Whole and peak physical characteristics of elite youth female soccer match-play

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Abstract

The aim of this study was to quantify whole and peak physical characteristics of Under (U)14 and U16 elite youth female soccer, and compare by position and age-group. Data was collected using 10Hz GPS units from 431 match observations, during 50 matches involving 201 players (U14 n=93; U16 n=108) representing Regional Talent Centres in The Football Association's Girl's England Talent Pathway League. Whole match data were reported as absolute and relative; total (TD), high speed running (HSR; ≥3.46m·s^{-1}), very high speed running (VHSR; ≥ 5.29 m·s^{-1}), and sprinting (SPR; ≥6.26 m·s^{-1}) distance, and maximum velocity. Moving average analysis determined peak data for 1-10 minute durations. Linear mixed modelling and effect sizes (ES) established position-specific differences. Results showed U16s covered greater; absolute distance at all speeds (small-moderate ESs; $p<0.001$); relative VHSR and SPR m·min^{-1} (small-moderate ESs; $p<0.001$); peak TD and HSR m·min^{-1} (small ESs) across several peak-durations, and VHSR m·min^{-1} (small ESs; $p<0.001$) across all peak-durations compared to U14s. Position-specific differences were observed across all positions between and within both age-groups, identifying whole and peak physical characteristics are age- and position-dependent within elite youth female soccer match-play. Findings may facilitate informed coaching practices and training programme design, talent identification and development processes.

Keywords: match demands, running demands, activity profiles, match analysis, football

Introduction

Over recent years, there has been substantial growth and development within elite female soccer. This has included the establishment of professional leagues and teams, investment within youth and senior environments, and, provision for improving support and pathways for the development of talented youth players. Furthermore, recent research has observed improvements in physical performance of elite senior female soccer match-play (Scott et al., 2020; FIFA, 2020), suggesting the increased professionalism of the game has translated to improvements on the pitch. Despite this growth, there is still a lack of scientific literature associated with elite female soccer, which in turn makes it challenging to develop an evidence informed approach to practice.

To date, the available scientific research predominantly quantifies the physical characteristics of match-play involving senior players (Mohr et al., 2008; Datson et al., 2017; Scott et al., 2020). Physical match characteristics (e.g. total distance, high-speed running or sprinting) have been reported to differ between positions (Datson et al., 2017; Datson et al., 2019). Situational variables such as; match outcome, standard of opposition, and environmental factors, have also been shown to influence physical outputs within elite senior female soccer (Trewin et al., 2018a). Knowledge of the physical characteristics of match-play and understanding how physical performances may differ between players is important for providing practitioners with an evidence-base to inform their practices, such as; preparing training programmes, monitoring training loads, or designing coaching practices to optimise players' physical readiness for match-play.

Whilst there is a growing body of research on the physical match characteristics of elite senior female players, to date, the understanding of physical match characteristics of elite youth female players is particularly limited. Such information is important for practitioners, to help inform age-specific practices, talent identification and talent development processes. To the best of the authors knowledge, only three known studies have quantified the physical characteristics of elite youth female match-play (Ramos, Nakamura, et al., 2019; Ramos et al., 2017; Vescovi, 2014). However, these studies mostly involved youth age-groups of Under (U)16 to U20, and consequently the physical match characteristics of younger age-groups are currently unknown. Furthermore, due to the methods adopted by these studies, it is difficult for practitioners working with elite youth female players to implement age-specific practices based on their results or findings. For example, Ramos, Nakamura et al. (2019) and Ramos et al. (2017) involved players from a single team with a low number of match observations, and consequently the results may not be generalizable to the population. Vescovi (2014) also had a low number of match observations and did not quantify position-specific characteristics at each age-group, which in senior elite female players has shown to influence physical characteristics (Datson et al., 2017). Additionally, these studies primarily quantified whole match characteristics with only one study quantifying the peak characteristics (at 5 minute durations) with U20 players (Ramos et al., 2017). Therefore, in addition to the limited knowledge of whole match physical characteristics, there is also presently no knowledge of the current peak characteristics experienced during elite youth female soccer match-play for younger age-groups. This is problematic, as whole match characteristics provide limited information regarding the intermittent nature of match-play, and likely underrepresent the true demands of match-play, particularly during the most intense periods. Whereas peak physical characteristics provide insight to these most

demanding periods of match-play. Increasing knowledge and understanding of how peak characteristics may differ across varying durations, playing position, or age-group, will help practitioners; physically prepare players for these specific 'worst case scenarios' experienced during match-play through evidence-informed training programme design and coaching practice design (Doncaster et al., 2020; Fereday et al., 2020).

Consequential of the growth and increased professionalism of elite female soccer, there has been increased provision within elite youth female populations (e.g. Regional Talent Clubs (RTCs) in England). These RTCs follow a similar structure to the Elite Player Performance Plan (EPPP) in male youth soccer in England, and aim to improve the standard of future senior players by improving the standard of youth players and providing greater support and focussed development of youth players across age-groups (U10 to U16 age-groups). However, the lack of research regarding match-play with elite youth female soccer players is problematic for practitioners working with the population. Currently practitioners are reliant on using literature involving male youth players or senior female players to inform their practice. The assumption that match performance, and particularly physical match characteristics, are similar between male and female youth players is inappropriate due to gender-differences in physical and physiological characteristics, particularly during maturation (Emmonds et al., 2018). Therefore, there is an importance and need for female-specific data to ensure coaches and practitioners can utilise population-specific research to inform their practice. Thus, the aims of the current study were to: (1) quantify the physical characteristics of match-play for U14 and U16 elite youth female soccer in RTCs in England, (2) compare whole match physical characteristics by positions and age-group, and (3) compare peak physical characteristics by positions and age-group.

Materials and Methods

Participants

A total of 201 elite youth female soccer players from 6 different RTCs participated in the study. Players participated at either U14 (n=93; age: 12.9 ±0.7 years, height: 158.7 ±6.4cm body mass: 48.5 ±8.9kg) or U16 (n=108; age: 15.0 ±0.6 years, height: 162.4 ±5.9cm; body mass: 56.1 ±6.4kg) age-groups. Both U14 and U16 age-groups are standard competitive age-groups within RTCs, determined by players' chronological age. Participants were considered elite, as RTCs are the highest standard of domestic youth female soccer in England. The study received institutional ethical approval, and all players (and parents/guardians) provided informed consent prior to participation.

Procedures

Data was collected from 50 matches (U14 n=26; U16 n=24) during the 2018-19 and 2019-20 seasons of The Football Association's Girl's England Talent Pathway league. Match duration differed between U14 and U16 age-groups (U14: 35-minute halves; U16: 40-minutue halves), and subsequent observed match duration was; 77:03 ±5:02 min and 82:56 ±3:16 min, respectively. Pitch dimensions also varied between U14 and U16 age-groups (75m x 45 *vs.* 91m x 56m). Match location included; home (U14 n=14; U16 n=14) and away (U14 n=12; U16 n=10), playing surface was either; artificial turf (U14 n=11; U16 n=15) or grass (U14

n=15; U16 n=9), and match outcomes included; wins (U14 n=10; U16 n=6), draws (U14 n=7; U16 n=5) and losses (U14 n=9; U16 n=12).

