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Seasonal Changes in the Physical Performance of Elite Youth Female Soccer Players.

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Running Head: Physical performance of elite youth female soccer players.

ABSTRACT

This study investigated the seasonal change in physical performance of 113 (Under 10: U10 (n=20), U12 (n=30), U14 (n=31) and U16 (n=32)) elite youth female soccer players. Players completed testing pre-, mid- and post-season, including speed (10 and 30m sprint), change of direction (CoD; 505 test), power (Countermovement jump, CMJ), strength (isometric mid-thigh pull) and aerobic capacity (YoYo Intermittent Recovery Test Level 1; YYIRL1). A general linear model was used to evaluate the change in physical characteristics and the influence of covariates (baseline performance; change in maturity status) on each characteristic across the season. U10's speed and CoD performance decreased from pre-post season, while relative strength *likely* improved. U12's relative strength *very likely* improved, however 10m sprint performance decreased. Relative strength *likely* decreased, while 30m sprint and CoD time *very likely* improved in U14's. U16's *likely* improved relative strength, CMJ, 10m sprint and *very likely* improved 30m sprint and CoD from pre-post season. U12-U16's improved YYIRL1 performance pre-post season. Strength and conditioning coaches working with U10-U12 players should look to develop speed, lower body power and CoD ability as part of structured strength and conditioning sessions as well as within warm ups prior to pitch based sessions. With U14-U16 players manipulation of SSG's combined with short duration high-intensity running drills may provide an efficient training stimulus to develop the aerobic system whilst concurrently developing technical/tactical skills. Findings of this study provide a basis for the implementation of strategies to enhance the long-term athletic development of youth female soccer players.

INTRODUCTION

In recent years there has been an increase in the profile of women's soccer (5). Professional women's soccer leagues now exist in several countries across the world. At the elite level, soccer requires high technical ability, tactical awareness, and a high level of physical conditioning (6). Therefore, women's soccer clubs are now investing in youth academies, designed to develop future professional players (10).

Straight line sprinting and jumps have been reported as frequent actions prior to goals during elite soccer for both the scoring and assisting player (12), and to discriminate between standard of competition (16), highlighting the importance of testing and developing such physical qualities in players from a young age. Furthermore, high intensity running ability has also been determined as a key physical attribute for elite soccer performance (1, 2, 24). Elite female players have been reported to perform more high intensity running during International matches compared to domestic matches (1) and perform high intensity running for 28% longer and sprint for 24% longer during matches than non-elite players (24). Similarly, Bradley et al. (2) reported that players performed better on the Yo-Yo Intermittent Endurance Test Level 2 (YYIEL2) than non-elite players, highlighting the importance of testing and training the ability to sustain high intensity running in female soccer players. Therefore, it is important that the monitoring development of these physical qualities as part of a long term athletic development (LTAD) programme is incorporated into the training programme for youth female soccer players (10).

Within England, talented youth female soccer players between the ages of 8-16 years are recruited to attend Regional Talent Centre's (RTC's), with the purpose to develop players for the elite senior game. Cross-sectional data examining the physical qualities of elite youth female soccer players exists, demonstrating that physical qualities develop with increasing age (10, 11, 31). While cross-sectional data are useful for player monitoring and evaluation purposes, the nature of such one-off assessments fails to provide information around the

development of physical qualities. This is important, particularly for youth players due to factors such as growth and maturation, which may impact upon physical performance (3, 29). Such analysis is required to facilitate the development of an appropriate long-term athletic development (LTAD) model in youth female soccer and to develop appropriate training interventions for players.

Bradley et al. (2) explored the seasonal change in YYIEL2 performance of elite youth female soccer players, reporting that performance on the test was greater in the middle and the end of the season compared with the preparation period ($1767 \pm 539\text{m}$ and $1742 \pm 503\text{m}$ vs $1564 \pm 504\text{m}$). However, players included in this study were 19 ± 1 years, therefore such findings may not be consistent with findings for younger players within RTC's who are 8-16 years, whereby growth and maturation may impact upon physical performance (12). To the authors knowledge, only one study has explored the within season change in sprint and change of direction (CoD) performance of U13 and U15 youth female soccer players (28). Taylor et al. (28) reported substantial decreases in sprint performance over 5 and 20m sprint distances and a decrease in CoD performance at both mid- and post-season when compared to pre-season. In contrast, Wright and Atkinson (33) reported that systematic training with one dedicated strength and conditioning session a week, improved sprint related outcomes in youth female soccer players over a 3-year period. While such findings can be used by practitioners working with youth female soccer players, both studies included data from only one club with a limited sample size (Taylor et al. (28) U13; $n = 10$, U15; $n = 9$, Wright and Atkinson (33) $n = 14$) and did not consider how change in maturity status influenced performance. Furthermore, previous literature exploring the longitudinal development of physical characteristics of male youth soccer players has highlighted the importance of controlling for baseline performance and change in maturity status when exploring changes in performance of youth players (34). Therefore, further research is still required with a larger sample size which also controls for changes in maturity status, to provide practitioners with a better understanding of the holistic physical development of youth female soccer players. Given the increasing demands in youth

