Seasonal training and match load and micro-cycle periodization in male Premier League academy soccer players

Hannon, Marcus P.; Coleman, Nicholas M.; Parker, Lloyd J.F.; McKeown, John; Unnithan, Viswanath B.; Close, Graeme L.; Drust, Barry; Morton, James P.

DOI:
10.1080/02640414.2021.1899610

Journal of Sports Sciences

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rjsp20

Seasonal training and match load and micro-cycle periodization in male Premier League academy soccer players

Marcus P. Hannon, Nicholas M Coleman, Lloyd J. F. Parker, John McKeown, Viswanath B. Unnithan, Graeme L. Close, Barry Drust & James P. Morton

To cite this article: Marcus P. Hannon, Nicholas M Coleman, Lloyd J. F. Parker, John McKeown, Viswanath B. Unnithan, Graeme L. Close, Barry Drust & James P. Morton (2021) Seasonal training and match load and micro-cycle periodization in male Premier League academy soccer players, Journal of Sports Sciences, 39:16, 1838-1849, DOI: 10.1080/02640414.2021.1899610

To link to this article: https://doi.org/10.1080/02640414.2021.1899610

JOURNAL OF SPORTS SCIENCES
2021, VOL. 39, NO. 16, 1838–1849
https://doi.org/10.1080/02640414.2021.1899610

Routledge
Taylor & Francis Group

PHYSIOLOGY AND NUTRITION

OPEN ACCESS Check for updates

Seasonal training and match load and micro-cycle periodization in male Premier League academy soccer players

Marcus P. Hannon[a,b], Nicholas M Coleman[b], Lloyd J. F. Parker[a,b], John McKeown[b], Viswanath B. Unnithan[c], Graeme L. Close[a,b], Barry Drust[d] and James P. Morton[a]

[a]Research Institute for Sport and Exercise Sciences (RISES), Liverpool John Moores University, Liverpool, UK; [b]Everton Football Club, Liverpool, UK; [c]Research Institute of Clinical Exercise and Health Science, School of Health and Life Sciences, University of the West of Scotland, Hamilton, UK; [d]School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, Birmingham, UK

ABSTRACT

We quantified on pitch external loading of English Premier League (EPL) academy soccer players (n=76; U12-U18 age groups) over an entire competitive season. Mean accumulative weekly duration and total distance, respectively, was similar in the U12 (329±29 min; 19.9±2.2 km), U13 (323±29 min; 20.0±2.0 km) and U14 (339±25 min; 21.7±2.0 km; P>0.05 for all comparisons) age-groups, though all teams were less than U15 (421±15 min; 26.2±2.1 km), U16 (427±20 min; 25.9±2.5 km) and U18 (398±30 min; 26.1±2.6 km) players (P<0.05 for all comparisons). Mean weekly high-speed running and sprint distance was not different between U12 (220±95 m and 6±9 m respectively), U13 (331±212 m and 6±27 m) and U14 (448±193 m and 21±29 m) age-groups (P>0.05 for all pairwise comparisons) though all squads were less than U15 (657±242 m and 49±98 m), U16 (749 ±152 m and 95±55 m) and U18 (979±254 m and 123±56 m) age-groups (P<0.05 for all pairwise comparisons). Data demonstrate that absolute weekly training volume in EPL academy soccer players increases throughout the academy pathway. Furthermore, although U16-U18 players are capable of achieving similar training and match volumes as previously reported in adult EPL players, they do not yet achieve the absolute intensities of adult EPL players.

ARTICLE HISTORY
Accepted 3 March 2021

KEYWORDS
Player development; load monitoring; GPS; periodization; LTAD

Introduction

Despite more than four decades of research examining the physical demands of soccer match play in adult players (Barnes et al., 2014; Reilly & Thomas, 1979), detailed analysis of the customary training loads of professional players is comparatively limited (Anderson et al., 2016; Malone et al., 2015). Nonetheless, available data demonstrate that training loads are lower than those experienced in match play, as evidenced by parameters such as total distance (<7 km vs. ~10-13 km), mean speed (<80 m·min^{-1} vs. ~100-120 m·min^{-1}), high-speed running distance (<300 m vs. >900 m) and sprint distance (<150 m vs. >200 m) (Anderson et al., 2016). In contrast to adult players, the habitual training loads completed by academy soccer players are less well studied. Indeed, previous reports to date are limited to quantifying the accumulative training and match load (TML) over a period of one-to-two weeks (Coutinho et al., 2015; Hannon et al., 2021; Wrigley et al., 2012) and are often confined to internal measures such as heart rate and/or rating of perceived exertion (Wrigley et al., 2012) or single training metrics such as session duration (Brownlee et al., 2018).

Given the use of GPS technology as a monitoring tool to quantify external loading in adult soccer players (Anderson et al., 2016; Malone et al., 2015), there is a definitive need to also quantify the absolute loading patterns completed by academy players so as to ascertain when players are physically capable of achieving similar volumes (i.e., total distances) and intensities (i.e., distances attained within specific absolute speed thresholds) that are associated with adult soccer. In this regard, we recently quantified the training and match volume in male players from an English Premier League (EPL) academy over a two-week in-season period. We specifically observed that physical loading patterns (e.g., accumulative total distance) progressively increased from under (U)12/13 (38.3 ± 5.1 km), U15 (53.7 ± 4.5 km) and U18 (54.4 ± 7.1 km) age-groups (Hannon et al., 2021). Such increases in absolute training load in conjunction with increases in fat-free mass also resulted in increased total daily energy expenditure (TDEE) between age-groups (2859 ± 265, 3029 ± 262 and 3586 ± 487 kcal·day^{-1} in the U12/13, U15 and U18 age-groups, respectively) (Hannon et al., 2021). It is noteworthy that weekly loading for the U18 players and the associated mean daily TDEE was comparable to previously published data from adult EPL (26 ± 5 km·week^{-1}, 3566 ± 585 kcal·day^{-1}) and Dutch Eredivisie (~35 km·week^{-1}, 3285 ± 354 kcal·day^{-1}) players (Anderson et al., 2017; Brinkmans et al., 2019). Additionally, we also observed that individual players in the U12/13 and U15 age-groups also presented with weekly training loads and TDEE that were comparable to (or in some cases exceeded) adult male players.

CONTACT James P. Morton J.P.Morton@ljmu.ac.uk Research Institute for Sport and Exercise Sciences (RISES), Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK

Nonetheless, we acknowledge that such assessments of physical loading and energy expenditure were limited to a two-week in-season period and hence may not be representative of the typical loading patterns that players experience throughout the course of an entire season. Research from adult players also demonstrates that daily training load is periodized across the weekly microcycle, largely as a reflection of fixture schedule and proximity to the next game (Anderson et al., 2016). However, it is not yet clear if such periodization models are also apparent in academy players.

A detailed understanding of potential periodization and progressions in loading patterns between age groups (especially during periods of growth and maturation) is of course important to help reduce injury risk (Bowen et al., 2017) and minimize time lost from training (Bourdon et al., 2017; Wrigley et al., 2012). Whilst previous reports have documented increases in both training volume and intensity between U14 and U18 age-groups (Wrigley et al., 2012), it is noteworthy that such data were collected before the introduction of the Premier League's Elite Player Performance Plan (EPPP), the latter recommending ~600-720 minutes of pitch-based activity per week for a U12 player rising to ~720-840 minutes per week for a U23 player (Premier League, 2011). Although such recommendations are congruent with traditional long-term athletic development (LTAD) models (Balyi & Hamilton, 2004; Lloyd et al., 2015), no data exist to corroborate whether EPL academies are adhering to such training models throughout the academy pathway.

With this in mind, the aims of the present study were to therefore (1) quantify the accumulative weekly training and match load for each age-group within an EPL academy over the course of a season and (2) to evaluate the periodization of daily loading patterns within a weekly microcycle for each age-group within an EPL academy. To this end, daily external physical loads were collected throughout the 2018–2019 season in a cohort of male academy soccer players ranging from U12 to U18.

Materials & methods

Participants

One hundred and eleven male outfield soccer players from a Category One EPL soccer academy initially volunteered to participate in the study. However, following the data filtering process (described in an overview of study design) 76 (n = 76) were included for the final analysis. Players were categorized according to their respective age-group (U12, U13, U14, U15, U16 and U18) based upon their chronological age. Participant characteristics are presented in Table 1. The study was approved by the Wales Research Ethics Committee, UK (REC approval number: 17/WA/0228), and written informed parental/guardian consent and player assent were obtained, respectively.