A total of 641 (U14: n=305; mean per player=3.2 ±1.5; range=1-8; U16: n=336; mean=3.2 ±1.9; range=1-8) individual player observations were obtained. Players were not allocated to specific playing positions as predominantly observed in the literature, as limited full match observations (U14 n=63; U16 n=68) occurred due to; rolling substitutions, return substitutions, and players rotating positions within matches, all of which are common practice within the RTC league. Instead, participants' respective playing time at each playing position contributed to respective positions' overall match observation. For example, within a match two participants play as a team's right back; participant A's data in the first half and participant B's data in the second half would both contribute to one overall right-back positional-observation. This approach has previously been adopted by research quantifying technical characteristics within this population (Harkness-Armstrong et al., 2020), however has yet to be adopted when quantifying physical data. Therefore, sub-analyses were conducted on a dataset adopting the positional approach (n=431) or involving whole match player observations only (n=131). No significant differences ($p>0.05$) occurred in physical match characteristics for all variables quantified in this study, across all playing positions and in both age groups. As whole and peak physical characteristics variables did not differ dependent upon whether observations were derived by player or playing position, the positional approach was adopted to maximise the available dataset. Thus, a total of 431 positional observations (U14 n=227; U16 n=204) were derived from player observations; central defenders (CD; U14 n=40; U16 n=42), wide defenders (WD; U14 n=49; U16 n=41), central midfielders (CM; U14 n=61; U16 n=53), wide midfielders (WM; U14 n=41; U16 n=42) and forwards (FWD; U14 n=36; U16 n=26).

Physical match characteristics were quantified using 10Hz global positioning units (GPS; Optimeye S5, Catapult Sports, Melbourne, Australia). The validity and reliability of these devices for quantifying physical characteristics in team sports have previously been described elsewhere (Scott et al., 2016). Prior to match warm-up routines, GPS units were switched on to facilitate sufficient satellite connection (11.9 ±0.1 satellites; 0.71 ±0.06 horizontal dilution of precision) and placed into a bespoke harness worn beneath the playing shirt, fitting the GPS unit to the upper back of each player. Data was downloaded post-match using Openfield software (Catapult Sports, Melbourne, Australia), then exported for subsequent analyses. The variables chosen for the current study were; total distance (TD), high speed running (HSR; $\geq 3.46 m \cdot s^{-1}$), very high-speed running (VHSR; $\geq 5.29 m \cdot s^{-1}$), sprinting (SPR; $\geq 6.26 m \cdot s^{-1}$), and maximum velocity, which were reflective of the velocity thresholds recently adopted by Scott et al. (2020) for elite female soccer players. These thresholds had been established by a previous methodological paper based on match-data of elite senior female soccer players (Park et al., 2019). Additionally, relative distances ($m \cdot min^{-1}$) were also included to facilitate comparisons between age-groups whilst accounting for differences in match durations.

To establish the peak data for each match observation, raw GPS data files of player observations were exported, and positional observations created from the relevant player observations. Subsequently, files were imported to R Studio (v1.2.1335; 2018) for analysis. Peak data were calculated for TD, HSR and VHSR (including SPR) variables, using a moving average for 1-10 minute durations. The maximum value recorded for each duration

during each match observation was determined as the peak for each variable. Peak data was expressed as relative distance ($m \cdot min^{-1}$) to facilitate practical application.

Statistical Analysis

All statistical analyses were conducted using RStudio (RStudio Team, 2018). Linear mixed models (lme4 package) were developed to quantify differences for each physical variable (dependent variable), between age-group and playing position (fixed effects). Repeated measures were accounted for within random effects, including; fixture, and position nested within team. The assumptions of linearity and normality of distributions of the model were verified visually, and homogeneity of variance was assessed using Levene's Test ($p>0.05$). Estimated means for each variable were derived from the models using the emmeans package, and reported as mean ± SE. To identify position-specific differences between age-groups and positions, Tukey's pairwise comparisons were conducted. Statistical significance was set at $p<0.05$. Effect size (ES) was also calculated to determine the magnitude of the difference (effsize package). ES was classified as trivial (<0.2), small (0.2-0.59), moderate (0.6-1.19), large (1.2-1.99) or very large (>2.0) (Batterham & Hopkins, 2006). Effects were considered unclear if the 90% confidence intervals included both substantial (<0.2) positive and negative values (Hopkins et al., 2009).

Results

Whole match characteristics

Table 1 presents the whole match physical characteristics by playing position for U14 and U16 age-groups and presents the comparisons between age-groups. Small to moderate differences were identified between U14 and U16 age-groups, with U14s performing less TD, HSR, VHSR, SPR, VHSR $m \cdot min^{-1}$, and SPR $m \cdot min^{-1}$, and had a lower maximum velocity.

Within position, there were no clear differences in relative whole match characteristics between U14 and U16 CDs, and U14 and U16 CMs. U14 WDs covered less TD $m \cdot min^{-1}$, HSR $m \cdot min^{-1}$, VHSR $m \cdot min^{-1}$, and SPR $m \cdot min^{-1}$ than U16 WDs. U14 WMs covered less HSR $m \cdot min^{-1}$, VHSR $m \cdot min^{-1}$, and SPR $m \cdot min^{-1}$ than U16 WMs. U14 FWDs performed less VHSR $m \cdot min^{-1}$, and SPR $m \cdot min^{-1}$ than U16 FWDs.

*** TABLE 1 NEAR HERE ***

Figure 1 presents the position-specific differences in relative whole match physical characteristics within U14 and U16 age-groups.

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Peak match characteristics

The position-specific peak relative distances for elite youth female soccer match-play, for duration-specific periods of 1-min to 10-min for TD m·min^{-1}, HSR m·min^{-1}and VHSR m·min^{-1} are presented in Figures 2, 3, and 4, respectively, alongside position-specific differences within age-groups.

U16s covered more TD m·min^{-1} at all durations except 10-min (small ESs: 0.21-0.54), and HSR m·min^{-1} at 1-min to 4-min durations (small ESs: 0.23-0.35) than U14s. U16s also performed more VHSR m·min^{-1} ($p<0.001$, small ES:0.40-0.52) at all durations. Position-specific differences compared peak characteristics between age-groups. The only clear differences between CDs were that U16s performed more VHSR m·min^{-1} (small ES: 0.25-0.51) than U14s at 1-min to 6-min durations. U16 WDs covered more TD m·min^{-1} (small-moderate ES: 0.36-0.88) at all durations, HSR m·min^{-1} (small ES: 0.27-0.47) at 1-min (small ES: 0.58 ±0.37), 2-min (small ES: 0.39 ±0.42), 3-min (small ES: 0.40 ±0.46) and 6-min (small ES: 0.29 ±0.46) durations, and VHSR m·min^{-1} (small-moderate ES: 0.58-0.82) at all durations compared to U14 WDs. U16 CMs covered more TD m·min^{-1} (small ES: 0.22-0.30) at 1-min to 3-min durations. However, U14 CMs covered more HSR m·min^{-1} at 6-min (small ES: 0.25 ±0.44), 7-min (small ES: 0.23 ±0.42) and 10-min (small ES: 0.22 ±0.42) durations. U16 WMs covered more TD m·min^{-1} at 1-min (moderate ES: 0.61 ±0.44), 2-min (small ES:0.59 ±0.47), 4-min (small ES: 0.40 ±0.47) and 5-min (small ES: 0.34 ±0.47) durations, and more HSR m·min^{-1} (small-moderate ES: 0.41-0.64) and VHSR m·min^{-1} ($p<0.05$; moderate ES: 0.76-0.98) at all durations compared to U14 WMs. U16 FWDs covered more TD m·min^{-1} (small-moderate ES: 0.37-0.78) at all durations, HSR m·min^{-1} at 1-min to 4-min, and 6-min durations (small-moderate ES: 0.31-0.61), and VHSR m·min^{-1} (small-moderate ES:0.41-0.76) at all durations, compared to U14 FWDs.