female soccer to identify and develop talent at a young age, such information would be advantageous for practitioners working with youth players to provide comparative data for expected seasonal changes across academy-aged squads and how changes in maturity status may impact upon performance. Therefore, the purpose of this study was to evaluate the seasonal changes in physical performance of U10-U16 elite youth female soccer players with consideration for baseline performance and change in maturity status across the season.

METHODS

Experimental Approach to the Problem

All subjects completed a physical testing battery at three time points (pre, mid and post season) during the 2016-2017 season. Testing was conducted a minimum of 48 hours post competitive match play or training at each respective RTC. A standardised warm-up, including jogging and dynamic movements were undertaken prior to testing, followed by full instruction and demonstrations of the assessments. The lead researcher undertook all testing.

The testing battery included assessments of anthropometry (standing height, sitting height and body mass), strength (isometric mid-thigh pull; IMTP), lower body power (countermovement jump; CMJ), speed (10 and 30 m sprint) and CoD (505 test left and right) and aerobic capacity (Yo-Yo intermittent recovery test level 1; YYIRL1). The YYIRL1 was not conducted at the U10 age category, as this was not current practice at the RTC's. Participant were randomly assigned to one of 3 groups; station 1: anthropometric characteristics, station 2: speed and CoD ability, station 3: strength and power. To prevent an order effect, each group of participants completed each station in a random order. The YYIRL1 was completed as one large group to limit the cumulative effects of fatigue on the speed, CoD, strength and power assessments.

Subjects

One hundred and thirteen players from three Tier 1 RTC's participated in the study. Players within the academies are grouped into specific age categories for training, including U10 ($n = 20$, 9.3 ± 0.5 years), U12 ($n = 30$, 11.3 ± 0.5 years), U14 ($n = 31$, 13.2 ± 0.7 years) and U16 ($n = 32$, 15.1 ± 0.7 years). U10 and U12 age categories trained twice per week (2 x 90 min pitched based sessions and 1 x 30-min strength and conditioning session) and U14 and U16 age categories trained three times per week (3 x 90 min based sessions and 2 x 60-min strength and conditioning session), with each age group having on average 20 matches over a 35-week season. Institutional ethics approval was granted from the University Research Ethics Committee. Parental consent and participant ascent were obtained prior to commencing the study.

Procedures

Anthropometric measures and maturity status:

Subjects body mass (kg) was measured to the nearest 0.1 kg using calibrated Seca Alpha (model 770) scales. Standing and sitting height (cm) were recorded to the nearest 0.1 cm using a 132 Seca Alpha stadiometer according to methods previously outlined by Malina and Koziel (21). Maturity was estimated from anthropometric measurements using the Mirwald et al. (23) equation (Equation 1) to predict the number of years from peak height velocity (PHV). While some studies have questioned the use of this method (21, 22), this method was chosen due to the non-invasive nature of the assessment and the satisfactory levels of measurement accuracy ($R^2 = 0.91$, $SEE = 0.50$; Mirwald et al. (23)). This equation has previously been used for the assessment of maturation in youth female soccer (10, 28, 33).

Maturity Offset = $-16.364 + 0.0002309 \times \text{leg length and sitting height interaction} + 0.006277 \times \text{age and sitting height interaction} + 0.179 \times \text{leg by height ratio} + 0.0009428 \times \text{age and weight interaction}$.

Equation 1.

Strength:

The IMTP was performed on a portable force platform (AMTI, ACP, Watertown, MA) with a sampling rate of 1,000 Hz. Subjects performed the IMTP on a customized pull rack, using a self-selected position similar to that of the second pull of a power clean (15). The self-selected mid-thigh position was preferred, as differences in knee and hip joint angles during the IMTP have previously been shown to have no influence on kinetic variables (4). Subjects were given two practice trials prior to testing commencing. Subjects were instructed to pull as “fast and hard” as possible, and received verbal encouragement (9). Each participant completed two trials lasting five seconds, with 5-min rest between each trial. The highest peak force (PF) achieved over the two trials was considered the participants ‘best trial.’ Relative PF was calculated using the ratio scaling method (i.e. PF / body mass) (18). PF intraclass correlation (ICC) and coefficient of variation (CV) were $r = 0.93$, $CV = 3.6\%$.