SS: start of season; ES: end of season; Δ: delta, i.e. changes throughout the season. [a] Significant difference from U12 age-group, $P < 0.05$. [b]Significant difference from U13 age-group, $P < 0.05$. [c]Significant difference from U14 age-group, $P < 0.05$. [d]Significant difference from U15 age-group, $P < 0.05$. [e]Significant difference from U16 age-group, $P < 0.05$. [f]Significant difference from U18 age-group, $P < 0.05$.

Overview of study design

Training and match data were collected throughout the 2018/19 season (pre-season and competitive season) from July 2018 until May 2019 at the club's training ground. Players underwent assessments of stature, sitting height and body mass in accordance with the International Society for the Advancement of Kinanthropometry guidelines (Marfell-Jones et al., 2006) in July 2018 (start of season) and May 2019 (end of season). Additionally, at these time-points, for players in the U12-U16 age-groups, somatic maturity timing was determined by calculating the maturity offset (Mirwald et al., 2002), and for all players, maturity status was determined using the Sherar equation (Sherar et al., 2005).

Only main squad sessions were considered for analysis, defined as a pitch-based training session or match that at

Table 1. A comparison of youth soccer players (U12–U18 age-groups; *n* = 76) from a Category One English Premier League academy. Table shows data for each age-group at the start and end of the 2018/2019 season and the change throughout the season for (chronological) age, maturity offset, current percent of predicted adult stature (PAS), stature and body mass.

Age-group	*n*	Time-point	Age (years)	Maturity offset (years)	Current percent of PAS (%)	Stature (cm)	Body mass (kg)
U12	15	SS	11.7 ± 0.2	−2.1 ± 0.4	84 ± 2	152 ± 6	41.0 ± 7.7
		ES	12.3 ± 0.2	−1.4 ± 0.4	86 ± 2	156 ± 6	43.4 ± 7.5
		Δ	**0.7 ± 0.1**	**0.7 ± 0.1**	**2 ± 1**	**3 ± 1** [f]	**2.5 ± 1.4** [d]
U13	13	SS	12.6 ± 0.3	−0.9 ± 0.5	88 ± 3	161 ± 5	48.6 ± 6.8
		ES	13.3 ± 0.3	−0.2 ± 0.5	91 ± 3	166 ± 5	53.5 ± 5.1
		Δ	**0.7 ± 0.1**	**0.7 ± 0.1**	**2 ± 2** [f]	**5 ± 1** [ef]	**4.9 ± 3.1** [f]
U14	12	SS	13.7 ± 0.2	−0.3 ± 0.6	90 ± 2	164 ± 7	50.8 ± 6.0
		ES	14.4 ± 0.2	0.5 ± 0.6	93 ± 3	169 ± 8	54.8 ± 8.9
		Δ	**0.7 ± 0.1**	**0.7 ± 0.1**	**3 ± 1** [f]	**5 ± 2** [ef]	**4.0 ± 4.1**
U15	10	SS	14.5 ± 0.3	0.7 ± 0.5	94 ± 2	172 ± 8	58.4 ± 8.1
		ES	15.4 ± 0.3	1.5 ± 0.5	97 ± 2	177 ± 6	65.5 ± 7.2
		Δ	**0.8 ± 0.0**	**0.8 ± 0.0**	**3 ± 2** [ef]	**5 ± 2** [ef]	**7.1 ± 1.9** [af]
U16	11	SS	15.5 ± 0.2	1.7 ± 0.6	97 ± 1	176 ± 8	65.9 ± 8.5
		ES	16.3 ± 0.2	2.5 ± 0.6	99 ± 1	178 ± 8	69.7 ± 7.4
		Δ	**0.8 ± 0.0**	**0.8 ± 0.0**	**1 ± 1** [d]	**2 ± 2** [bcd]	**3.8 ± 3.5**
U18	15	SS	17.0 ± 0.4	-	100 ± 1	181 ± 5	73.3 ± 6.9
		ES	17.9 ± 0.5	-	100 ± 1	182 ± 5	74.4 ± 6.1
		Δ	**0.8 ± 0.0**	-	**1 ± 1** [bcd]	**1 ± 1** [abcd]	**1.1 ± 2.3** [bd]

least 50% of the respective age-group completed. Individual sessions such as additional training or rehabilitation were excluded from analysis. Goalkeepers were also excluded from the analysis. In total, 14,556 individual sessions from 111 players were initially considered for analysis. Of these sessions, 217 (U12 1.8%; U13 1.3%; U14 1.2%; U15 1.4%; U16 1.0%; U18 1.8%) had "estimated" data either due to malfunctioning GPS hardware or players forgetting to wear their GPS units, and consequently were excluded from analysis. To be included in the next stage of analysis, players must have completed at least 70% of the total number of sessions for their respective age-group for the season – leaving 76 players (69%) remaining. Completion of 60% of total sessions (90 players/81%) was deemed too few and completion of 80% (59 players/53%) excluded too many players. The mean number of sessions per week per age-group was three for the U12's, U13's & U14's and four for the U15's, U16's and U18's. As such, to be considered a "representative" week and to be included in the next stage of analysis, at least three sessions (inclusive of one match) had to be completed by players in the U12, U13 and U14 age-groups and at least four (inclusive of one match) in the U15, U16 and U18 age-groups. 76% (414 weeks), 75% (359 weeks), 83% (341 weeks), 72% (259 weeks), 66% (252 weeks) and 71% (424 weeks) of individual weeks were included in the U12, U13, U14, U15, U16 and U18 age-groups, respectively. The final number of sessions included for analysis was 10,986 (2049 individual weeks). Session content was not influenced by the research team.

Quantification of session load

Pitch-based training and match load were measured using global positioning system (GPS) technology (Apex, STATSports, Newry, Northern Ireland). Each portable GPS unit (30 × 80 mm, 48 g) sampled at 10 Hz providing information on positioning and time and thus velocity and distance. These devices have been shown to provide valid and reliable estimates of distance and velocity (<2% typical error of measurement) when compared to criterion measures during a range of typical team sport movement activities (Beato et al., 2018; Thornton et al., 2019). These types of GPS devices have also been shown to provide both valid and reliable estimates of immediate (e.g., quick accelerations) and continuous (e.g., linear running) movements during linear and multidirectional soccer-specific movements (Coutts & Duffield, 2010; Varley et al., 2012). The GPS unit was placed inside a custom-made manufacturer-provided vest (Apex, STATSports, Northern Ireland) that held the unit on the upper back between both scapulae, allowing clear exposure of the GPS antennae to acquire a clear satellite connection. The GPS units were turned on around 30 minutes before use and left outside (as per the manufacturer's instructions) to obtain a sufficient satellite signal (i.e., a lock with at least four different satellites) and to synchronize the GPS clock with the atomic clock in the satellites (Larsson, 2003). Whilst inter-unit reliability for most GPS derived metrics from the same manufacturer (including TD and different speed thresholds) is considered good (CV: 0.2–1.5%) (Thornton et al., 2019), players wore the same unit for all sessions unless there was a hardware failure with their unit in which case they were provided with a new unit. At the end of each session, data were downloaded and then cropped from the start of the warm-up to the end of the last organized drill or end of match play, on the manufacturer's software (Apex 10 Hz version 2.0.2.4, STATSports, Northern Ireland). The external load variables selected for the analysis were training and match duration (minutes), total distance covered (km), average speed (m·min^{-1}; total distance covered divided by duration), high-speed running distance (metres; 19.8–25.2 km·h^{-1}) and sprint distance (>25.5 km·h^{-1}) (Anderson et al., 2016; Malone et al., 2015). To ascertain when academy soccer players are capable of achieving the training and match intensities of adult EPL players, absolute speed thresholds commonly used within the adult game were deliberately selected (Anderson et al., 2016; Malone et al., 2015).

Data analysis

The number of weeks included in the final analysis was 28 ± 3, 28 ± 5, 28 ± 5, 26 ± 3, 23 ± 6 and 29 ± 3 weeks in the U12, U13, U14, U15, U16 and U18 age-groups, respectively. From these included weeks, to determine a "mean" week the mean value for each TL variable was determined for each player. To determine if any periodization within the week occurred, mean values (for all included weeks) for each TL variable were determined for each player for each day of the week. Days were classified as number of days from match day (MD): MD-5, MD-4, MD-3, MD-2, MD-1 and MD (Malone et al., 2015). Each age-group always had a rest day the day after a match (MD+1). Additionally, the U12, U13 and U14 age-groups had MD-1 off, and the U15, U16 and U18 age-groups had MD-3 off.

