**Isometric maximal voluntary force evaluated using an isometric mid-thigh pull differentiates English Premier League youth soccer players from a maturity matched control group**

**Abstract**

*Purpose* The purpose of the present study was to record normative isometric maximum voluntary force (MVF) data at baseline and after an 8-week training period using the isometric mid-thigh pull (IMTP) for English Premier League academy players and a maturation-matched control group.

*Methods* One-hundred-and-fifty-five English Premier League academy players across Under 9 to Under 21 age groups and ninety-three, maturation-, weight- and height-matched control participants performed an IMTP. One-hundred-and-forty-two and sixty-two of the elite and control cohorts respectively were retested 8-weeks later following a period of integrated soccer training or physical education lessons. Allometrically scaled (peak force divided by body mass0.66) MVF was recorded. MVF was analysed in three maturity groups based on years from/to age of predicted peak height velocity (PHV): pre-PHV, mid-PHV, and post- PHV in elite and control groups.

*Results* A small difference was seen in isometric MVF in elite (115.42 ± 21.96 N) compared to control (109.36 ± 29.90 N) at baseline (*P*=0.004) though no difference was seen between or within groups after 8 wks. (*P*>0.167).

*Conclusion* Differences in baseline MVF suggests that strength is likely important to elite youth soccer performance though training undertaken by this elite group may be insufficient to elicit adaptation in isometric strength.

Key Words: Soccer, Force, Maturation, Testing, LTAD

**Introduction**

The physical demands of soccer require competency in aerobic fitness, speed and strength. The determination of the relative importance of a single attribute, such as maximal strength, to overall physical performance is therefore difficult (Andersson et al. 1988). Powerful actions precede many goal-scoring opportunities during match-play (Faude et al. 2012), which could suggest an importance of force production to soccer performance. These ideas are also supported by proposals that isometric strength may be a defining characteristic of elite soccer players (Manolopoulos et al. 2013; Gissis et al. 2006). Such data on the importance of strength are however sparse in elite youth soccer populations (ESP; McGuigan & Winchester 2008), making specific inferences into the importance of the attribute to this population difficult.

When understanding muscular strength in such populations, it is important to consider the approach used to evaluate the attribute. Key considerations in strength testing include test validity, reliability, specificity and safety (Young et al. 2014). Appropriate tests to establish force production capabilities in youth soccer should allow both acute and chronic measurements. The isometric mid-thigh pull (IMTP) is likely suitable for strength assessment in this population as it is representative of a commonly adopted position in multidirectional sport known as the “ready” or “athletic” position (Suchomel et al. 2014; Garhammer 1993). It may therefore reflect the production of muscular force involving whole-body actions as performed during matches and training. The IMTP is also highly reliable in youth (Haff et al. 2015), trained (Wang et al. 2016) and novice (Beckham et al. 2013) populations and correlates well with one-repetition maximum (1RM) testing (Wang et al. 2016) and dynamic characteristics such as jump performance (Secomb et al. 2015). As a result, it is becoming increasingly popular in the applied setting due to its relatively low cost, complexity and time of administration (Haff et al. 2015; James et al. 2015).

Despite its increased popularity, published data regarding ESP currently does not exist for the IMTP. Such information could lead to greater understanding of the importance of strength in soccer, which could aid determining the effectiveness of training programmes aimed at increasing strength throughout development. This may provide benchmarks for strength profiles to underpin soccer performance in ESP (Currell & Jeukendrup 2008). An understanding of similar data from non-elite individuals would also allow comparison to the soccer playing population further contextualising the potential importance and impact of strength in ESP.

The determination of baseline strength and changes in the attribute following completion of systematic training programming may aid programming evaluation. Such evaluations are crucial to understanding the impact of training interventions included in player development programmes. Currently, elite soccer training at youth level can be broadly divided into those activities completed on and off the field-of-play. On-field training generally mimics soccer match play to some extent and frequently involves soccer drills, actual match play or variations of both (Wrigley et al. 2014). Off-field training tends to focus on developing physical attributes desirable during match-play as well as to reduce injury risk. It is likely that sub-components from all training types, or an interaction of these may affect MVF capabilities. Due to the importance of accumulated training likely playing a role in progression toward senior elite status (Wrigley et al. 2014), an understanding of how muscular strength plays a part in this, gained via suitable testing may be crucial. Currently though, no data exists on MVF, or its responses to systematic training, in ESP.

The present study had two major aims: (1) To compare MVF data on soccer players attached to an elite academy to a non-elite maturation-matched control group in order to provide normative data for these populations and understanding of the impact of current training on the attribute (2) To evaluate the effect of a typical 8-wk. training period completed by the ESP on MVF. It was hypothesised the soccer-playing cohort would display greater MVF than the control group, and that these outputs would further improve as a consequence of the completion of an 8-week training period.