*** FIGURE 2 NEAR HERE ***

*** FIGURE 3 NEAR HERE ***

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Discussion

The aim of the current study was to quantify the physical characteristics of U14 and U16 elite youth female soccer match-play and compare position-specific differences between and within these age-groups for whole and peak match characteristics. This was the first known study to (a) quantify physical performances of U14 youth female soccer players during match-play, (b) provide position-specific characteristics for U14 and U16 female soccer players, (c) provide relative distances at different velocity zones in female youth soccer players, and (d) provide peak characteristics at differing durations in female soccer match-play. This study also utilised the largest dataset to date quantifying elite youth female soccer match characteristics, involving 201 players from six different RTCs.

The physical characteristics of U16 match-play were greater than U14 match-play; whole match results showed that U16s covered greater TD, HSR, VHSR and SPR ($p<0.001$; small-moderate ESs: 0.53-1.06), achieved higher maximum velocity ($p<0.001$; small ES: 0.59), and performed more VHSR m·min^{-1} and SPR m·min^{-1} ($p<0.001$; small-moderate ES: 0.53-0.67)

than U14s. Additionally, peak characteristics identified that U16s performed greater TD (small ESs: 0.21-0.54) at all durations except 10-min, HSR $m \cdot min^{-1}$ (small ESs: 0.23-0.35) during 1-min to 4-min peak durations, and VHSR $m \cdot min^{-1}$ ($p<0.001$; small ESs: 0.40-0.52) across all peak durations compared to U14s. Furthermore, there were position-specific differences observed between age-groups for all metrics, further evidencing that physical characteristics of elite youth female soccer match-play are age-group dependent. Findings also identified that physical match characteristics are position-dependent, with differences observed between all positions within both age-groups for both whole and peak physical characteristics. The current study contributes to the limited body of literature regarding elite youth female soccer match-play, and the results and findings from this study can be used by practitioners to inform age- and position-specific practices for the physical development of elite youth female soccer players.

When comparing the absolute TD covered by U14 and U16 players to elite senior female soccer players, all positions covered notably less than their respective senior players (U14=6602 - 7798m; U16=6954 - 8385m; *vs.* senior=9398 - 10644m; Scott et al., 2020). This will partially be due to the differences in match durations between youth and seniors. However, it may also be due to senior players having increased physical capacity and match-specific fitness (Emmonds et al., 2018; Ramos, Nakamura et al., 2019) or that senior match-play generally occurs at greater intensities than youth match-play, as the differences between youth and senior players seem more apparent when considering the absolute HSR (U14=1245 - 1742m; U16=1308 - 2023m; *vs.* senior=1936 - 2749m), VHSR (U14=116 - 249m; U16=124 - 326m; *vs.* senior=316 - 666m) and SPR (U14=13 - 43m; U16=17 - 75m; *vs.* senior=59 - 248m) distances (Scott et al., 2020). Conversely, it is also likely that given that the youth maximum velocity is notably lower than seniors for all positions (U14=23.0 – $24.6 km \cdot h^{-1}$; U16=23.8 – $25.3 km \cdot h^{-1}$; *vs.* senior=28.7 – $30.6 km \cdot h^{-1}$), the velocity thresholds used for this study, which were established from senior elite female match-data (Park et al., 2019), may be too high for the youth players to achieve (VHSR $>19.0 km \cdot h^{-1}$; SPR $>22.5 km \cdot h^{-1}$) as consistently as senior players, or potentially at all. This is particularly notable at the U14 age-group as players covered less absolute and relative VHSR and SPR than U16 players, with a velocity maximum of only $0.57 m \cdot s^{-1}$ ($2.05 km \cdot h^{-1}$) above the SPR threshold. Consequently, as velocity thresholds created for senior players are not proportionate to the physical capacities of youth players, adopting these velocity thresholds in research or practice will likely lead to an underestimation of distance and $m \cdot min^{-1}$ within the VHSR and SPR zones, and therefore not accurately reflect the true physical characteristics of elite youth female soccer match-play. Future research should therefore aim to establish age-specific velocity thresholds for the appropriate quantification of physical characteristics within match-play at youth age-groups. However, it is important to note that adopting either senior or age-specific velocity thresholds should be dependent upon the research aim or practitioner's intended use. For example, the use of senior-derived velocity thresholds as adopted within this study is necessary for the comparison of physical characteristics across the talent pathway, which may provide valuable insight for practitioners preparing players transitioning from youth to senior playing levels. Whilst, for example, the use of youth velocity thresholds when analysing youth players' physical performance or monitoring load throughout a season, may be the most appropriate approach. Ultimately, researchers and practitioners should make an informed decision regarding the most appropriate approach for their context and the intended use of data.
The relative data showed some position-specific similarities between age-groups for TD and HSR $m \cdot min^{-1}$, yet players in both age-groups covered considerably less TD $m \cdot min^{-1}$ than elite senior female players (U14=85.4 – $100.9 m \cdot min^{-1}$; U16=83.8 – $100.5 m \cdot min^{-1}$; *vs.* senior=101.3 – 110.3 $m \cdot min^{-1}$; Ramos, Datson et al., 2019), further suggesting that match

demands increase between youth and senior levels (Ramos, Nakamura, et al., 2019). The relative data shows an increase in VHSR and SPR m·min^{-1} from U14 to U16 age-groups, which further suggests that; players' ability to perform more higher speed distances increase, match intensities increase with age, or that the velocity thresholds adopted are too excessive for accurately capturing the true physical characteristics of these U14 players. Comparisons of HSR, VHSR and SPR m·min^{-1} with existing senior and male youth literature were not possible as studies reporting relative variables utilised different velocity boundaries. Coaches and practitioners should consider how to prepare players transitioning from U16 to senior environments for the notable increase in absolute and relative external load players experience during match-play. Furthermore, coaches within senior environments who may have players transitioning from U16s age-groups, should consider how players' physical capacities and usual external loads may impact training and match performances, load monitoring and injury prevention. Additionally, future research should aim to quantify the match-play characteristics of The FA's recently established Women's Super League Academy (16-19 years) league, to help practitioners inform further specific practices for RTC players progressing into this elite youth environment prior to transitioning into senior environments. In addition, future research should aim to explore whether Women's Super League Academy match-play helps bridge the gap between youth (specifically RTCs) and senior match-play.

Findings identified differences in both absolute and relative whole match data between positions within each age-group. When considering the relative data, several position-specific similarities were observed between age-groups which were consistent with previous senior female research (Datson et al., 2017; Mara et al., 2017; Scott et al., 2020); CD performed the least TD and HSR m·min^{-1}, whilst CMs performed the least VHSR and SPR m·min^{-1}. CMs covered the most TD m·min^{-1}, WMs performed the greatest HSR m·min^{-1}, and FWDs performed the most SPR m·min^{-1}. Both age-groups highlighted that wide players covered greater distances than their central counterparts (i.e. CD v WD; CM v WM), which is likely influenced by the differing technical-tactical aspects associated with their positional roles. To provide greater insight into the match characteristics of elite youth female soccer match-play, future research should aim to incorporate capturing technical data alongside physical data, to provide further context to the specific situations which players from different playing positions experience during match-play. Coaches and practitioners may use the findings from this study to inform position-specific coaching practices at each age-group, to prepare players for match-play and assist players transitioning between youth age-groups for the increase in external loads experienced during match-play.