Statistical analysis

To determine differences in a "mean" week between age-groups, statistical comparisons for normally distributed data were assessed using a one-way between-groups analysis of variance (ANOVA). Where significant main effects were present, a Bonferroni post-hoc analysis was conducted to locate specific differences (level of significance [α] set at $P < 0.05$). For non-normally distributed data, statistical comparisons were assessed via the non-parametric, Kruskal–Wallis test. Where significant main effects were present, a Mann-Whitney U post-hoc analysis with a Bonferroni correction was conducted to locate specific differences (level of significance [α] set at $P < 0.003$). To determine between-day differences within each age-group, statistical comparisons for normally distributed data were assessed using a one-way within-group ANOVA. If Mauchly's test of sphericity was violated (Greenhouse Geisser epsilon of <0.75), data were corrected using Greenhouse Geisser epsilon. Where significant main effects were present, a Bonferroni post-hoc analysis was conducted to locate specific differences (level of significance [α] set at $P < 0.05$). For non-normally distributed data, statistical comparisons were assessed via the non-parametric, Friedman's ANOVA. Where significant main effects were present, Wilcoxon signed-rank post-hoc analysis with a Bonferroni correction was conducted to locate specific differences (level of significance [α] set at $P < 0.05$).

Results

Comparisons of "mean" accumulative training and match loads between age-groups

Mean weekly training and match load for each metric per each age-group can be seen in Figure 1. Weekly duration and TD for a mean week in the U12 (329 ± 29 min; 19.9 ± 2.2 km), U13 (323 ± 29 min; 20.0 ± 2.0 km) and U14 (339 ± 25 min; 21.7 ± 2.0 km) age-groups were not different between squads (P > 0.05 for all comparisons), though all three age-groups were lower than the U15 (421 ± 15 min; 26.2 ± 2.1 km), U16 (427 ± 20 min; 25.9 ± 2.5 km) and U18 (398 ± 30 min; 26.1 ± 2.6 km) age-groups (P < 0.01 for all comparisons). No differences existed in either duration or TD between the U15 to U18 players (P > 0.05 for all comparisons).

Weekly mean speed in the U18 age-group (66 ± 6 m·min^{-1}) was higher than the U12's (60 ± 3 m·min^{-1}; P = 0.001) and U16's (60 ± 5 m·min^{-1}; P = 0.003). There were no differences in mean speed between any other age-group (U13 63 ± 2 m·min^{-1}; U14 61 ± 11 m·min^{-1}; U15 64 ± 6 m·min^{-1}; P > 0.05 for all comparisons).

Weekly HSR distance in the U12 (220 ± 95 m) and U13 (331 ± 212 m) age-groups was similar to the U14's (448 ± 193 m; P > 0.05 for all comparisons), but less than the U15 (657 ± 242 m), U16 (749 ± 152 m) and U18 (979 ± 254 m) age-groups (P < 0.01 for all comparisons). The U14's HSR distance was similar to the U15's (P = 0.25), but less than the U16 (P < 0.01;

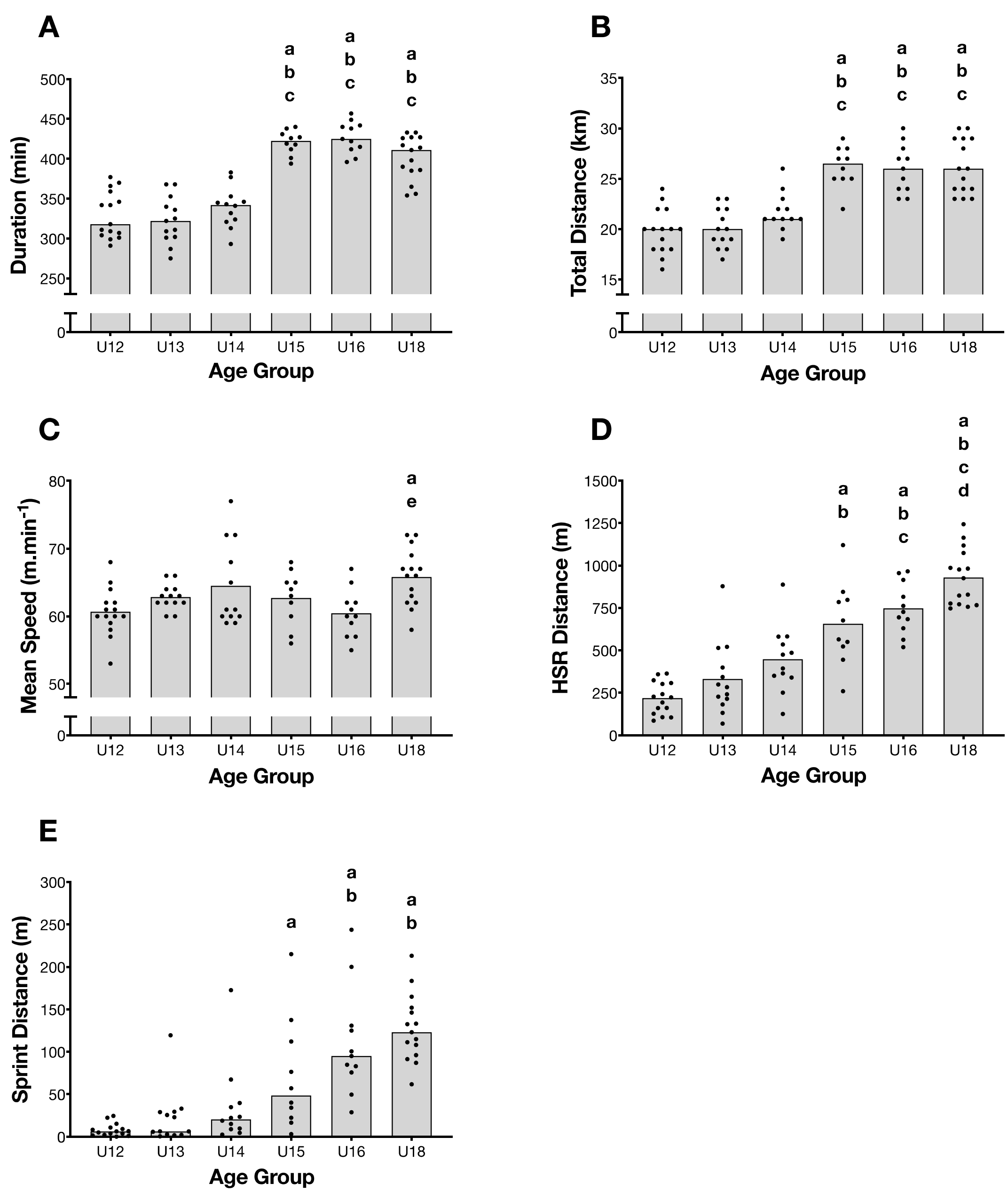

Figure 1. Accumulative weekly loading patterns of youth soccer players (U12-U18 age-groups; n = 76) from a Category One English Premier League academy. Pitch-based training and match (A) duration, (B) total distance, (C) mean speed, (D) high-speed running (HSR) distance and (E) sprint distance. [a]Significant difference from U12 age-group. [b]Significant difference from U13 age-group. [c]Significant difference from U14 age-group. [d]Significant difference from U15 age-group. [e]Significant difference from U16 age group. Black circles represent individual players.