**Methods**

This investigation was based around two data collection periods. These were associated with the determination of baseline strength comparisons to satisfy aim 1 and the evaluation of current training (aim 2). In an attempt to provide clarity around the presentation of the methodological detail of this investigation this section will be split in to two parts.

*Part 1 – Determination of baseline strength*

*Experimental Approach to the Problem*

This cross-sectional study assessed the isometric MVF of ESP and controls (CON). Participants were asked to refrain from physical activity for 24-hr before all testing sessions. Standing height, sitting height, and mass were measured. From this data, participants’ maturity status was determined using maturity offset (Mirwald et al. 2002). Maturity offset was then used to divide cohorts into pre- (PRE), mid- (MID) and post (POST)-peak height velocity (PHV) groups for MVF comparison. All testing was conducted on the same day for each participant with data gathered over a two-week period (September/October 2015) for ESP and a one-week period (May 2015) for CON.

*Participants*

One-hundred-and-fifty-five ESP were recruited from the under 9 (U9), U10, U11, U12, U13, U14, U15, U16, U18 and U21 age groups of an English Premier League soccer academy. Ninety-three local schoolboys, not linked to any elite sporting organisation, were also recruited to form a controlgroup. Participant characteristics are presented in Table 1. The study was approved by the Institutional Ethics Committee and conformed to the Declaration of Helsinki.

*\*\*\*\*Table 1 around here\*\*\*\**

*Study design*

*Warm up protocol for the isometric MVF assessment*

Participants performed a standardised five-minute warm up on a cycle ergometer (gear six, ~80 RPM) (Keiser M3, USA), a dynamic whole-body stretching routine and three sub-maximal IMTP efforts using a back-strength dynamometer (Takei A5402, Japan). One sub-maximal IMTP was then completed on the specific testing equipment used for the IMTP pull prior to data collection for experimental trials.

*Protocol for isometric MVF assessment*

All testing was conducted on customised apparatus developed for the data collection. Rack pins and hooks of squat stands (Perform Better, U.K.) with ratchet straps were used to fix an Olympic weightlifting bar in a position (Eleiko, U.S.A.) corresponding to each participant’s theoretical power clean second pull position (knee and hip angles at 138 ± 3°; 134 ± 9°, respectively, see Figure 1). This is similar to testing positions observed previously (140 ± 7°; 138 ± 13°) and the IMTP was performed with standardised procedures based upon the same work (Haff et al., 2015).

\*\*\*\*Figure 1 around here\*\*\*\*

To collect isometric MVF data participants stood upon a force platform sampling at 1000 Hz (Pasco, Rosedale, USA; data analysed using NMP ForceDecks (London, UK)). Following warm up, three maximal IMTP trials were performed with each trial separated by ≥30 s rest. Prior to the IMTP, participants were instructed to pull as hard as possible for ~2 s until being told to stop. Maximal efforts commenced following a verbal countdown of “3, 2, 1, pull” (Haff 2015). In real time, activity force traces were observed by the researcher in an attempt to determine attainment of a force plateau. Once a stable plateau in the observable force for a period of 1-2 secs was subjectively observed peak force was deemed to have been achieved. If the third trial resulted in the greatest force, another repetition was performed until this was not the case. All data analyses were performed on the effort that produced greatest MVF.

*Part 2 – Re-measurement after 8-week training period*

*Experimental Approach to the Problem*

Part 2 of this study was conducted 8-wks. after participants had completed Part 1 of the study. During this period players undertook systematic training that included both soccer-specific and non-soccer-specific training. Typically, U9 to U14 age groups engaged in training on a part-time basis and participated in one 60-min match/week. Of the training undertaken during a similar period 97 ± 4% was soccer-specific while the remaining time was focused upon training that may have been programmed to aid increases in muscular strength (Brownlee *et al.,* In Press). U15 to U16 groups were also engaged in training on a part-time basis and participated in one (80-min) match/week. U18 and U21 groups were engaged in full-time training, five days/week with one competitive (90-min) match/week. Of the training undertaken by these groups 73.8 ± 3.2% was soccer-specific during a similar time period, with this decrease compared to the younger groups coinciding with the introduction of specific resistance training (Brownlee *et al.,* In Press). Investigators ensured this section of testing was performed at the identical venue/time of testing. It was also requested participant activity in the 48 hrs. pre-testing was matched to that of Part 1. All testing was conducted on the same day for each participant with data gathered over a two-week period (November/December 2015) for ESP and a one-week period (July 2015) for CON.

*Participants*

One-hundred-and-forty-two and sixty-two of the initial elite and schoolboy participants were re-recruited respectively. Participant characteristics are presented in Table 1. The information in Table 2 illustrates a “standardised” 1-wk training schedule, determined from the average frequency of sessions in the 8-wk period of training at the time of testing, for the elite group.