Lower Body Power:

Lower body power was assessed using a CMJ in an indoor gym facility and performed according to previously described methods (25) using a portable photoelectric cell system (Optojump; Microgate, Bolzano, Italy). This equipment has been reported as both reliable and valid ($CV = 6\%$, standard error of estimate = 1%) for vertical jump assessment compared with a biomechanical force plate (14). Jump height was calculated using the cell system software (Optojump Next v1.7.9; Microgate). Subjects completed 3 submaximal CMJ efforts prior to testing commencing and then completed 3 attempts with a 2-min rest period between jumps in line with the methods utilised by Emmonds et al. (10). The highest jump was selected for analysis. ICC and CV for CMJ were $r = 0.96$, $CV = 4.5\%$.

Change of Direction (CoD) Time:

CoD was assessed using the 505 test. Subjects were positioned 15 m from a turning point with timing gates placed 10 m from the start point and 5 m from the turn point. Subjects

accelerated from the start through the timing gates, turning 180^0 at the 15 m mark and sprinted back through the timing gates. Subjects completed 3 alternate attempts on each foot (i.e., right and left leg), separated by a 2–3 min rest period. Times were recorded to the nearest 0.01 sec with the quickest of the 3 attempts used as the final score. ICC and CV for the 505 test were $r = 0.995$, $CV = 2.2\%$.

Sprint time:

Sprint times were assessed over 10 and 30m using timing gates (Brower Timing Systems, IR Emit, USA). Subjects started 0.5m behind the initial timing gate and were instructed to set off in their own time and run maximally past the 30 m timing gate. Each subject had 3 attempts, separated by a 3-minute rest period. Times were recorded to the nearest 0.01 seconds with the quickest of the three attempts used for the sprint score. ICC and CV's for 10 and 30 m sprint time were $r = 0.76$, $CV = 4.8\%$ and $r = 0.78$, $CV = 3.9\%$, respectively.

Soccer Specific Fitness:

Soccer specific fitness was assessed using the YYIRL1. The YYIRL1 was selected as it has been reported as a valid and reliable test ($ICC = 0.82-0.84$, $CV = 7-16\%$) for the assessment of soccer specific fitness in youth soccer players (8). While the test is not a true measure of aerobic performance *per se*, given the duration of the test, the aerobic system will make the largest proportionate contribution to energy production. The test consisted of repeated 20 m shuttle runs at progressively increasing speeds dictated by an audio bleep from a CD player. Between each shuttle a recovery period of 10 seconds is allowed involving walking around a marker placed 5m behind the finishing line. Failure to achieve the shuttle run in time on two occasions resulted in termination of the test. The final level achieved and total running distances were recorded.

Statistical Analyses

A general linear model was conducted using SAS University Edition (SAS Institute, Cary, NC). A general linear model is a generalisation of multiple linear regression model to the case of more than one dependent variable and therefore allows the control of confounding variables. This was used to evaluate the change in performance variables and the influence of the covariates on each performance variable over the course of the season. The change in performance of each variable was used as the dependent variable, with time (mid and end of season) and age group (U10's, U12's, U14's, U16's) added as fixed factors. The pre-season score in the appropriate variable and the change in maturity over the specific period of the study (e.g. pre- to mid-season) were used as covariates. A separate general linear model was used to evaluate the changes in performance from pre-post season.

Results were analysed for practical significance using magnitude-based inferences (17). The threshold for a change to be considered practically important (the smallest worthwhile change; SWC) was set as $0.2 \times$ observed between participant SD, based on Cohen's *d* effect size (ES) principle. Thresholds for ES were set as: 0.2 *small*; 0.6 *moderate*; 1.2 *large*, 2.0 *very large*. The probability that the magnitude of change was greater than the SWC was rated as: <0.5% *almost certainly not*; 0.5-5% *very unlikely*; 5-25% *unlikely*; 25-75% *possibly*; 75-95% *likely*; 95-99.5% *very likely*; >99.5% *almost certainly* (17). Where the probabilities of a substantial positive and negative change were both greater than 5%, the effect is considered *unclear*. Effect sizes are reported ES; \pm 90% confidence intervals.

RESULTS

The raw changes in performance for each age group across all variables are presented in Table 1. Standardised differences between pre, mid and post season independent of baseline performance and change in maturity status are presented in Figures 1-4 for each age group.

***** Insert Table 1 Near Here*****

All age groups experienced *almost certainly* increases in body mass and height from pre-post season. There were unclear and possibly trivial changes in PF for U10 and U12's respectively, however when made relative to body mass, there were *likely to very likely* improvements in relative strength from pre-post season. Both age groups experienced *unclear to very likely* negative changes in CMJ height, sprint and CoD times (Figures 1-2) from pre-post season.