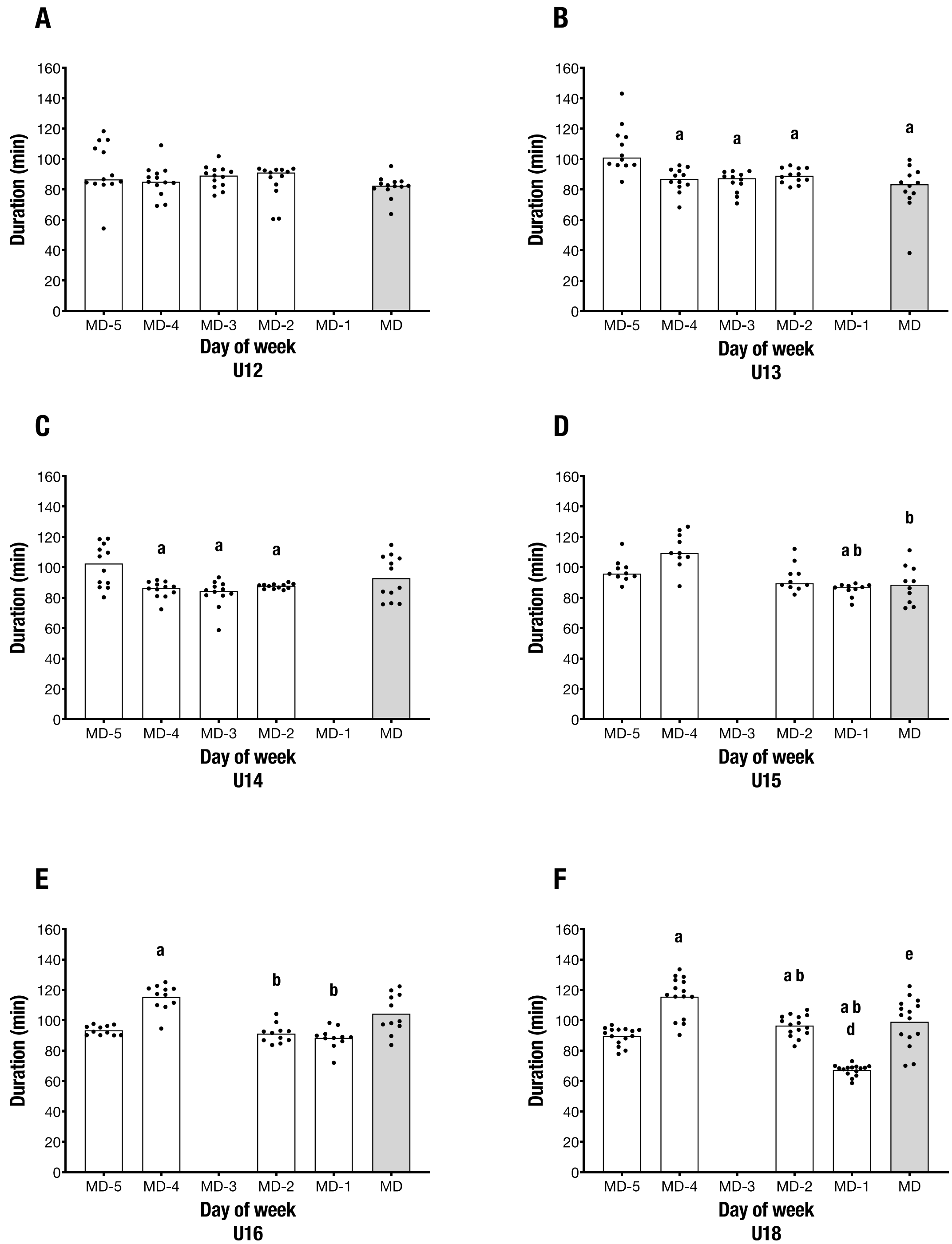

Figure 2. Daily training and match duration of the (A) U12, (B) U13, (C) U14, (D) U15, (E) U16 and (F) U18 age-groups from a category one English Premier League soccer academy (n = 76). White bars represent training days, denoted as days away from match day (MD), i.e., MD-5, etc., and grey bars represent match day. No training was completed on days with no data bars. [a]Significant difference from MD-5 (P < 0.05). [b]Significant difference from MD-4 (P < 0.05). [c]Significant difference from MD-3 (P < 0.05). [d]Significant difference from MD-2 (P < 0.05). [e]Significant difference from MD-1 (P < 0.05). Black circles represent individual players.

95% CI = –553 to –49 m) and U18 (P < 0.01; 95% CI = –762 to –301 m) age-groups. HSR distance in the U15 age-group was similar to the U16 (P = 1.00) but less than the U18's (P < 0.01; 95% CI = –565 to –79 m), with no differences in mean weekly HSR distance between the U16 and U18 age-groups (P = 0.06).

Weekly sprint distance in the U12's (6 ± 9 m) was similar to the U13's (6 ± 27 m; P = 0.279) and U14's (21 ± 29 m; P = 0.009), but lower than the U15's (49 ± 98 m; P < 0.001), U16's (95 ± 55 m; P < 0.001) and U18's (123 ± 56 m; P < 0.001). Sprint distance in the U13's was similar to the U14's (P = 0.264) and U15's (P = 0.014), but lower than the U16's (P < 0.001) and U18's (P < 0.001). Sprint distance in the U14's was similar to the U15's (P = 0.093) but lower than the U16's (P = 0.001) and U18's (P < 0.001). Sprint distance was similar between the U15, U16 and U18 age-groups (P > 0.003 for all pairwise comparisons).

Periodization of weekly loading patterns within each age-group

Daily session duration, total distance, mean speed, high-speed running distance and sprint distance for each age-group can be seen in Figures 2, 3, 4, 5 and 6, respectively. Session duration did not differ between days in the U12 age-group (P = 0.33). There was a main effect of day on session duration in the U13, U14, U15, U16 and U18 age-groups (P < 0.01 for all age-groups). There was a main effect of day on total distance, mean speed, HSR distance and sprint distance in the U12, U13, U14, U15, U16 and U18 age-groups (P < 0.01 for all age-groups), respectively.

Discussion

The aim of the present study was to quantify the weekly training and match load in male academy soccer players from an

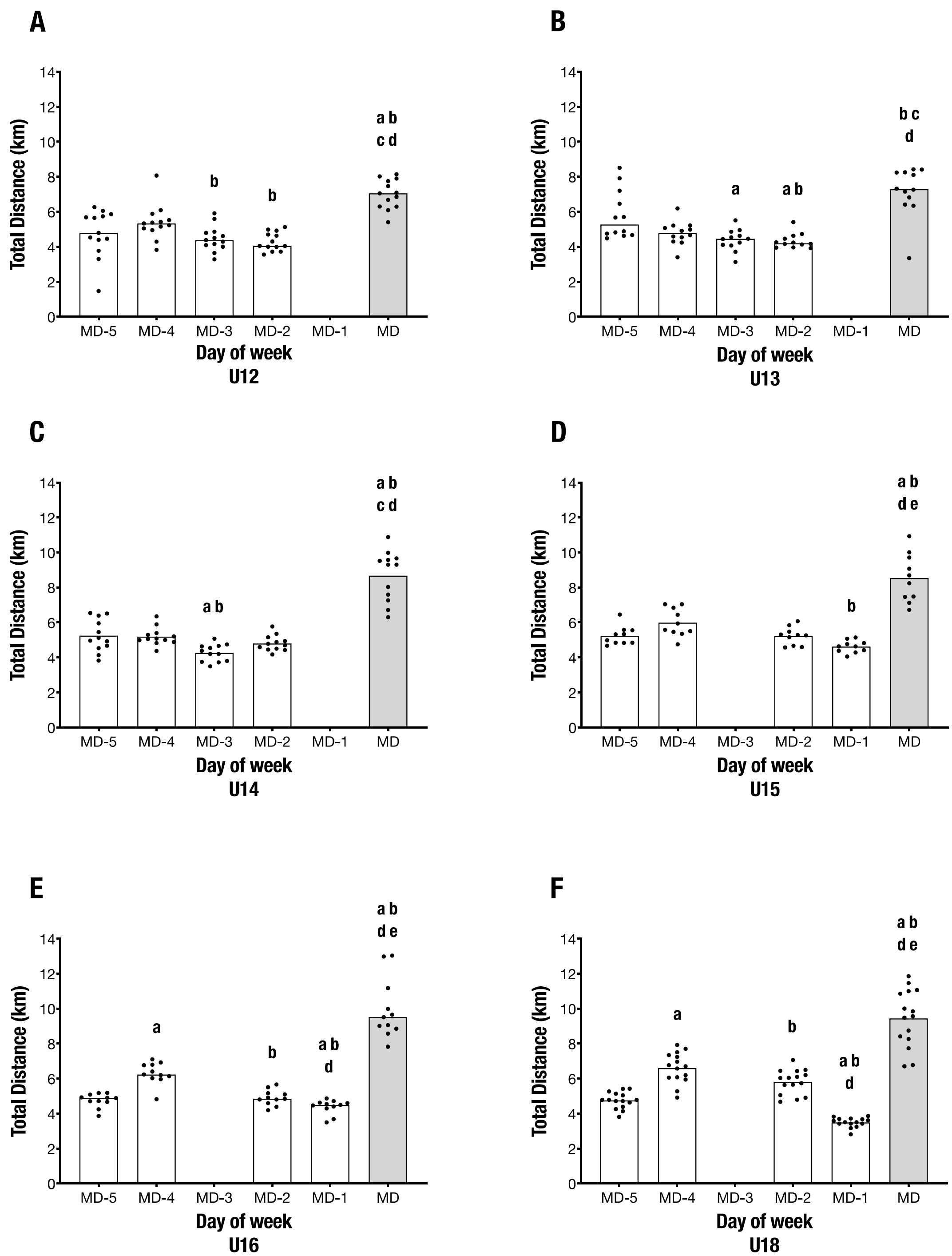

Figure 3. Daily training and match total distance of the (A) U12, (B) U13, (C) U14, (D) U15, (E) U16 and (F) U18 age-groups from a category one English Premier League soccer academy (n = 76). White bars represent training days, denoted as days away from match day (MD), i.e., MD-5, etc., and grey bars represent match day. No training was completed on days with no data bars. [a]Significant difference from MD-5 (P < 0.05). [b]Significant difference from MD-4 (P < 0.05). [c]Significant difference from MD-3 (P < 0.05). [d]Significant difference from MD-2 (P < 0.05). [e]Significant difference from MD-1 (P < 0.05). Black circles represent individual players.

