suggest that a higher physically demanding session may have been required in order to see any differences in workload, and that the intensity of session prescribed as a potential limiting factor in identifying maturity-related differences in training workload in this study. Further study should investigate the effects of physically demanding technical training, when looking for maturity-related difference in workload.

To this author's knowledge, this is the first study to report training workload with reference to biological maturity in elite youth football. The lack of affect by maturity status on relative RPE response may be explained by investigating the maturity-related physiological differences within the training group. Whilst it has been shown that physiological changes throughout adolescence lead to an increase in aerobic capacity, peaking in velocity of growth around PHV (Philippaerts et al., 2006), it could be questioned whether the effect of this increase would be evident within a small age-matched training group. Whilst aerobic capacity was found to peak during PHV, increases in capacity slightly lower than the peak were also observed 6 months either side of PHV (Philippaerts et al., 2006). This extended period of development may result in the peak in growth not being enough to separate the participants from the peers at contrasting stages of maturity, especially in sub-maximal training. Research investigating the aerobic capacity academy football players failed to find a significant difference in Yo-Yo IR1 score of players in the U12-U13, U14-U15, and U16-U17 age groups (Deprez, Vaeyens, Coutts, Lenoir, & Philippaerts, 2012). This findings may help to explain the results from the current study, in that the physiological developments of the aerobic system during maturity, may not have been large enough to differentiate fitness levels between the squad, resulting in similar perception of effort in matched tasks. Several authors have suggested that the talent identification and selection processes youth football players, in order to enter and remain in an elite academy, may create homogenous groups of players possessing very similar physiological capabilities (Carling, Le Gall, Reilly, & Williams, 2009, Deprez et al., 2012). The authors also suggested that as a result of players receiving squad-based training protocols, as such receiving similar exposure hours and physical stimulus, a homogeneity of training outcome may also appear (Deprez et al., 2012). This being said, the use of RPE and sRPE methods to quantify internal load is a limitation of this study. Whilst they have been suggested as a valid measure of global internal load, high coefficient of variance (31.9 %) have been reported in response to intermittent activity (Scott, Black, Quinn, & Coutts, 2013). Furthermore, the sensitivity to small changes in perception have been questioned, which is relevant to the results of this study where small changes were found. However, authors have stated the difficulty in determining reliability of RPE scales due to the multifactorial nature of perception of effort (Day, McGuigan, Brice, & Foster, 2004), and the CR10 scale as used in this study was found to be as valid as more refined and suggested to be more sensitive measures

(Scott et al., 2013). This being said, the limitations of RPE sensitivity and reliability must be considered when interpreting the results of this study and may explain why very small changes were detected; further investigation should include multiple measures of internal load in an effort to overcome these limitations and provide clarity in findings.

Whilst the above studies have investigated the influence of players with varying chronological ages within a year group in elite football, it must be noted that whilst relative age can account for at most 1 year difference in chronological age, biological development can vary as much as 6 years in extreme cases between players of the same chronological age (Johnson, Farooq, & Whitely, 2017). In the U14 group analysed in this study, two players at the lowest and highest % PAH (87.1 % and 95.7 % respectively) represent the typical onset and conclusion of the adolescent growth spurt; where less than 89% would be classed as pre-pubertal, and 95 % and above would be post-pubertal (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017). This difference represents the potential wide range in biological development between players who usually train within the same age group. Interestingly, research by Figueiredo et al. (2009) on the effect of contrasting maturity status on physical capabilities amongst soccer players failed to find a significant difference between them. However this research compared non-elite players to elite players, whereas an elite vs elite comparison would be insightful in understanding the effect of maturity on physiological capabilities of players in the same age group at an elite football academy. Further research should investigate the range in physical qualities, including endurance, present within elite training groups and how these interact with internal training load response.