*****Insert Figure 1 Near Here ******

*****Insert Figure 2 Near Here******

U14 and U16 players demonstrated the greatest improvements in 10m speed, CoD, and strength from pre-to mid-season, with limited improvement mid-post season (Figures 3-4). *Very likely* improvements in CoD, 30m sprint and *likely* improvements in CMJ and relative PF were observed from pre-post season for both U14 and U16 players. *Likely* improvements in 10m sprint also occurred for U16s. *Likely* and *very likely* improvements in PF were observed for U14 and U16 players respectively. U12-U16 players all experienced *likely negative* changes in YYIRL1 scores from pre-to mid-season, however all age groups displayed *almost certainly positive* changes in their scores at post-season compared to mid-season.

*****Insert Figure 3 Near Here ******

*****Insert Figure 4 Near Here******

DISCUSSION

The purpose of this study was to investigate the seasonal change in physical characteristics of elite youth female soccer players, while controlling for both baseline performance and change

in maturity status. Findings demonstrate that U10 and U12 youth female soccer players may experience decrements in speed, CoD and lower body power across a season, while U14 and U16 players may experience improvements in these physical qualities. However, all age groups either did not improve or experienced negative changes in strength, speed, CoD time and lower body power from mid-post season, potentially questioning whether RTC's are currently focussed upon enhancing physical development within youth female players. Coaches and practitioners need to be aware of this when designing training, prescribing training loads and monitoring changes in physical development across a season. These findings provide a basis for the development of strategies to further enhance the LTAD of youth female soccer players.

U10 and U12 players experienced decrements in CMJ, sprint and CoD performance from pre-to post-season, despite an increase in relative strength. These findings are consistent with the findings of Taylor et al. (28) who observed that U13 youth female soccer players also experienced decrements in speed and CoD ability across a season. Taylor et al. (28) attributed this to the influence of maturation, which can cause disturbances in motor coordination abilities (26). Given that change in maturity status was accounted for with the statistical model employed within the present study there may be other reasons for this observation. Without the quantification of training load or prescribed stimuli, it is unknown if this finding is due to the biological stage of the athletes (-2.5 YPHV to -0.5 YPHV), or indeed sub-optimal training practices. Either way, a greater focus on the physical development of players at these age groups within RTC's may be advantageous, particularly focusing on the development of motor coordination given the decrements in speed and CoD ability observed.

When evaluating the change for U14 and U16 players, this study observed improvements in 30 m sprint time, CMJ height, relative strength and CoD ability from pre-to post season. Noteworthy, greatest improvements in performance occurred from pre-to mid-season, with *likely trivial* improvements observed mid-post season. These findings contradict the findings

of Taylor et al. (28) who reported that U15 youth female soccer players improved more in the second half of the season. Taylor et al. (28) did not control for changes in maturation status of the players across the season, which may explain the contrasting findings. This is supported by the findings of Wright and Atkinson (33) who observed a strong correlation between change in sprint speed and maturation status across a 3-year period in youth female soccer players. In addition to the positive adaptations from training, changes in performance in youth athletes will also reflect the effects of normal growth and maturation (30), therefore any conclusions regarding the magnitude of performance improvement to specific training must account for changes in maturation (34). As such this highlights the importance of considering physical testing results in the context of maturation status when evaluating the performance of youth female soccer players.

Noteworthy, decrements in speed, CoD time, CMJ height and relative strength were observed for all age groups mid-post season and is consistent with findings reported for youth male soccer players (32). This could possibly be explained by the accumulative effect of fatigue across a season or change in training focus (e.g., technical and tactical, rather than physical). However, within this study it was not possible to obtain training load or fatigue monitoring data, therefore it is not possible to confirm this. Previous studies in senior male players have shown that soccer seasonal variations in physical and physiological capacities are strongly related to variations in total training load. Increased training load has been reported to enhance aerobic fitness (27) and have a negative effect on sprint and CMJ performance (19, 20). Therefore, future research should look to consider the influence of training load on physical performance of youth female players. While it is not possible to explain why these findings occurred in the current study, it is likely not optimal given the decrements in performance, thus some modification to the current development programme is required. Given that speed and power are reported to be important for successful performance during match play (12), coaches may need to consider training strategies to support the continued physical development in the second half of the season. From pre-post season U12-U16 all

improved their aerobic capacity, however all experienced *likely* decreases in YYIRL1 scores at mid-season, with *very likely* to *almost certainly* improvements from mid-post season. As the first testing point (Pre) occurred at the start of the season (following pre-season), it is possible that these decrements at mid-season may be a consequence of an increased focus on the technical and tactical aspects of performance during the first part of the season as opposed to physical preparation, which may have been the focus in pre-season. While it is logical that the focus in season may be more on the technical and tactical aspects of the game, coaches need to ensure that they continue to ensure that the LTAD of players is still a focus of training. For example, the manipulation of small sided games (SSG) may provide an appropriate stimulus to maintain aerobic conditioning within season (7) and targeted warm ups may provide an opportunity to develop speed and CoD qualities (10).