Due to the intermittent nature of soccer match-play, consideration of only whole match physical characteristics to inform practices, may not adequately prepare players for the most intense periods of match-play. Therefore, the peak characteristics of match-play were further explored in this study. Furthermore, this study is the first in female soccer literature to quantify peak characteristics across differing time-periods, i.e. 1-min to 10-min, which may be useful for informing prescription of duration-specific practices to ensure optimal preparation for the most intense periods of match-play. The peak results showed the 1-min duration resulted in the highest distances for all positions in both age-groups (TD: U14=156.6 – 165.6m·min^{-1}; U16=159.1 – 172.6m·min^{-1}; HSR: U14=74.6 – 89.5m·min^{-1}; U16=77.0 – 99.1m·min^{-1}; VHSR: U14=28.6 – 34.4m·min^{-1}; U16=28.6 – 42.6m·min^{-1}), and as the peak duration increased, relative distances decreased. This is similar to previous findings within male soccer (Doncaster et al., 2020; Fereday et al., 2020) and other team sports (Whitehead et al., 2019). The position-specific peak 5-min duration TD m·min^{-1} results were notably less

than previously observed in elite senior female players (U14=112.2 - 126.1 m·min^{-1}; U16=112.6 - 127.7 m·min^{-1} *vs.* senior=132 - 146 m·min^{-1}; Trewin et al., 2018b). Comparisons of HSR and VHSR m·min^{-1} with existing senior female literature were not possible as studies reporting peak variables utilised different velocity boundaries. Additionally, comparisons of different durations were also not possible, as no other known research has quantified peak characteristics of elite female soccer match-play across differing peak-durations.

Similar to the whole match data, peak match characteristics were dependent upon age-group and playing position, and also vary between durations. Wide players and FWDs had more differences between age-groups across all durations compared to CDs and CMs. U16 positions consistently performed more distance in these observed differences, however U14 CMs covered more HSR m·min^{-1} at three different durations, which were the only observations where any U14 position had higher peak distances than their U16 counterparts. This discrepancy suggests potential differentiation in CM demands at both age-groups, however it is not possible to identify the contributing reasons for the observed discrepancies with the available data. Future research should include technical characteristics alongside the peak characteristics, to provide further context to the specific situations in which players are performing peak physical characteristics, and explore how these vary between age-groups and positions.

The peak results suggest that research which only includes TD m·min^{-1} may not capture the true position-specific peak characteristics of match-play, and consequently the differences in age- and position-specific peak characteristics. In addition to the discrepancies in peak distances at differing speeds previously discussed between U14 and U16 CMs; CMs performed the highest TD m·min^{-1}, yet covered the least VHSR m·min^{-1}of all positions. Therefore, the inclusion of relative distances at differing speed zones, enables further differentiation in position-specific characteristics. The peak results provide valuable insight into the worst case scenarios players experience during match-play at differing durations (e.g. TD m·min^{-1} 1-min: U14=156.5 - 165.5 m·min^{-1}; U16=159.1 - 170.6 m·min^{-1}; to 10-min: U14= 103.5 - 118.1 m·min^{-1}; U16=103.5 - 118.9 m·min^{-1}) within U14 and U16 elite youth female soccer. The findings can help assist practitioners when designing coaching practice and conditioning programmes for replicating match characteristics to prepare players for the worst case scenarios during match-play.

There are some limitations to the current study which should be acknowledged. As this is only the second study to adopt the velocity thresholds established by Park et al. (2019), there is limited literature to directly compare results. However, this is common within elite female soccer literature, as different velocity thresholds have been utilised due to a lack of consensus regarding the most appropriate velocity thresholds to adopt (Lovell et al., 2019; Vescovi, 2019). As previously discussed, the velocity thresholds used in this study may be too high for the physical capacities of youth players and so may not accurately reflect the true physical characteristics of elite youth female soccer match-play. Thus, whilst the Park et al. (2019) velocity thresholds may be the most statistically valid to date for quantifying senior female match-play, future research should aim to establish specific velocity thresholds for the quantification of physical match-play characteristics of youth players. Additionally, future research may consider not using qualitative descriptors alongside velocity thresholds to avoid misinterpretation of data. A further limitation to the current study, is that whilst match contextual and situational variables were detailed, these were not accounted for within the linear mixed model. Future research should explore the effect of contextual or situational

variables, such as match outcome, on physical characteristics within elite youth female soccer. Another limitation is that it only includes U14 and U16 age-groups. However, this study utilises the largest dataset to date in literature quantifying female youth soccer match-play, and includes multiple RTCs whilst the majority of literature only involves a single team. Additionally, collecting the physical characteristics of match-play with younger age-groups would not have been appropriate comparisons, as U10 and U12 RTC age-groups compete predominantly in mixed-gender competitions.

In conclusion, this study is the first to quantify the physical characteristics of U14 and U16 elite youth female soccer match-play, included players from multiple teams and identified position-specific differences between and within these age-groups. Additionally, this study presents both absolute and relative physical characteristics, and peak characteristics at differing durations of U14 and U16 elite youth female soccer match-play. The results provide insight into the total external loads experienced by players for whole match and at the most physically demanding periods of match-play, but also facilitate relative comparisons between U14 and U16 players, specific to each position. Coaches and practitioners may use both the absolute and relative whole match, and peak data in this study to inform age-specific training programme design and coaching practices to prepare youth female players for match-play, aid player development, and to prepare or support transitioning players from U14 to U16 age-groups, or from U16 into senior environments. Future research is required to establish age-specific velocity thresholds for the appropriate quantification and description of physical characteristics involving youth players alongside exploring the technical characteristics associated with specific physical characteristics of match-play to add further context to the data.

Disclosure Statement

No potential conflict of interest was reported by the authors.

References

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50-57.DOI: 10.1123/ijspp.1.1.50

Datson, N., Drust, B., Weston, M., & Gregson, W. (2019). Repeated high-speed running in elite female soccer players during international competition. *Science and Medicine in Football*, *3*(2), 150-156. DOI: 10.1080/24733938.2018.1508880

Datson, N., Drust, B., Weston, M., Jarman, I. H., Lisboa, P. J., & Gregson, W. (2017). Match physical performance of elite female soccer players during international competition. *The Journal of Strength & Conditioning Research*, *31*(9), 2379-2387. DOI: 10.1519/JSC.0000000000001575

Doncaster, G., Page, R., White, P., Svenson, R., & Twist, C. (2020). Analysis of physical demands during youth soccer match-play: considerations of sampling method and epoch length. *Research Quarterly for Exercise and Sport*, *91*(2), 326-334. DOI: 10.1080/02701367.2019.1669766

Emmonds, S., Till, K., Redgrave, J., Murray, E., Turner, L., Robinson, C., & Jones, B. (2018). Influence of age on the anthropometric and performance characteristics of high-level youth female soccer players. *International Journal of Sports Science & Coaching*, *13*(5), 779-786. DOI: 10.1177/1747954118757437