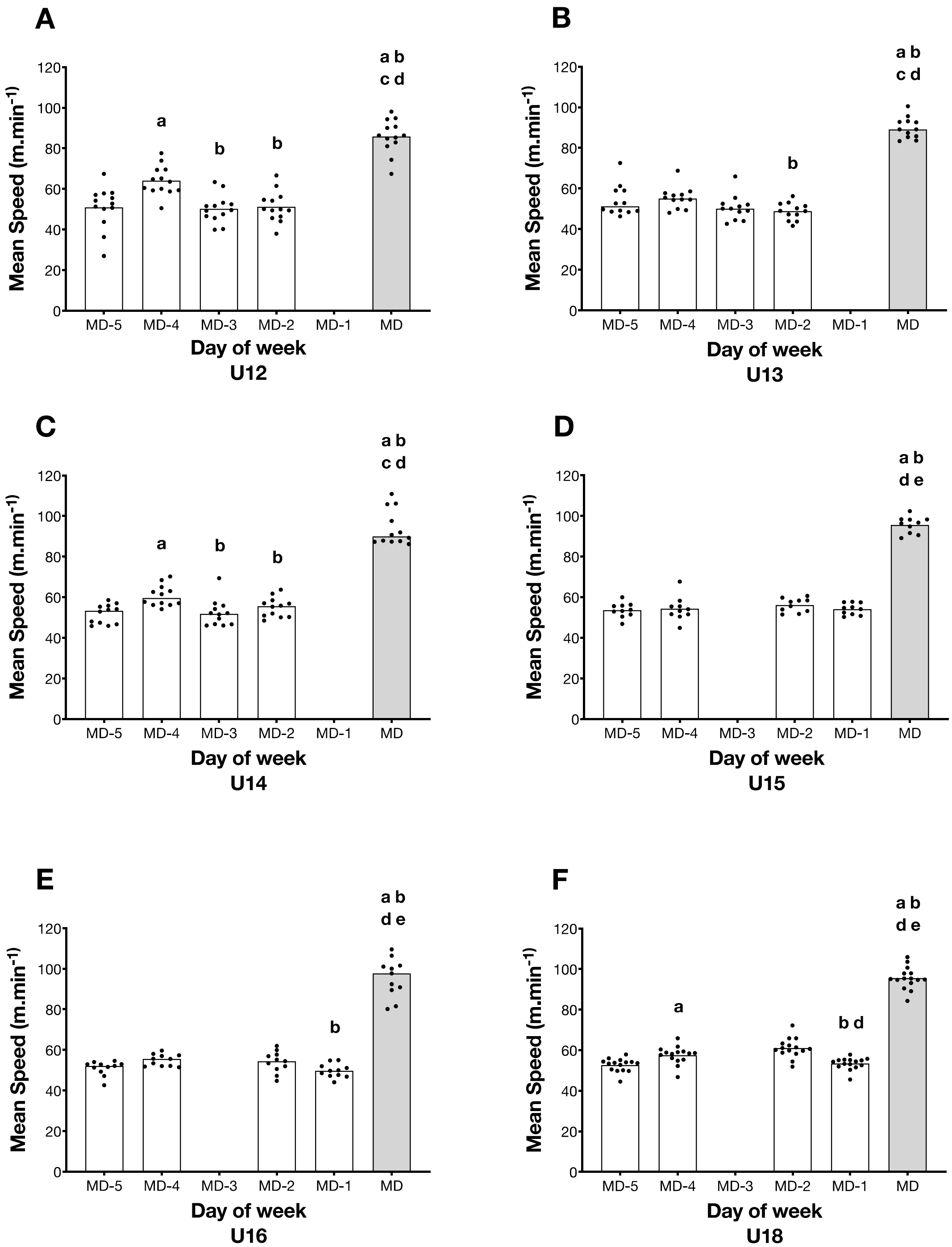

Figure 4. Daily training and match mean speed of the (A) U12, (B) U13, (C) U14, (D) U15, (E) U16 and (F) U18 age-groups from a category one English Premier League soccer academy (n = 76). White bars represent training days, denoted as days away from match day (MD), i.e., MD-5, etc., and grey bars represent match day. No training was completed on days with no data bars. [a]Significant difference from MD-5. [b]Significant difference from MD-4. [c]Significant difference from MD-3. [d]Significant difference from MD-2. [e]Significant difference from MD-1.

EPL academy. Using a season-long analysis, we provide the first report to quantify absolute training and match load (according to commonly used GPS metrics) across the range of academy age-groups. Our data demonstrate that weekly training and match load is progressive in nature between age-groups whereby absolute loading patterns are comparable between U12-U15 players, whereas U16-U18 players experience absolute loading patterns that are comparable to adult players (Anderson et al., 2016; Malone et al., 2015). Additionally, we also observed that periodization of loading across the weekly micro-cycle (as commonly observed in adult soccer players) only becomes apparent in the U16-U18 players.

To address our aim, we performed a seasonal-long analysis to quantify the external load of pitch-based training and games using typical GPS metrics and crude markers such as training and match duration. In relation to the latter, we observed that weekly training and match duration was comparable amongst the younger age-groups (U12-U14: ~330 min per week, range:

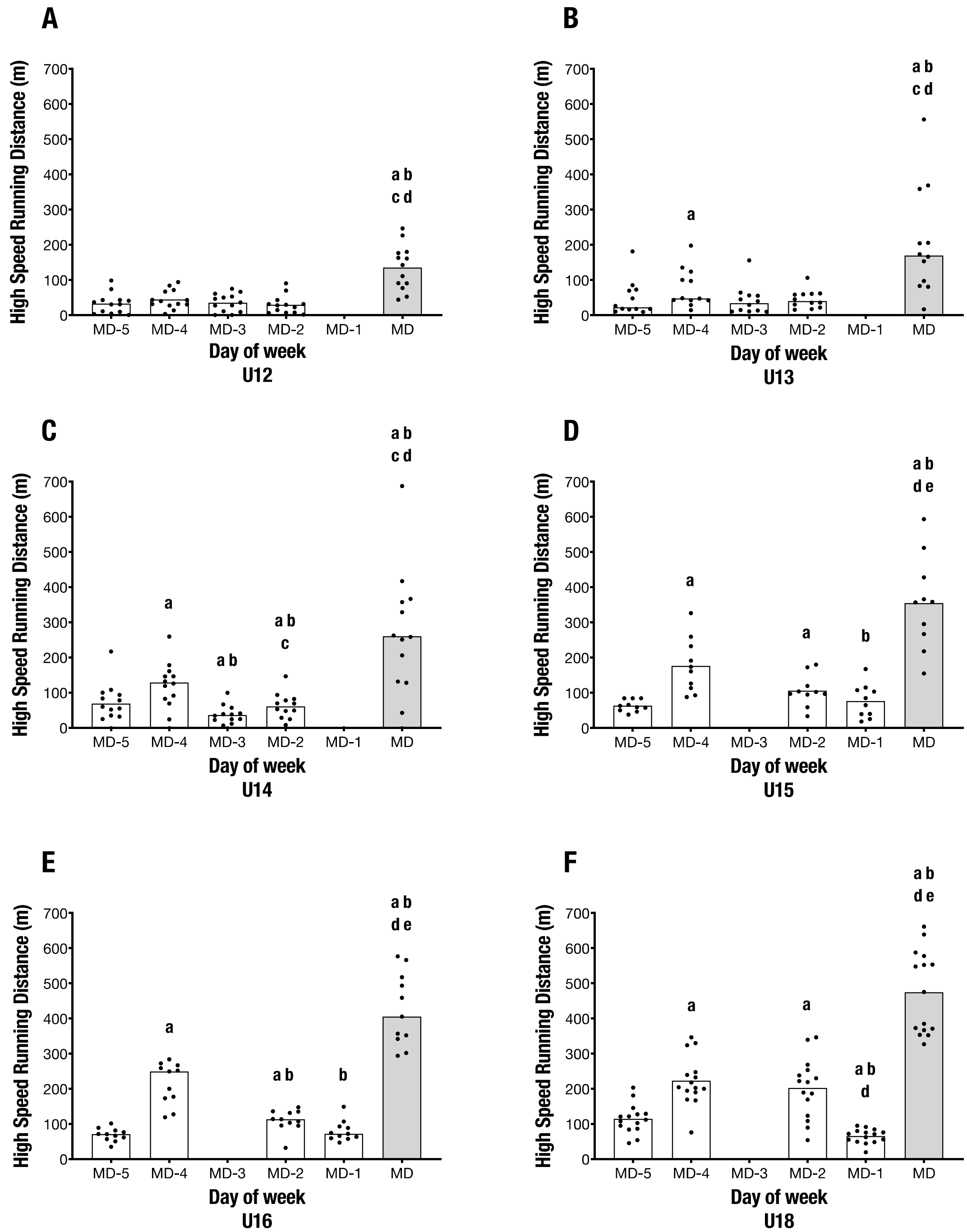

Figure 5. Daily training and match high-speed running distance of the (A) U12, (B) U13, (C) U14, (D) U15, (E) U16 and (F) U18 age-groups from a category one English Premier League soccer academy (n = 76). White bars represent training days, denoted as days away from match day (MD), i.e., MD-5, etc., and grey bars represent match day. No training was completed on days with no data bars. [a]Significant difference from MD-5. [b]Significant difference from MD-4. [c]Significant difference from MD-3. [d]Significant difference from MD-2. [e]Significant difference from MD-1.

275–383 min), before increasing in the older age-groups (U15-U18: ~400-420 min per week, range: 354–457 min). Although the higher volumes in the U18 age-group are not unexpected given their full-time training status, it is somewhat surprising the U15 and U16 age-groups experienced similar volumes to U18 players given their part-time training status. Indeed, these data appear to contrast with Wrigley and colleagues (Wrigley et al., 2012), who reported that U18 players (~700 min·week^{-1}) experienced greater volumes over a two-week period compared to U16 (~560 min·week^{-1}) and U14 (~500 min·week^{-1}) age-groups, a finding attributed to the increased number of sessions completed in the U18 players. We acknowledge, however, that a comparison between studies is limited given that the previous authors also accounted for the duration of gym-based training in their U18 (~90 min·week^{-1}), U16 (~60 min·week^{-1}) and U14 (60 min·week^{-1}) players. Nonetheless, even when accounting for gym-based training, the typical duration of activity presented here is still somewhat lower than those reported by Wrigley and colleagues (Wrigley et al., 2012). In contrast, a more recent study reported a higher pitch-based training and match duration in the

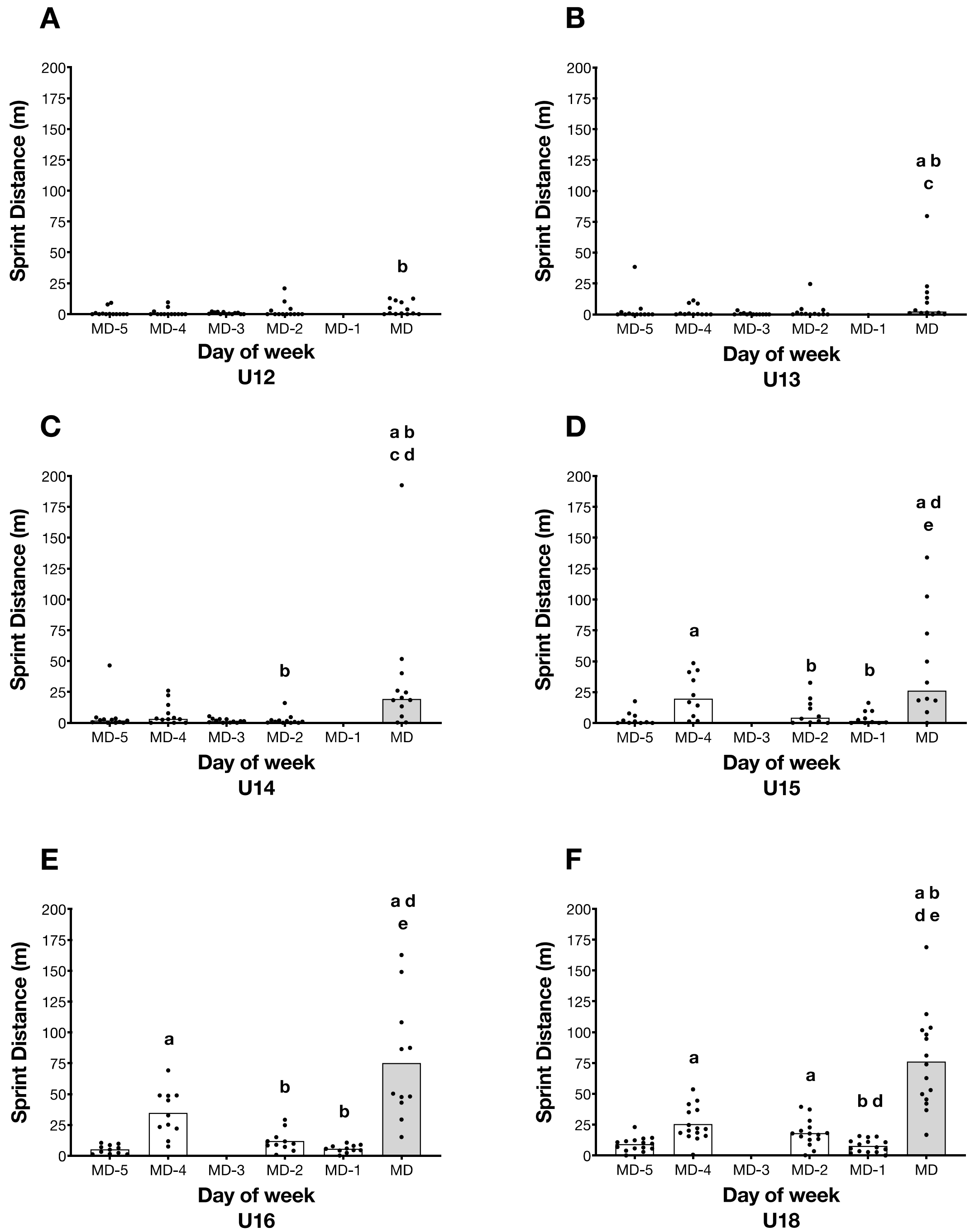

Figure 6. Daily training and match sprint distance of the (A) U12, (B) U13, (C) U14, (D) U15, (E) U16 and (F) U18 age-groups from a category one English Premier League soccer academy (n = 76). White bars represent training days, denoted as days away from match day (MD), i.e., MD-5, etc., grey bars represent match day. No training was completed on days with no data bars. [a]Significant difference from MD-5. [b]Significant difference from MD-4. [c]Significant difference from MD-3. [d]Significant difference from MD-2. [e]Significant difference from MD-1.

younger age-groups (U12-U14: ~400 min·week^{-1}) when compared to U15 (~200 min·week^{-1}) and U16 and U18 players (~250 min·week^{-1}), also from a Category One EPL soccer academy (Brownlee et al., 2018). When taken together, these data demonstrate clear differences between different EPL academies, likely a reflection of differences in coaching and training philosophies between clubs. Moreover, such data also suggest that academy players are not being exposed to the required coaching time stated in the EPPP, i.e., ~600-720 min·week^{-1} for U12 players increasing to ~720-840 min·week^{-1} for U23 players (Premier League, 2011).