A limitation of this research is that it was not possible to include an age matched control group. Comparing changes in performance between youth female soccer players in an RTC and an age matched control group, would allow researchers to specifically quantify the degree to which the current training programmes enhances physical performance beyond normal growth and maturation. Therefore, this should be a direction for future research, in addition to further longitudinal monitoring over a number of seasons to further evaluate the effectiveness of academy training programmes on physical development. A second major limitation of the study was that it was not possible to have further objective training load data. This does limit the ability to explain the observed changes in physical performance across the season. Therefore, future research should look to make comparisons between changes in training load across a season and physical performance.

PRACTICAL APPLICATIONS

This study is the first to assess the seasonal changes in physical performance of youth female soccer players, while controlling for both baseline performance and change in maturity status.

Findings suggest that U10 and U12 youth female soccer players experience decrements in sprint speed, CoD ability and lower body power across a season, despite increases in relative strength. It is advised that strength and conditioning coaches working with U10-U12 players specifically look to develop speed, lower body power and CoD ability as part of their training sessions. This may be achieved as part of structured strength and conditioning sessions as well as focusing on running mechanics, sprinting and plyometric training within warm ups prior to pitch based sessions (10). In contrast, U14 and U16 players experience improvements in speed and CoD across a season, although there appears to be limited improvement in the second half of the season for all age groups. While aerobic capacity improves pre-to post-season, players experienced a decrease in aerobic capacity from pre-to mid-season. Therefore, it is advised that coaches look to develop specific training strategies within season that maintain aerobic fitness. Manipulation of SSG's combined with short duration intermittent high-intensity running drills may provide an efficient training stimulus to develop the aerobic system in U14-U16 players whilst concurrently developing technical/tactical skills within the same session in season (7). It is recommended that coaches use the findings of this study to consider the within-season changes in physical characteristics of youth female soccer players to support the planning of LTAD programmes based on a player's age and stage of development.

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Table 1: Anthropometric and physical characteristics of U10-U16 youth female soccer players at pre, mid and post season.

	U10 (<i>n</i> = 20)			U12 (<i>n</i> = 30)			U14 (<i>n</i> = 31)			U16 (<i>n</i> = 32)		
	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
YPHV (y)	-2.5 ± 0.4	-2.2 ± 0.5	-1.9 ± 0.4	-1.0 ± 0.7	-0.9 ± 0.6	-0.5 ± 0.9	1.0 ± 0.7	1.3 ± 0.7	1.5 ± 0.7	2.2 ± 0.5	2.3 ± 0.6	2.7 ± 0.5
Height (cm)	134.7 ± 7.4	136.1 ± 7.2	137.7 ± 7.1	147.8 ± 8.6	149.3 ± 8.7	151.3 ± 8.7	159.3 ± 7.5	160.5 ± 6.6	161.5 ± 6.5	164.5 ± 6.4	164.9 ± 6.2	165.3 ± 6.0
Body Mass (kg)	29.6 ± 4.8	31.8 ± 11.1	32.2 ± 5.5	38.2 ± 8.2	39.5 ± 8.8	41.6 ± 9.3	49.3 ± 7.3	50.8 ± 6.8	52.8 ± 6.9	56.9 ± 7.3	57.2 ± 6.7	58.4 ± 6.8
Peak Force (N)	751.9 ± 131.2	820.4 ± 116.3	846.2 ± 122.4	642.7 ± 249.6	1112.1 ± 254.8	1148.9 ± 235.5	1278.7 ± 245.0	1393.8 ± 185.7	1425.5 ± 201.1	1505.2 ± 182.7	1592.2 ± 194.7	1608.9 ± 216.9
Relative Peak Force (N·s⁻¹·kg⁻¹)	25.6 ± 3.7	26.8 ± 4.6	26.9 ± 3.9	25.9 ± 2.7	28.7 ± 3.5	27.8 ± 2.8	25.9 ± 2.7	27.6 ± 2.6	27.2 ± 3.3	26.6 ± 3.6	28.5 ± 2.2	27.6 ± 3.0
10m Speed (s)	2.23 ± 0.14	2.17 ± 0.15	2.27 ± 0.12	2.06 ± 0.13	1.94 ± 0.23	2.11 ± 0.10	2.04 ± 0.13	2.64 ± 3.32	2.04 ± 0.06	1.97 ± 0.14	1.90 ± 0.16	1.99 ± 0.10
30m Speed (s)	5.57 ± 0.35	5.67 ± 0.33	5.65 ± 0.29	5.26 ± 0.26	5.00 ± 0.51	5.19 ± 0.26	4.98 ± 0.25	5.04 ± 0.27	4.91 ± 0.25	4.82 ± 0.23	4.70 ± 0.31	4.81 ± 0.23
CMJ (cm)	22.9 ± 5.7	23.7 ± 2.8	23.4 ± 3.2	27.9 ± 4.4	28.1 ± 4.8	28.4 ± 4.5	29.5 ± 3.3	29.4 ± 4.9	30.2 ± 6.5	31.9 ± 4.4	29.4 ± 4.9	33.7 ± 4.7
CoD (s)	2.89 ± 0.15	2.77 ± 0.19	3.00 ± 0.42	2.68 ± 0.18	2.68 ± 0.14	2.70 ± 0.15	2.66 ± 0.16	2.60 ± 0.12	2.59 ± 0.09	2.58 ± 0.12	2.52 ± 0.09	2.53 ± 0.09
YYIRL1 (m)				643 ± 249	557 ± 169	789 ± 247	919 ± 328	851 ± 269	998 ± 278	964 ± 310	867 ± 275	1010 ± 293