Whilst relative maturity within a training group did not cause a significant difference in internal training load response, this study did find a significant difference in internal training load by manipulating the training environment through biologically grouping players for training. A significant difference was found when players moved down in training groups, with players moving down to a biologically matched group causing internal training load response to significantly reduce. Table 2 highlights the ranges in maturity status of the players present in chronological age groups. The U14 age group (8.6 %) show the highest range of maturity within the squad, which is in accordance to findings the literature (Malina, Ribeiro, Arosa, & Cumming, 2007). However this range was able to be reduced through bio-banding training groups (5.3 %). The concept of biologically grouping training, or bio-banding, in youth sports is gaining popularity in elite youth sports (Cumming et al., 2017). The premise of bio-banding is centred on limiting some of the disadvantages, including selection biases, of chronological age groupings. One proposed benefit of bio-banded training was to accommodate individual differences in maturity status, and adjust the training load they received (Cumming et al., 2017). The results of this study suggest that by moving a later maturing player down into a biologically matched group, the relative training load can be lowered for the individual despite a similar external load being prescribed. This could be beneficial as temporary intervention, as modifying training loads present a favourable option to potential days lost to burnout or overuse injuries, even if there is potential for a level of detraining (DiFiori et al., 2014). However, as stated previously the difference found within this study, when considering the confidence intervals, show small change in RPE response and must be interpreted with understanding of the limitations of the RPE and sRPE methods discussed previously.

Potentially advanced fitness levels due to more advanced training methods in their normal age group could explain a lower relative effort needed to complete the training drills. However, the psychological impact of training with peers of a younger chronological age could also help to explain the findings. Research investigating internal load by Moreira, McGuigan, Arruda, Freitas, and Aoki (2012) examined objective (cortisol) and subjective (sRPE) measures of internal load in response to a simulated and official basketball matches. The authors found that both internal load markers diminished in the simulated match play, suggesting that the environment can affect response to a matched external load (Moreira et al., 2012). One of the benefits of internal load monitoring is that it provides a holistic athlete response, taking into account other factors than just the physical activity, including stress response (Impellizzeri et al., 2004). In playing down an age group, players are removed from comparison against their peers and judgement from their technical coach; alongside this they are moving from a training group which may be stretching them, due to a lower maturity status, to one where they are better matched (Malina et al., 2007, Figueiredo et al., 2009). This may lead to a more relaxed environment and lower stress response during training (Gaab, Rohleder, Nater, & Ehlert, 2005), in turn lowering the internal load response. Initial player feedback obtained through a series of focus groups from a Premier League bio-banding initiative, found that later maturing players reported positive experiences from playing down an age group. These include greater feelings of self-confidence, in terms of being able to try skills and in their ability to compete, and also having the opportunity to act as a leader within the group (Bengsch, 2016). This would support the suggestion of a less pressured environment, potentially influencing the internal training load response. This could have practical applications for coaches, including later maturers, as means of providing a varied environment for players eliciting a lower stress response, reducing the monotony of training and risk of burnout (DiFiori et al., 2014). However, since the psychological effects of bio-banded training appear to have not been previously studied in the literature, further research is needed to investigate and explain these findings further.

In contrast, no difference was found when players moved up into an older chronological age group. Whilst the findings of this study trend against explanation for the reduction in training load given above, the lack of difference found and direction of change could attributed to the small sample size of the moving up group. Part of forming the biological training groups was also to fulfil biologically matched fixtures, resulting in each squad having positional requirements, leading to small number of players moving up. As a small sample size increases the chance of type II error and lowers the statistical power of the findings (Faber & Fonseca, 2014), this can be deemed a limitation of these results. However, further investigation into the effect of player movement, both up and down age groups, seems warranted.

Several limitations to this study have been mentioned throughout the discussion and should be considered when interpreting the results. A further limitation is that whilst every effort was made to control the prescription of external load within the technical session, the session content was flexible depending on session attendance. In instances this lead to smaller or larger numbered small sided games, or varied pitch sizes being utilised compared to the other sessions. Whilst research has shown pitch size, team numbers and other manipulations to have an effect on the physical demands of football small-sided games (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011, Castellano, Casamichana, & Dellal, 2013), this limitation was minimised by removing any sessions which were significantly different in the external load variables from the analysis. Whilst it was the intention of this author to replicate normal training environments, further research should investigate monitoring internal load with more controlled training load prescription, potentially as found in similar studies (Hill-Haas et al., 2009).