In accordance with training and match duration, "mean" weekly TD in the younger age-groups (U12-U14: ~20-22 - km·week^{-1}, range: 16–26 km) was similar between squads but less than that of the older age-groups (U15-U18: ~26 km·week^{-1}, range: 22–30 km). Interestingly, such data are largely comparable with our previous findings (over a 14-day period) (Hannon et al., 2021) and with mean weekly distances completed by adult EPL players (~26 km·week^{-1}), as also completed during a one game per week micro-cycle (Anderson et al., 2016). The increase in TD (and duration) in the older age-groups (U15-U18) also coincides with increases in chronological and biological age as most players have progressed through peak height velocity (PHV; Table 1). It is also important to note that weekly mean speed (Figure 1C) was similar across all age-groups. This suggests that the higher weekly TD completed by the U15-18 age-groups was a product of longer session durations rather than players' increased physical ability or desire. This likely demonstrates the academies coaching practice (as opposed to player's self-selecting training volume and intensity) of adjusting session frequency and/or duration to effectively tailor the training programme to meet the needs of the specific age-group within an LTAD programme. This apparent progression in load is congruent with traditional LTAD models (Balyi & Hamilton, 2004; Lloyd et al., 2015) and follows the trend advised (i.e., progressive increase in volume) by the Premier League (Premier League, 2011).

To ascertain when academy soccer players are capable of achieving the training and match intensities of adult EPL players, we deliberately selected absolute speed thresholds commonly used within the adult game (Anderson et al., 2016; Malone et al., 2015). Weekly HSR and sprint distance (i.e., intensity) were higher in the older age-groups compared to the younger age-groups (Figure 1). In the U18 age-group, weekly HSR distances were consistent with those previously reported for EPL academy players of a similar age for a "mean" (~1000 m) week (Bowen et al., 2017). The progressive increases in both HSR and sprint distance throughout the age-groups coincide with increases in both chronological and biological age (Table 1) and are likely, therefore, simply a product of growth and maturation (Malina et al., 2004). Indeed, it is well documented that the maximal speed progressively increases in academy soccer players until ~12-18 months post-PHV (Philippaerts et al., 2006; Vaeyens et al., 2006). Specific developments that influence speed production include anatomical growth (e.g., increase in leg length), biomechanical (e.g., changes in stride frequency and length) and metabolic (e.g., larger phosphocreatine storage capacity and re-synthesis ability) changes, morphological changes to the muscle and tendon (e.g., increased stiffness) and motor skill improvements (e.g., sprinting mechanics) (Ford et al., 2011; Oliver et al., 2019). It is likely that the combination of such factors in addition to an increased training age improves speed production and capabilities as players progress through the age-groups (Ford et al., 2011; Oliver et al., 2019).

In the U16 and U18 age-groups (one-match per weekly micro-cycle), HSR distance was similar to that of adult EPL players during a two and a three match week, though sprint distance was significantly less than adult players for a two (~520 m) and three (~1000 m) match week (Anderson et al., 2016). In addition to the physical developments described above, it is noteworthy that academy players possess considerably less FFM than adult players (Hannon et al., 2020), an important component that is closely associated with power and speed production (Murtagh et al., 2018; Wrigley et al., 2014). When considered in this way, our data demonstrate that whilst academy players in the U16 and U18 age-groups are capable of achieving the training and match volumes experienced by adult EPL players, they do not achieve the absolute intensities completed by elite adult soccer players. Such data are of practical relevance given that the physical demands of match play are typically completed as an absolute demand as opposed to individualized demands.

Similar to adult players (Anderson et al., 2016), players in all age-groups experienced the greatest physical load on MD, as was the case for markers of volume (e.g., TD, Figure 3) and intensity such as mean speed (Figure 4) and HSR distance (Figure 5). Consequently, MD is likely to incur the largest daily energy expenditure for academy soccer players. Whilst there are some elements of daily periodization of loading across the weekly micro-cycle in U12-U15 age-groups, the periodization pattern that is typically observed in adult players (Anderson et al., 2016) only appears evident in the U16 and U18 age-groups. For example, during the training week preceding a match, TD (Figure 3), HSR (Figure 5) and sprint distance (Figure 6) were greatest on MD-4, with significant reductions in all parameters on MD-1 in preparation for the match. These fluctuations in loading (of both volume and intensity) throughout the week are likely a reflection of the goal of each training day (e.g., a greater emphasis on technical and tactical elements versus a greater emphasis on specific physical elements). The loading patterns experienced by the U16 and U18 age-groups are consistent with previous reports in both academy (Coutinho et al., 2015; Wrigley et al., 2012) and adult (Anderson et al., 2016) soccer players. The changes in weekly micro-cycle periodization between age-groups may reflect a shift in the academy's coaching philosophy as players progress throughout the pathway, from technical development in the younger age-groups towards preparation for competition in the older age-groups (Coutinho et al., 2015; Wrigley et al., 2012).

This study provides reference data on customary training and match loads of academy soccer players. Such information may assist coaches and practitioners in developing optimal training and nutritional prescription for adolescent players. For example, from a nutritional perspective, the periodization of daily loading in adult players has resulted in the suggestions that daily energy intake should also be adjusted and periodized accordingly (Anderson et al., 2017). However, given the lack of periodization of daily loads in the younger age-groups in combination with the fact that these players are progressing through a period of rapid biological growth and maturation (i.e., through PHV, Table 1), the present data demonstrate that daily periodization of energy intake is not warranted within these age-groups. The increase in loading patterns within EPL academy soccer players is congruent with traditional LTAD models (Balyi & Hamilton, 2004; Lloyd et al., 2015) and Premier League advice (Premier League, 2011). Despite the novelty of our data, we acknowledge that our findings are reflective of one academy and may not be representative of the customary training and match demands of English academies with a different category status or of those academies in other countries that may be influenced by different coaching and/or training philosophies. It is also accepted that the use of absolute speed thresholds does not consider the inter-individual variation in a player's sprinting "capacity"; i.e. for a given absolute speed, a quicker player will be running at a lower percentage of their maximum speed (relatively) compared to a slower player, and vice versa. However, we deliberately selected absolute speed thresholds commonly used within the adult game to ascertain when academy soccer players are physically capable of achieving the training and match intensities of adult EPL players (Anderson et al., 2016; Malone et al., 2015). The individualization of speed thresholds requires regularly updating speed thresholds due to increases in speed associated with growth and maturation (Philippaerts et al., 2006; Vaeyens et al., 2006) and was considered unfeasible for this study. Whilst this study used validated and widely accepted metrics to determine external load such as TD and different absolute speed thresholds (Anderson et al., 2016; Beato et al., 2018; Malone et al., 2015), future studies should aim to quantify accelerations and decelerations, given the different physiological and mechanical demands that these movements impose on players (Harper et al., 2019). Additionally, considering the large inter-individual variation in a player's internal response (e.g., heart rate) to an external load (Drust et al., 2007), future studies should report both external and internal loads simultaneously.

In summary, we report for the first time the weekly training and match loads of youth soccer players between age-groups of the same EPL academy. Our data demonstrate that weekly training and match load are progressive in nature in that absolute loading patterns are comparable between U12 and U14 players, whereas U15-U18 players experience absolute loading patterns that are comparable to those previously reported in adult EPL players. Additionally, we also observed that the periodization of loading across the weekly micro-cycle (as commonly observed in adult soccer players) only becomes apparent in the U16-U18 players. Future studies should aim to determine customary training loads and periodization practices in different academies, including those in different countries with different philosophies, and should incorporate internal load metrics and other validated metrics of external load, perhaps quantified using micro-electrical mechanical systems.

Disclosure statement

The authors report no conflict of interest.

ORCID

Marcus P. Hannon http://orcid.org/0000-0002-4452-6501
Lloyd J. F. Parker http://orcid.org/0000-0002-9921-0790
Viswanath B. Unnithan http://orcid.org/0000-0001-5147-1679
Graeme L. Close http://orcid.org/0000-0002-7210-9553
Barry Drust http://orcid.org/0000-0003-2092-6962
James P. Morton http://orcid.org/0000-0003-2776-2542

References

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Morgans, R., Drust, B., & Morton, J. P. (2016). Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: Implications for carbohydrate periodisation. *Journal of Sports Sciences*, *34*(13), 1250–1259. https://doi.org/10.1080/02640414.2015.1106574

Anderson, L., Orme, P., Naughton, R. J., Close, G. L., Milsom, J., Rydings, D., O'Boyle, A., Di Michele, R., Louis, J., Hambly, C., Speakman, J. R., Morgans, R., Drust, B., & Morton, J. P. (2017). Energy intake and expenditure of professional soccer players of the English Premier League: Evidence of carbohydrate periodization. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(3), 228–238. https://doi.org/10.1123/ijsnem.2016-0259

Balyi, I., & Hamilton, A. (2004) Long-term athlete development: Trainability in childhood and adolescence. Windows of opportunity. Optimal trainability. *Training*, pp. 1–6. MPE Advanced Training and Performance Ltd. Victoria, B.C., Canada. Available at: http://www.athleticsireland.ie/content/wp-content/uploads/2007/03/bayliLTAD2004.pdf%5Cnhttp://pellatrackclub.org/files/www.athleticsireland.ie_content_wp-content_uploads_2007_03_bayliLTAD2004.pdf .