Data presented as mean ± standard deviation. YPHV = Years from Peak Height Velocity, CoD = Change of direction, CMJ = Countermovement jump, YYIRL1 = Yo-Yo intermittent recovery test level 1.

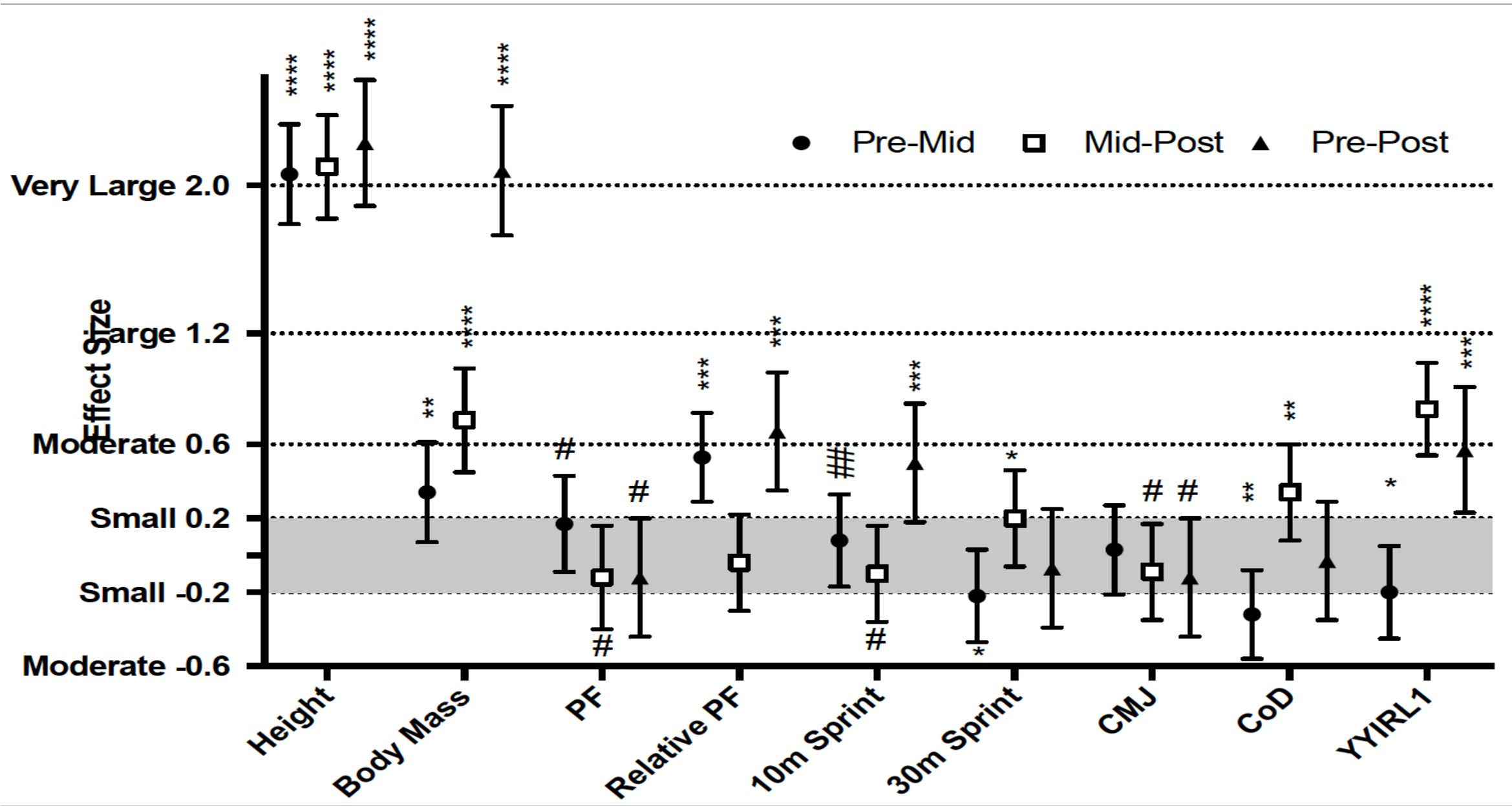