Chapter 5: Practical Applications

The results of this present study suggest that relative maturity within training groups does not significantly affect the player's internal training load response. This is helpful for technical and strength & conditioning coaches to know that players, especially later maturers, within the training group are not being disproportionately affected by the training load prescribed. The literature suggests that a homogeneity of training and adaptation may be responsible for this. Further investigation is needed to understand if group-based training protocols are developing physiological capabilities maximally in elite academy football players. Furthermore, this study presents a means by which to potentially reduce the internal load response of players through bio-banded training groups. Whilst further investigation is needed to explore these findings further, bio-banded training may offer a means of reducing training loads for identified players at risk of overuse and burnout injuries.

Chapter 6: References

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Chapter 7: Appendices

Appendix 1. Signed Ethics Application

St Mary's University Twickenham London

13 February 2017 Unique Ref: SMEC_2016-17_048

Sam Beaglehole (SHAS): 'Is relative training load affected by maturation and training environment in elite youth football players?'

Dear Sam

University Ethics Sub-Committee

Thank you for submitting your ethics application for the above research.

I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.

Yours sincerely

Prof Conor Gissane
Chair, Ethics Sub-Committee

Cc Dr Stephen Patterson

Appendix 2. Participant Information Sheet

PARTICIPANT INFORMATION SHEET (Youth)

Is relative training load affected by maturation and training environment in elite youth football?

- The purpose of the study is to investigate how different maturity statuses within a training age group (earlier, average, and later) may affect the physiological response to a technical training session. Secondly, to also investigate whether closer matching of the maturity status of the training squad (bio-banded) affects the physiological response to training when compared to a non-matched training squad (normal training squad). This information will help guide decisions by coaches and strength & conditioning coaches on load monitoring, planning, and the organisation of training groups (chronological or biological ages).
- I am inviting you to take part in this study as you are part of the population that is relevant to my study.
    - As you are an elite youth football player completing regular technical training in groups organised by chronological age. Also, you have been injury free for 1 month and have completed at least two weeks of training leading up to data collection.
- The results will be written up as part of my MSc. dissertation project for St. Mary's University College.

What your participation in this study will involve?

- If you agree to take part you we will use some of the basic measurements we collect, including your height and weight, to establish your percentage of predicted adult height at the time of intervention. Should your biological age be very different to the rest of your training squad, you will be placed into a biobanded squad which will be closer matched to your maturity for a 6 week period. This is the same as the biobanded training groups previously organised for the schoolboy's age groups. Your rate of perceived exertion (RPE) was collected after one technical training session each week.

Information for you

- You are entitled to refuse for your data to be used in this study. Your data may be withdraw from the study at any time via written communication; there is a reply slip at the bottom of the consent form.
- Any information collected from your participation in this study was in anonymity.

- Your participation in the project will be kept confidential and anonymous.
- Agreement to participate in this research should not compromise your legal rights if something goes wrong.

Who am I?

- Sam Beaglehole, Assistant Academy Strength & Conditioning Coach at Southampton FC, and MSc. Student at St. Mary's University College, Twickenham.
- Contact Information: Mobile – 07894 573 090; E-mail – 080073@live.stmarys.ac.uk / sbeaglehole@saintsfc.co.uk

Benefits from taking part

You will be able to gain an insight into how you are monitored as a youth athlete at Southampton FC, whilst also helping to inform decisions by the technical coaching staff as to how your training is organised to ensure you are receiving the best programme for your athletic development. Feedback on the results of the study will be provided in a write up summarising the findings.

Thank you.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Appendix 3. Parent/Guardian Information Sheet

St Mary's University College Twickenham London

PARENT/GUARDIAN INFORMATION SHEET

Is relative training load affected by maturation and training environment in elite youth football?