Fereday, K., Hills, S. P., Russell, M., Smith, J., Cunningham, D. J., Shearer, D., ... & Kilduff, L. P. (2020). A comparison of rolling averages versus discrete time epochs for assessing the worst-case scenario locomotor demands of professional soccer match-play. *Journal of Science and Medicine in Sport*, *23*(8), 764-769. DOI: 10.1016/j.jsams.2020.01.002

FIFA. (2020). *Physical analysis of the FIFA Women's World Cup France 2019.* Retrieved from https://img.fifa.com/image/upload/zijqly4oednqa5gffgaz.pdf

Harkness-Armstrong, A., Till, K., Datson, N., & Emmonds, S. (2020). Technical characteristics of elite youth female soccer match-play: position and age group comparisons between under 14 and under 16 age groups. *International Journal of Performance Analysis in Sport*, *20*(6), 942-959. DOI: 10.1080/24748668.2020.1820173

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, *41*(1), 3-12. DOI: 10.1249/MSS.0b013e31818cb278

Lovell, R., Scott, D., & Park, L. (2019). Soccer Velocity Thresholds: Do we really know what's best?. *Science and Medicine in Football*, *3*(1), 85-86. DOI: 10.1080/24733938.2019.1565361

Mara, J. K., Thompson, K. G., Pumpa, K. L., & Morgan, S. (2017). Quantifying the high-speed running and sprinting profiles of elite female soccer players during competitive matches using an optical player tracking system. *The Journal of Strength & Conditioning Research*, *31*(6), 1500-1508. DOI: 10.1519/JSC.0000000000001629

Mohr, M., Krustrup, P., Andersson, H., Kirkendal, D., & Bangsbo, J. (2008). Match activities of elite women soccer players at different performance levels. *The Journal of Strength & Conditioning Research*, *22*(2), 341-349. DOI: 10.1519/JSC.0b013e318165fef6

Park, L. A., Scott, D., & Lovell, R. (2019). Velocity zone classification in elite women's football: where do we draw the lines?. *Science and Medicine in Football*, *3*(1), 21-28. DOI: 10.1080/24733938.2018.1517947

RStudio Team (2018). Rstudio: Integrated Development for R. RStudio, Inc., Boston, MA. URL: http://www.rstudio.com/.

Ramos, G. P., Nakamura, F. Y., Pereira, L. A., Junior, W. B., Mahseredjian, F., Wilke, C. F., ... & Coimbra, C. C. (2017). Movement patterns of a U-20 national women's soccer team during competitive matches: influence of playing position and performance in the first half. *International Journal of Sports Medicine*, *38*(10), 747-754. DOI: 10.1055/s-0043-110767

Ramos, G. P., Nakamura, F. Y., Penna, E. M., Wilke, C. F., Pereira, L. A., Loturco, I., ... & Coimbra, C. C. (2019). Activity profiles in U17, U20 and senior women's Brazilian National soccer teams during international competitions: Are there meaningful differences? *Journal of*

Strength and Conditioning Research, *33*(12), 3414-3422. DOI: 10.1519/JSC.0000000000002170

Ramos, G. P., Datson, N., Mahseredjian, F., Lopes, T. R., Coimbra, C. C., Prado, L. S., ... & Penna, E. M. (2019). Activity profile of training and matches in Brazilian Olympic female soccer team. *Science and Medicine in Football*, *3*(3), 231-237. DOI: 10.1080/24733938.2019.1615120

Scott, D., Haigh, J., & Lovell, R. (2020). Physical characteristics and match performances in women's international versus domestic-level football players: A 2-year, league-wide study. *Science and Medicine in Football*. DOI: 10.1080/24733938.2020.1745265

Scott, M. T., Scott, T. J., & Kelly, V. G. (2016). The validity and reliability of global positioning systems in team sport: a brief review. *The Journal of Strength & Conditioning Research*, *30*(5), 1470-1490. DOI: 10.1519/JSC.0000000000001221

Trewin, J., Meylan, C., Varley, M. C., Cronin, J., & Ling, D. (2018a). Effect of match factors on the running performance of elite female soccer players. *The Journal of Strength & Conditioning Research*, *32*(7), 2002-2009. DOI: 10.1519/JSC.0000000000002584

Trewin, J., Meylan, C., Varley, M. C., & Cronin, J. (2018b). The match-to-match variation of match-running in elite female soccer. *Journal of Science and Medicine in Sport*, *21*(2), 196-201. DOI: 10.1016/j.jsams.2017.05.009

Vescovi, J. D. (2014). Motion characteristics of youth women soccer matches: Female Athletes in Motion (FAiM) Study. *International Journal of Sports Medicine*, *35*(02), 110-117. DOI: 10.1055/s-0033-1345134

Vescovi, J. D. (2019). Women's soccer velocity thresholds: statistical techniques or physiological metrics–context is critical. *Science and Medicine in Football*, *3*(1), 81-82. DOI: 10.1080/24733938.2018.1562278

Whitehead, S., Till, K., Weaving, D., Hunwicks, R., Pacey, R., & Jones, B. (2019). Whole, half and peak running demands during club and international youth rugby league match-play. *Science and Medicine in Football*, *3*(1), 63-69. DOI: 10.1080/24733938.2018.1480058

Table 1. Estimated mean ± SE of whole match physical characteristics of U14 and U16 elite youth female soccer match-play. *Position-specific statistical significance (p<0.05*, p<0.01**, p<0.001***) between U14 and U16 age-groups, and effect size (ES ± 90% CI) of age-group are shown.*