Barnes, C., Archer, D., Hogg, B., Bush, M., & Bradley, P. (2014). The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine*, *35*(13), 1095–1100. https://doi.org/10.1055/s-0034-1375695

Beato, M., Coratella, G., Stiff, A., & Iacono, A. D. (2018). The validity and between-unit variability of GNSS units (STATSports Apex 10 and 18 Hz) for measuring distance and peak speed in team sports. *Frontiers in Physiology*, *9*(September), 1–8. https://doi.org/10.3389/fphys.2018.01288

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., Gabbett, T. J., Coutts, A. J., Burgess, D. J., Gregson, W., & Cable, N. T. (2017). Monitoring athlete training loads: Consensus statement. *International Journal of Sports Physiology and Performance*, *12*(s2), S2-161-S2-170. https://doi.org/10.1123/IJSPP.2017-0208

Bowen, L., Gross, A. S., Gimpel, M., & Li, F.-X. (2017). Accumulated workloads and the acute: Chronic workload ratio relate to injury risk in elite youth football players. *British Journal of Sports Medicine*, *51*(5), 452–459. https://doi.org/10.1136/bjsports-2015-095820

Brinkmans, N. Y. J., Iedema, N., Plasqui, G., Wouters, L., Saris, W. H. M., Van Loon, L. J. C., & Van Dijk, J.-W. (2019). Energy expenditure and dietary intake in professional football players in the Dutch Premier League: Implications for nutritional counselling. *Journal of Sports Sciences*, *37*(24), 2759–2767. https://doi.org/10.1080/02640414.2019.1576256

Brownlee, T. E., O'Boyle, A., Morgans, R., Morton, J. P., Erskine, R. M., & Drust, B. (2018). Training duration may not be a predisposing factor in potential maladaptations in talent development programmes that promote early specialisation in elite youth soccer. *International Journal of Sports Science & Coaching*, *13*(5), 674–678. https://doi.org/10.1177/1747954117752127

Coutinho, D., Gonçalves, B., Figueira, B., Abade, E., Marcelino, R., & Sampaio, J. (2015). Typical weekly workload of under 15, under 17, and under 19 elite Portuguese football players. *Journal of Sports Sciences*, *33*(12), 1229–1237. Routledge. https://doi.org/10.1080/02640414.2015.1022575

Coutts, A. J., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medicine in Sport*, *13*(1), 133–135. Sports Medicine Australia. https://doi.org/10.1016/j.jsams.2008.09.015

Drust, B., Atkinson, G., & Reilly, T. (2007). Future perspectives in the evaluation of the physiological demands of soccer. *Sports Medicine*, *37*(9), 783–805. https://doi.org/10.2165/00007256-200737090-00003

Ford, P., De Ste Croix, M., Lloyd, R., Meyers, R., Moosavi, M., Oliver, J., Till, K., & Williams, C. (2011). The long-term athlete development model: Physiological evidence and application. *Journal of Sports Sciences*, *29*(4), 389–402. https://doi.org/10.1080/02640414.2010.536849

Hannon, M. P., Carney, D. J., Floyd, S., Parker, L. J. F., McKeown, J., Drust, B., Unnithan, V. B., Close, G. L., & Morton, J. P. (2020). Cross-sectional comparison of body composition and resting metabolic rate in Premier League academy soccer players: Implications for growth and maturation. *Journal of Sports Sciences*, *38*(11–12), 1326–1334. https://doi.org/10.1080/02640414.2020.1717286

Hannon, M. P., Parker, L. J. F., Carney, D. J. McKeown, J., Speakman, J. R., Hambly, C., Drust, B., Unnithan, V. B., Close, G. L., & Morton, J. P. (2021). Energy Requirements of Male Academy Soccer Players from the English Premier League. *Medicine & Science in Sports & Exercise,53*(1), 200–210. http://doi.org/10.1249/MSS.0000000000002443

Harper, D. J., Carling, C., & Kiely, J. (2019). High-intensity acceleration and deceleration demands in elite team sports competitive match play: A systematic review and meta-analysis of observational studies. *Sports Medicine*, *49*(12), 1923–1947. Springer International Publishing. https://doi.org/10.1007/s40279-019-01170-1

Larsson, P. (2003). Global positioning system and sport-specific testing. *Sports Medicine*, *33*(15), 1093–1101. https://doi.org/10.2165/00007256-200333150-00002

League, P. (2011). *Elite Player Performance Plan*. (May). pp. 117. Premier League.

Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Howard, R., De Ste Croix, M. B. A., Williams, C. A., Best, T. M., Alvar, B. A., Micheli, L. J., Thomas, D. P., Hatfield, D. L., Cronin, J. B., & Myer, G. D. (2015). Long-term athletic development. Part 2: Barriers to success and potential solutions. *Journal of Strength and Conditioning Research*, *29*(5), 1451–1464. https://doi.org/10.1519/01.JSC.0000465424.75389.56

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation and physical activity*. Second. Edited by Human Kinetics.

Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in Elite English Premier League soccer players. *International Journal of Sports Physiology and Performance*, *10*(4), 489–497. https://doi.org/10.1123/ijspp.2014-0352

Marfell-Jones, M., Stewart, A., & Olds, T. (2006). Kinanthropometry IX: Proceedings of the 9th International Conference of the International Society for the Advancement of Kinanthropometry. Routledge

Mirwald, R. L., Baxter-Jones, A. D., Bailey, D., A. & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine & Science in Sports & Exercise,34*(4), 689–694.

Murtagh, C. F., Brownlee, T. E., O'Boyle, A., Morgans, R., Drust, B., & Erskine, R. M. (2018). Importance of speed and power in elite youth soccer depends on maturation status. *Journal of Strength and Conditioning Research*, *32*(2), 297–303. https://doi.org/10.1519/JSC.0000000000002367

Oliver, J. L., Cahill, M., & Uthoff, A. (2019). Speed training for young athletes. In R. S. Lloyd & J. L. Oliver (Eds.), *Strength and conditioning for young athletes: Science and application* (2nd edn. ed., pp. 207–227). Routledge.

Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Bourgois, J., Vrijens, J., Beunen, G., & Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences*, *24*(3), 221–230. https://doi.org/10.1080/02640410500189371

Reilly, T., & Thomas, V. (1979). Estimated daily energy expenditures of professional association footballers. *Ergonomics*, *22*(5), 541–548. https://doi.org/10.1080/00140137908924638

Sherar, L. B., Mirwald, R. L., Baxter-Jones, A. D. G., & Thomis, M. (2005). Prediction of adult height using maturity-based cumulative height velocity curves. *The Journal of Pediatrics*, *147*(4), 508–514. https://doi.org/10.1016/j.jpeds.2005.04.041

Thornton, H. R., Nelson, A. R., Delaney, J. A., Serpiello, F. R., & Duthie, G. M. (2019). Interunit reliability and effect of data-processing methods of global positioning systems. *International Journal of Sports Physiology and Performance*, *14*(4), 432–438. https://doi.org/10.1123/ijspp.2018-0273

Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., Vrijens, J., Philippaerts, R. M., & E Silva, M. J. C. (2006). A multidisciplinary selection model for youth soccer: The Ghent youth soccer project. *British Journal of Sports Medicine*, *40*(11), 928–934. discussion 934. https://doi.org/10.1136/bjsm.2006.029652

Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, *30*(2), 121–127. https://doi.org/10.1080/02640414.2011.627941

Wrigley, R., Drust, B., Stratton, G., Atkinson, G., & Gregson, W. (2014). Long-term soccer-specific training enhances the rate of physical development of academy soccer players independent of maturation status. *International Journal of Sports Medicine*, *35*(13), 1090–1094. https://doi.org/10.1055/s-0034-1375616

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Sciences*, *30*(15), 1–8. https://doi.org/10.1080/02640414.2012.709265 November