- The purpose of the study is to investigate how different maturity statuses within a training age group (earlier, average, and later) may affect the physiological response to technical training sessions. Secondly, to also investigate whether closer matching of the maturation status of the training squad (bio-banded) affects the physiological response to training when compared to a non-matched training squad (normal training squad). This information will help guide decisions by coaches and strength & conditioning coaches on load monitoring, planning, and the organisation of training groups.
- I am inviting you to take part in this study as you are part of the population that is relevant to my study.
    - As your child is an elite youth football player completing regular technical training in groups organised by chronological age.
- The results will be written up as part of my MSc. dissertation project for St. Mary's University.

What your participation in this study will involve?

- If you and your son agrees to take part, your parental height data, already collected by the medical department, will be used alongside your son's measurements to establish his predicted adult height. This process is used regularly by the club to inform us of the biological age of your son, which helps us to understand their physical development through maturation. Due to the individual nature of maturation, with regards to the timing and tempo it occurs within youths, there is often a spread of maturational statuses within a chronological age group. Where your son's biological age was very different to the rest of their normal training squad, they were placed into a biobanded training squad which will be closer matched to their maturity for a 6 week period. This is the same as the biobanded training groups previously organised for the schoolboy's age groups. They completed technical training sessions and matches as normal but in these newly formed squads, and were asked to report their rate of perceived exertion (RPE) for that session 30 minutes after completion of the session as is normal procedure as part of the monitoring procedures in the club.

Information for you

- You and your son are entitled to refuse for his data to be used. Your data may be withdrawn from the study at any time via written communication; there is a reply slip at the bottom of the consent form.
- Any information collected from your son's participation in this study will be used in anonymity.
- Your participation in the project will be kept confidential and anonymous.
- Agreement to participate in this research should not compromise you or your son's legal rights if something goes wrong.

Who am I?

- Sam Beaglehole, Assistant Academy Strength & Conditioning Coach at Southampton FC, and MSc. Student at St. Mary's University College, Twickenham.
- Contact Information: Mobile – 07894 573 090; E-mail – 080073@live.stmarys.ac.uk / sbeaglehole@saintsfc.co.uk

Benefits from taking part

You and your son will be able to gain an insight into how you are monitored as a youth athlete at Southampton FC, whilst also helping to inform decisions by the technical coaching staff as to how training is organised to ensure each player is receiving the best programme for their athletic development. Feedback on the results of the study will be provided in a write up summarising the findings to Southampton FC coaches and medical staff.

Thank you.

Appendix 4. Participant Consent Form

St Mary's University College Twickenham London

St Mary's University, School of Human Sciences

CONFIDENTIAL CONSENT FORM (Participant)

All sections of this form must be completed

Confidential Consent Form
I have been made aware of the exercise protocol by the *Test Coordinator and I have had the opportunity to ask questions. Consequently, I agree to participate in the proposed protocol(s) which I am voluntarily undertaking. I fully understand the risks and benefits involved and that I am free to withdraw from the test/study at any point. I am aware that my data may not be used in the event of an injury in the month prior to or during the data collection period.

I agree that the *Test Coordinator will retain this form in accordance with the Data Protection Act 1998 throughout the testing period and will retain the form after all tests have been completed.

I release St Mary's University and the *Test Coordinator from all liability for injury and/or illness during or after testing, unless this has arisen due to negligence on the part of the test coordinator/university.

Print Child's name:		**Signature:**		**Date:**	
Witness name:		**Witness signature:**		**Date:**	

Appendix 5. Parental Consent Form

Parental Consent Form

Name of Participant: ____

Title of the Project: Is training load affected by maturation and training environment in elite youth football?

Main investigator and contact details:

Sam Beaglehole, Assistant Academy Strength & Conditioning Coach at Southampton FC, and MSc. Student at St. Mary's University, Twickenham.

Contact Information: Mobile – 07894 573 090; E-mail – 080073@live.stmarys.ac.uk / sbeaglehole@saintsfc.co.uk

1. I agree to my child taking part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my child's role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw my child from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I and my child provides will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I and my child have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of parent (print)……………………………………………………………………………………..

Parental height (cm) Dad ………. Mum ……….

Signed………………..…………………………… Date…………………………........

If you wish to withdraw your child from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW MY CHILD FROM THIS STUDY

Name of Participant: ____

Name of Parent ____

Signed: __________________________________ Date: _____________________