		All	Central Defenders	Wide Defenders	Central Midfielders	Wide Midfielders	Forwards
Total Distance (m)	U14	7148.0 ± 147.2***	6602.9 ± 189.4	6905.0 ± 184.3**	7798.6 ± 182.8**	7471.8 ± 189.1	6961.7 ± 192.7
	U16	7678.7 ± 148.0	6954.1 ± 187.9	7603.2 ± 188.7	8385.4 ± 188.5	7934.3 ± 188.3	7516.3 ± 200.4
	vs.	Moderate ES: -1.06 ± 0.25	Moderate ES: -0.70 ± 0.54	Large ES: -1.39 ± 0.54	Moderate ES: -1.17 ± 0.52	Moderate ES: -0.92 ± 0.54	Moderate ES: -1.10 ± 0.61
High speed running (m)	U14	1530.4 ± 61.6***	1246.0 ± 91.0	1470.8 ± 87.2	1609.0 ± 86.1	1742.3 ± 90.7	1584.1 ± 93.1
	U16	1695.5 ± 62.1	1308.0 ± 89.7	1729.2 ± 90.1	1688.9 ± 89.0	2023.3 ± 90.0	1728.2 ± 98.7
	vs.	Small ES: -0.53 ± 0.21	Unclear ES: -0.20 ± 0.47	Moderate ES: -0.83 ± 0.45	Small ES: -0.26 ± 0.43	Moderate ES: -0.90 ± 0.47	Unclear ES: -0.30 ± 0.53
Very high speed running (m)	U14	187.6 ± 10.1***	188.4 ± 21.7	182.5 ± 20.6**	115.7 ± 20.3	202.1 ± 21.6***	249.4 ± 22.3
	U16	249.4 ± 10.3	203.5 ± 21.3	276.5 ± 21.4	123.7 ± 21.0	325.7 ± 21.4	315.9 ± 23.9
	vs.	Moderate ES: -0.72 ± 0.20	Unclear ES: -0.18 ± 0.44	Moderate ES: -1.10 ± 0.43	Unclear ES: -0.09 ± 0.40	Large ES: -1.45 ± 0.45	Moderate ES: -0.78 ± 0.50
Sprinting (m)	U14	28.8 ± 3.8***	32.8 ± 7.3	25.3 ± 6.9***	12.6 ± 6.7	30.1 ± 7.3***	43.0 ± 7.6*
	U16	53.4 ± 3.9	40.7 ± 7.2	61.8 ± 7.2	17.4 ± 7.0	75.3 ± 8.2	71.9 ± 7.2
	vs.	Moderate ES: -0.76 ± 0.19	Small ES: -0.24 ± 0.42	Moderate ES: -1.12 ± 0.41	Unclear ES: -0.15 ± 0.38	Large ES: -1.28 ± 0.42	Moderate ES: -0.99 ± 0.48
Maximum velocity ($m \cdot s^{-1}$)	U14	6.67 ± 0.03***	6.76 ± 0.08	6.65 ± 0.07*	6.39 ± 0.07	6.71 ± 0.07**	6.83 ± 0.08
	U16	6.90 ± 0.03	6.80 ± 0.07	6.97 ± 0.07	6.62 ± 0.07	7.07 ± 0.07	7.02 ± 0.09
	vs.	Small ES: -0.59 ± 0.18	Unclear ES: -0.10 ± 0.39	Moderate ES: -0.83 ± 0.38	Small ES:- 0.58 ± 0.35	Moderate ES: -0.93 ± 0.39	Small ES: -0.50 ± 0.45
TD per minute ($m \cdot min^{-1}$)	U14	92.4 ± 1.7	85.4 ± 2.3	89.1 ± 2.2	100.9 ± 2.2	97.2 ± 2.3	89.2 ± 2.3
	U16	92.6 ± 1.7	83.8 ± 2.3	91.7 ± 2.3	100.5 ± 2.3	95.7 ± 2.3	91.4 ± 2.4
	vs.	Unclear ES: -0.04 ± 0.24	Unclear ES: 0.25 ± 0.54	Small ES: -0.42 ± 0.53	Unclear ES: 0.06 ± 0.52	Unclear ES: 0.23 ± 0.54	Unclear ES: -0.35 ± 0.60
HSR metres per minute ($m \cdot min^{-1}$)	U14	19.8 ± 0.8	16.1 ± 1.2	19.0 ± 1.1	20.8 ± 1.1	22.7 ± 1.2	20.2 ± 1.2
	U16	20.5 ± 0.8	15.8 ± 1.1	20.8 ± 1.2	20.3 ± 1.1	24.4 ± 1.2	21.0 ± 1.3
	vs.	Trivial ES: -0.18 ± 0.21	Unclear ES: 0.08 ± 0.47	Small ES: -0.46 ± 0.46	Unclear ES: 0.14 ± 0.44	Small ES: -0.43 ± 0.47	Unclear ES: -0.21 ± 0.53
VHSR metres per minute ($m \cdot min^{-1}$)	U14	2.4 ± 0.1***	2.5 ± 0.3	2.4 ± 0.3*	1.5 ± 0.3	2.7 ± 0.3***	3.2 ± 0.3
	U16	3.0 ± 0.1	2.5 ± 0.3	3.3 ± 0.3	1.5 ± 0.3	3.9 ± 0.3	3.8 ± 0.3
	vs.	Small ES: -0.53 ± 0.20	Unclear ES: -0.00 ± 0.43	Moderate ES: -0.91 ± 0.42	Unclear ES: 0.03 ± 0.39	Moderate ES: -1.16 ± 0.43	Moderate ES: -0.60 ± 0.49
SPR metres per minute ($m \cdot min^{-1}$)	U14	0.4 ± 0.1***	0.4 ± 0.1	0.3 ± 0.1***	0.2 ± 0.1	0.4 ± 0.1***	0.5 ± 0.1
	U16	0.6 ± 0.1	0.5 ± 0.1	0.7 ± 0.1	0.2 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
	vs.	Moderate ES: -0.67 ± 0.19	Unclear ES: -0.16 ± 0.42	Moderate ES: -1.05 ± 0.40	Unclear ES: -0.10 ± 0.37	Moderate ES: -1.14 ± 0.42	Moderate ES: -0.90 ± 0.48

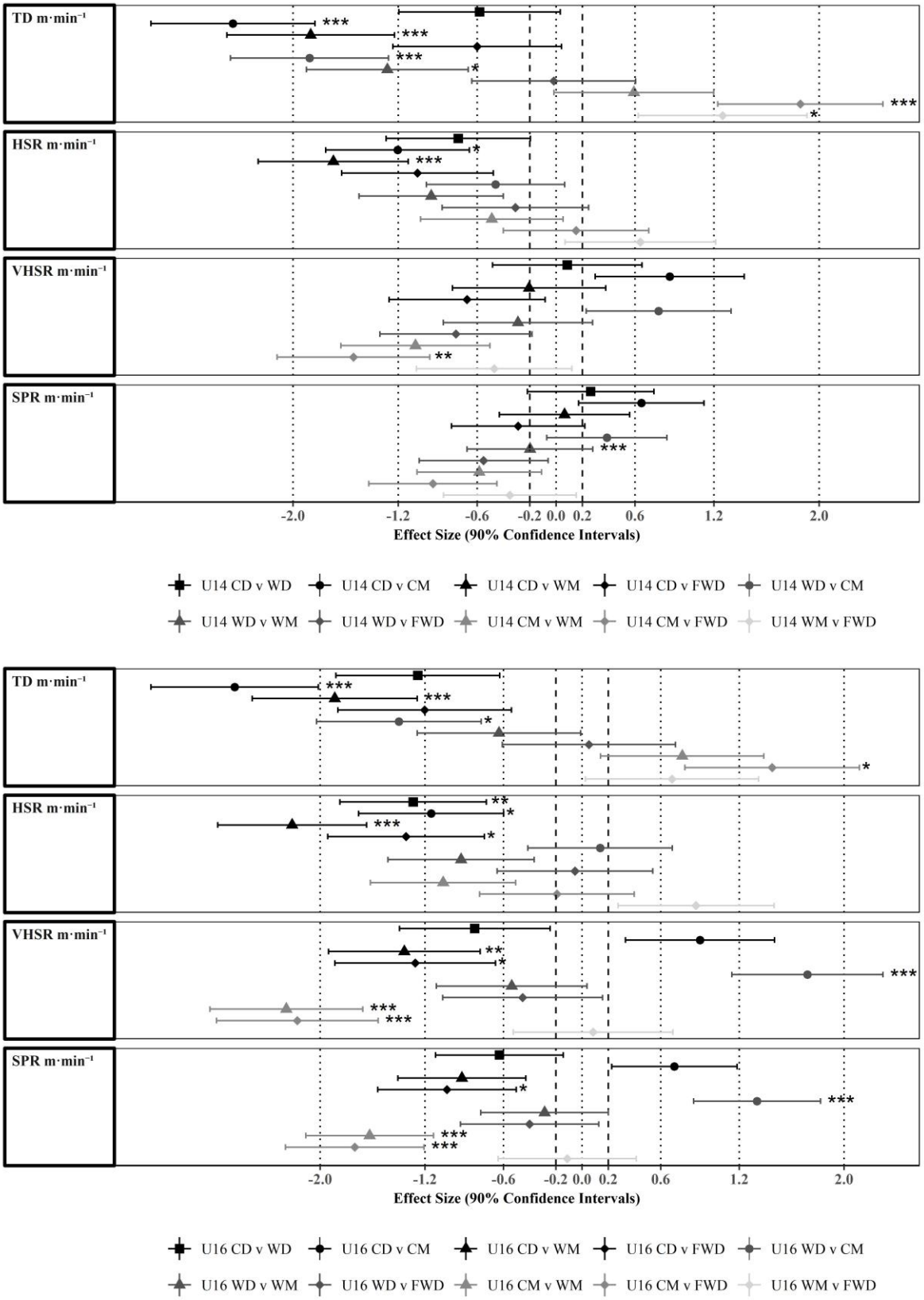

Figure 1. Effect sizes of differences in estimated mean and statistical significance of relative whole match physical characteristics between A) U14 and B) U16 players by position. **Significant difference (p<0.05*, p<0.01**, p<0.001***).*