Figure 2: Seasonal changes in physical characteristics of U12 players

* Possibly, **Likely, ***Very Likely, # Possibly Trivial, ## Likely Trivial

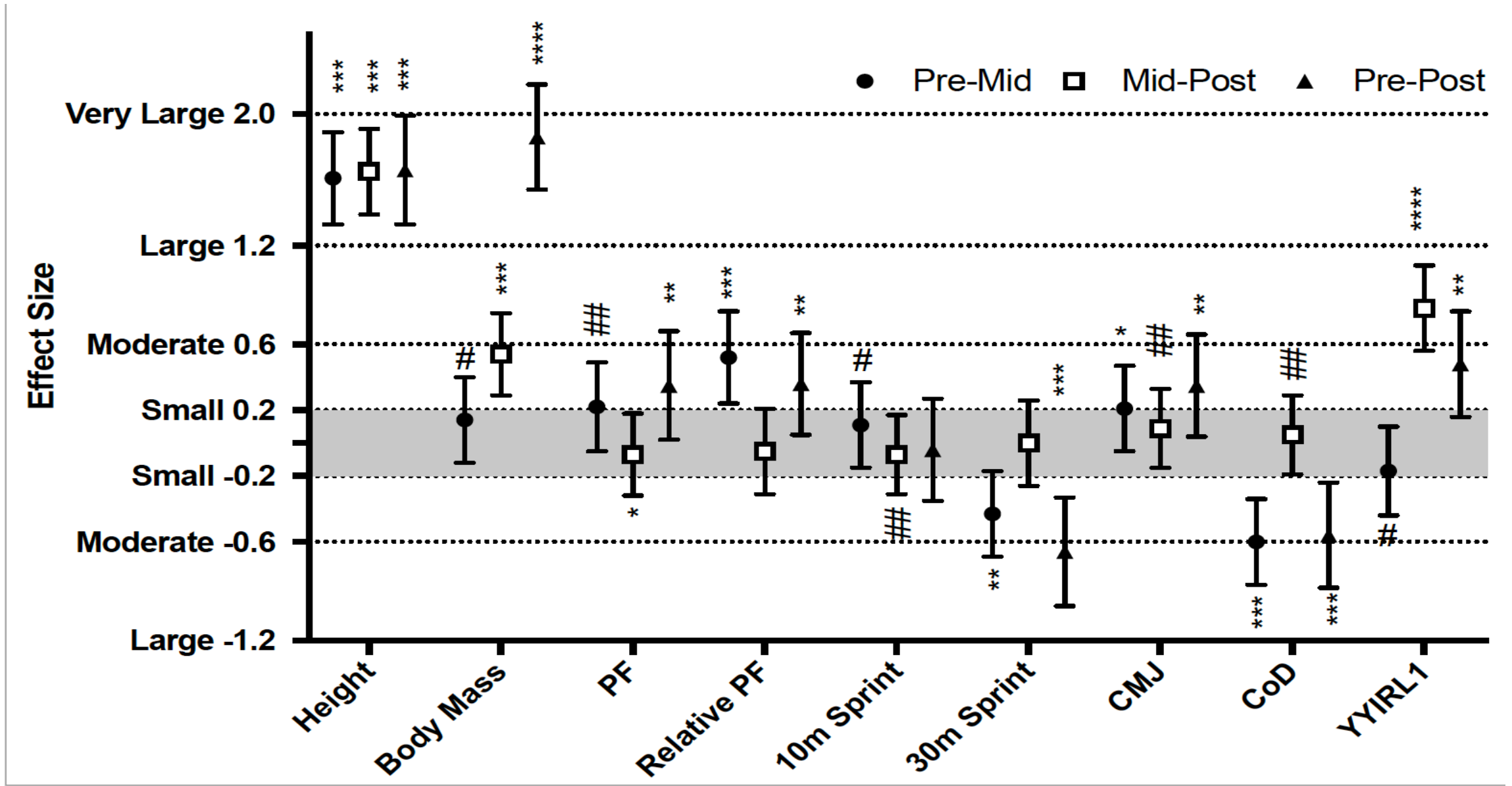


Figure 3: Seasonal changes in physical characteristics of U14 players