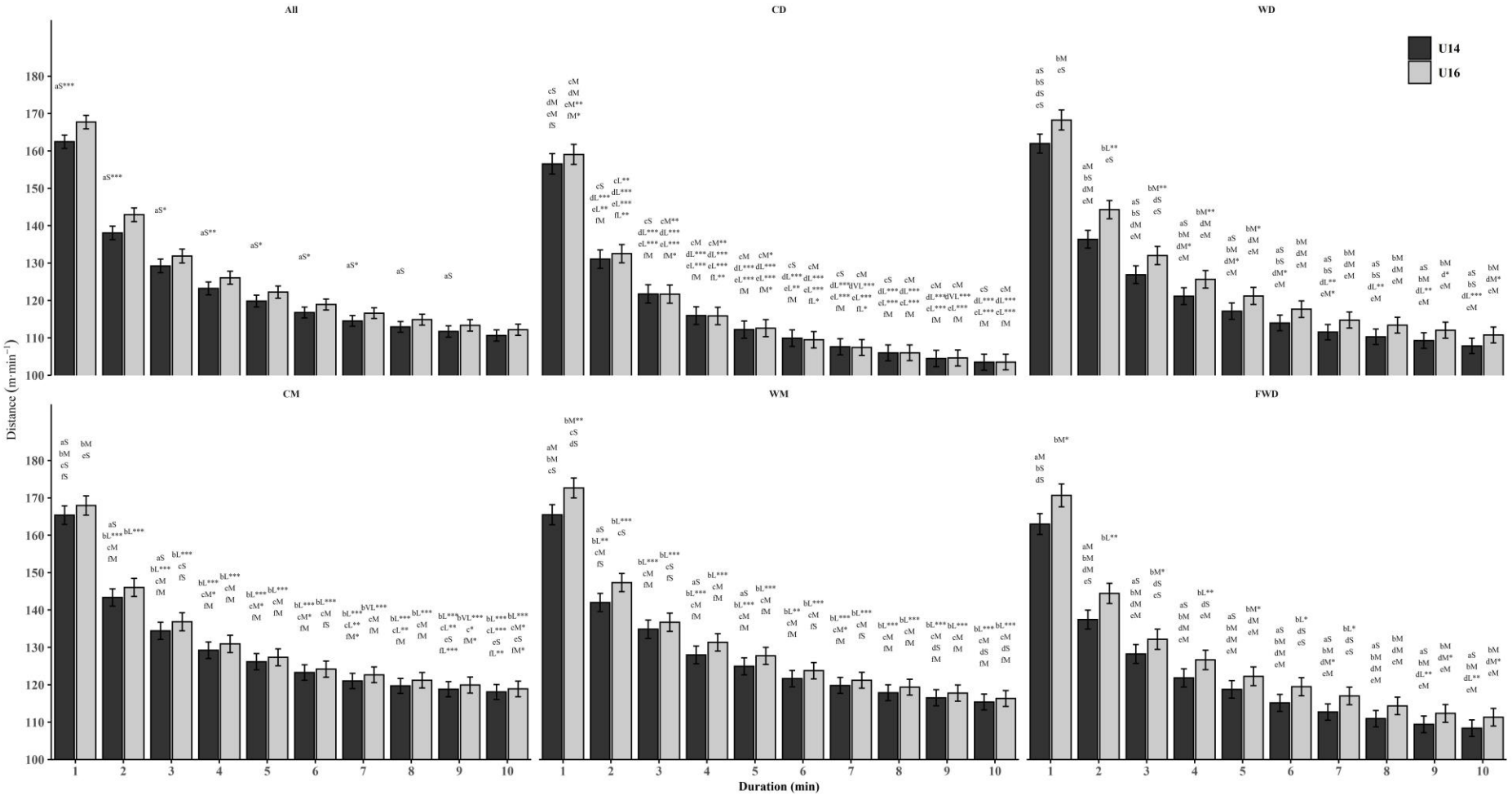

Figure 2. Estimated mean and ±SE of peak relative total distance of U14 and U16 elite youth female soccer match-play at 1-10 minute durations according to playing position. All: all players; CD: central defenders; WD: wide defenders; CM: central midfielders; WM: wide midfielders; FWD: forwards. Position-specific statistical significance ($p<0.05$*, $p<0.01$**, $p<0.001$***) between a) U14 and U16 age-groups, and within age-group difference between b) CD, c) WD, d) CM, e) WM, and f) FWD. Clear effect sizes are shown; S) small ES (0.2-0.59); M) moderate ES (0.6-1.19); L: large ES (1.2-2.0); VL: very large ES (>2.0).

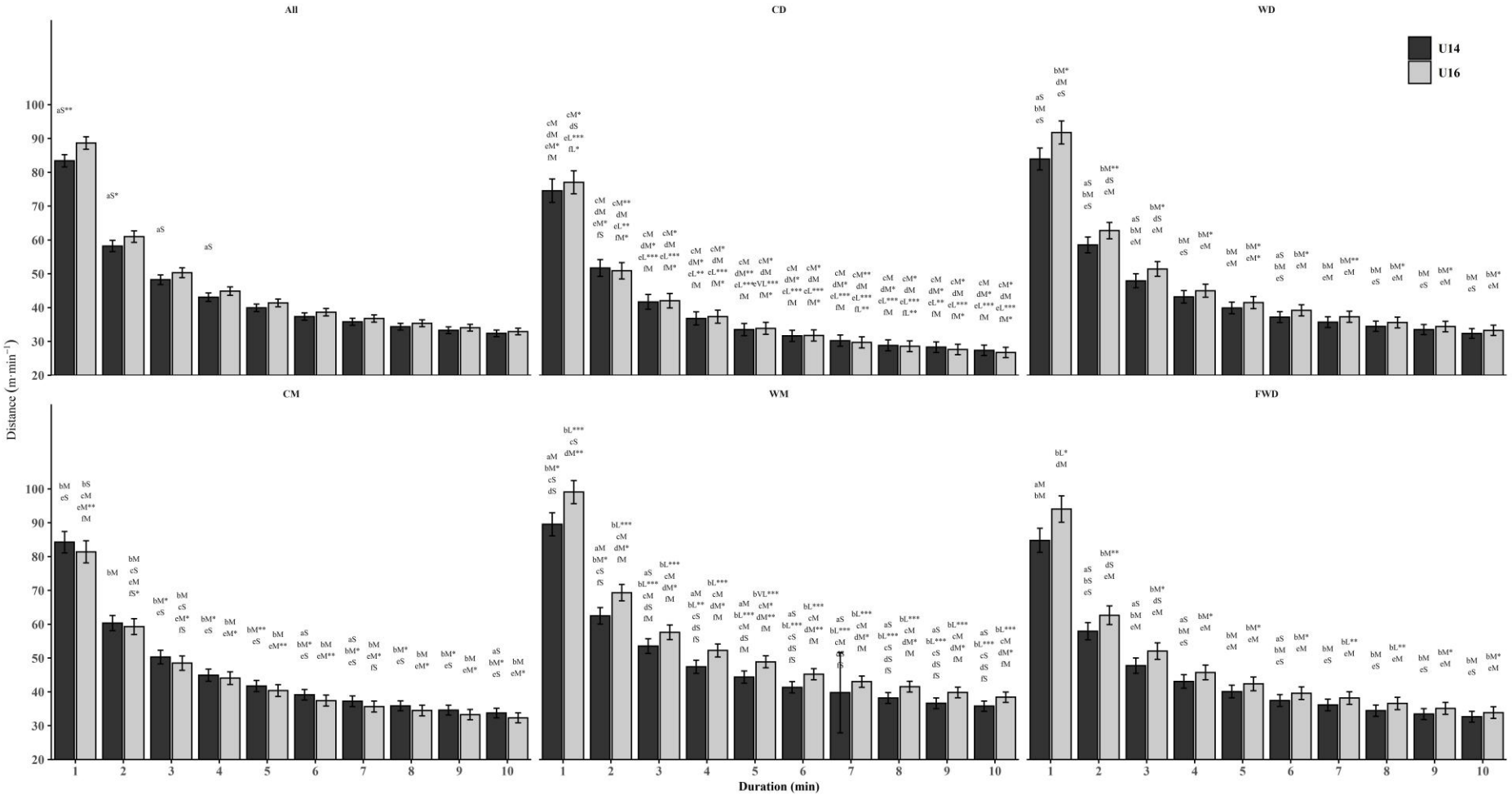

Figure 3. Estimated mean and ±SE of peak relative high speed running distance of U14 and U16 elite youth female soccer match-play at 1-10 minute durations according to playing position. CD: central defenders; WD: wide defenders; CM: central midfielders; WM: wide midfielders; FWD: forwards. Position-specific statistical significance ($p<0.05$*, $p<0.01$**, $p<0.001$***) between a) U14 and U16 age-groups, and within age-group difference between b) CD, c) WD, d) CM, e) WM, and f) FWD. Clear effect sizes are shown; S) small ES (0.2-0.59); M) moderate ES (0.6-1.19); and L: large ES (1.2-2.0).

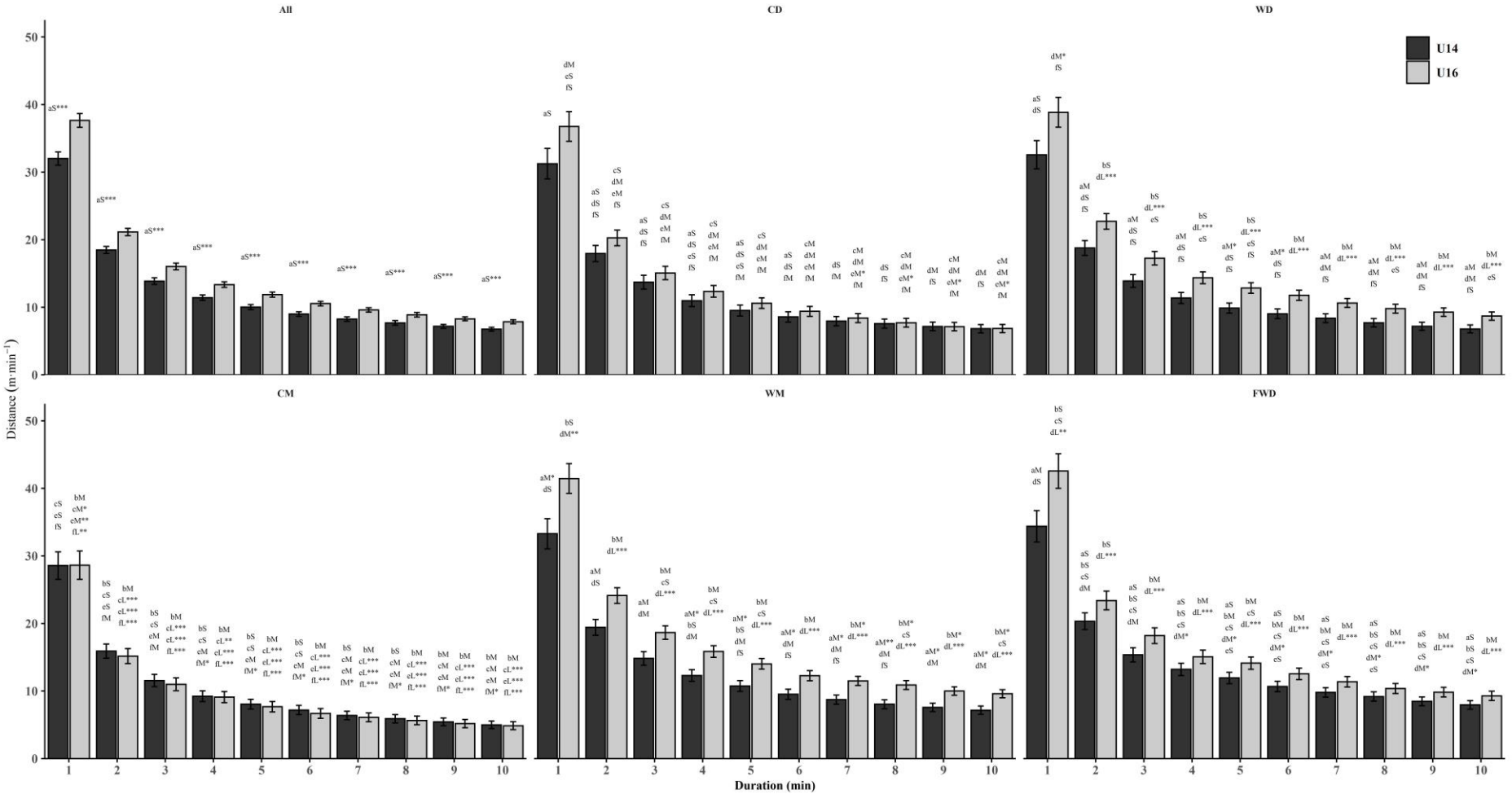

Figure 4. Estimated mean and ±SE of peak relative very high speed running distance of U14 and U16 elite youth female soccer match-play at 1-10 minute durations according to playing position. CD: central defenders; WD: wide defenders; CM: central midfielders; WM: wide midfielders; FWD: forwards. Position-specific statistical significance ($p<0.05$*, $p<0.01$**, $p<0.001$***) between a) U14 and U16 age-groups, and within age-group difference between b) CD, c) WD, d) CM, e) WM, and f) FWD. Clear effect sizes are shown; S) small ES (0.2-0.59); M) moderate ES (0.6-1.19); and L: large ES (1.2-2.0).