* Possibly, **Likely, ***Very Likely, # Possibly Trivial, ## Likely Trivial

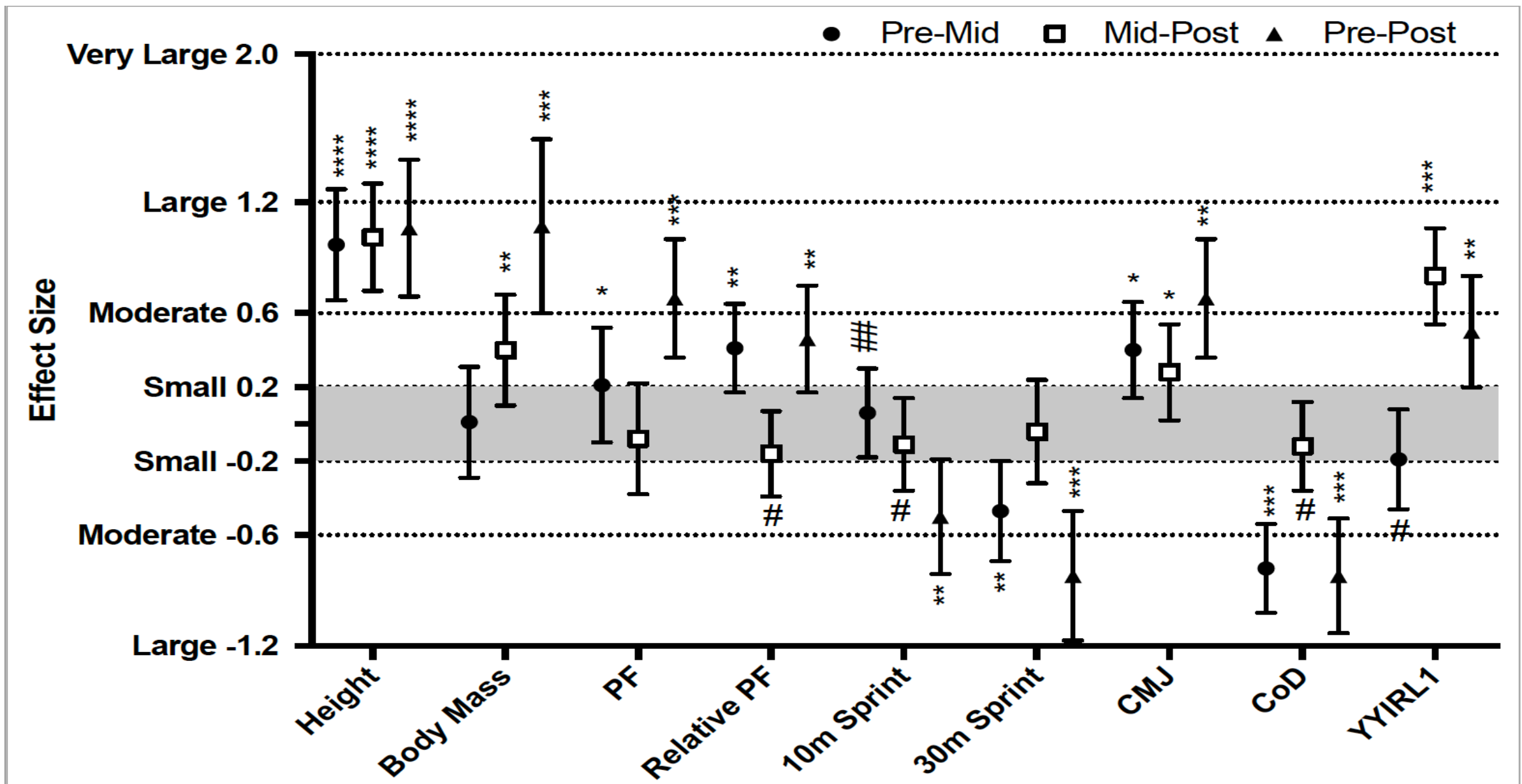


Figure 4: Seasonal changes in physical characteristics of U16 players

* Possibly, **Likely, ***Very Likely, # Possibly Trivial, ## Likely Trivial