*Study Design and protocol for isometric maximum voluntary force assessment*

Pre-testing anthropometry, warm up and main testing protocol was also ensured to be as close to that used in Part 1 as possible.

\*\*\*\*Table 2 around here\*\*\*\*

*Statistical analyses*

Allometrically scaled MVF was calculated by dividing peak force by body mass0.66(Folland et al. 2008).All data were initially assessed for normality of distribution according to the Shapiro–Wilk’s test and inspection of histograms. All force data were deemed normally distributed and are presented as mean ± *SD*. Statistical comparisons between ESP/CON and maturation groups were subsequently performed according to a two-way between-groups analysis of variance (ANOVA) or the Kruskal–Wallis test. Two-way repeated-measures ANOVA (Time x Group) was applied to test for main effects between week 0 and week 8 testing and between the two groups (ESP vs. CON) of all individuals who participated in both testing sessions. Where significant main effects were present, Tukey *post hoc* analyses were conducted to assess pairwise differences. Estimated differences are presented with 90% confidence limits (CL) as markers of uncertainty in the estimates. Effect sizes (ES) were calculated as the difference between the means divided by the pooled standard deviation, to assess the magnitude of the differences. Standardized thresholds of 0.2, 0.6, 1.2, 2.0, and 4.0 multiplied by the pooled between-group SD were used to anchor small, moderate, large, very large and extremely large differences, respectively (Hopkins et al. 2009). Inference was then based on the disposition of the confidence interval of the mean difference in relation to these thresholds via the magnitude-based inference approach, using the usual scale of probabilistic terms (Hopkins et al. 2009). A difference was deemed unclear if the CL overlapped both substantially positive and negative thresholds by ≥5%. All analyses were completed using the statistical package R- Version-3.2.1 Software (The R Foundation for Statistical Computing, 2015) where *P*<0.1 was indicative of statistical significance.

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### RESULTS

*Part 1 – Baseline isometric MVF assessment*

*Participant Characteristics*

There were no differences between ESP and CON for age (*P*=0.234), body mass (*P*=0.643) or stature (*P*=0.553). Anthropometric characteristics for all maturation groups are shown in Table 1.

*Allometrically Scaled IMTP MVF*

Differences in MVF between groups are displayed in Figure 2. There was no interaction between group and maturation status on MVF (*P*=0.167) suggesting increases in force with maturation was not different between elites and controls. The ESP demonstrated a possibly small difference in MVF when compared to CON (estimated difference = 6.06 N, 90% CI= 2.62 to 9.49, ES= 0.24 ± 0.14, *P*=0.004). A likely and possibly moderate effect was seen between ESP and CON at PRE (9.85 N, 90% CI= 2.22 to 17.49, ES= 0.82 ± 0.64, *P*=0.011) and MID (13.37 N, 90% CI= -2.30 to 29.03, ES= 1.08 ± 1.28, *P*=0.23) respectively. Differences were unclear between POST groups (2.57 N, 90%= -6.49 to 11.62, ES= 0.11 ± 0.41, *P*= 0.98). Maturation influenced MVF with a likely moderate increase seen from PRE-to MID (11.08 N, 90% CI = 4.27 to 17.89, ES= 0.82 ± 1.30, *P*=0.003) and a likely large increase from MID to POST (28.63 N, 90% CI= 21.53 to 35.73, ES= 1.62 ± 0.40, *P*<0.001).

\*\*\*\*Figure 2 around here\*\*\*\*

\*\*\*\*Table 3 around here\*\*\*\*

*Part 2 – Follow up testing 8 wks. post-baseline isometric MVF assessment*

*Participant Characteristics*

There were no differences between elite and control groups for age (*P*=0.133), weight (*P*=0.560) or height (*P*=0.775), with all maturation group characteristics (Table 1).

*Allometrically Scaled IMTP MVF*

MVF following an 8-wk training period for the elite players is shown in Figure 3. Following training, there were no interactions between MVF and group, maturation status and time (*P*=0.386). Additionally, MVF was not different over the time period, at any maturation, for either group (*P*>0.723).

\*\*\*\*Figure 3 around here\*\*\*\*

**Discussion**

The primary aim of this study was to investigate if differences existed in MVF between a group of elite youth soccer players and a non-elite control group. The secondary aim was to evaluate the effectiveness of a period of 8 weeks training, at the club in question on MVF. Our data demonstrates a possibly small difference in baseline MVF in elite players compared to controls, which supported our hypothesis. Despite this, likely and possibly moderate differences were observed at both PRE and MID stages between cohorts respectively. These differences in groups may suggest that strength, as reflected by isometric MVF, could be an important attribute for soccer performance in youth players especially before and during PHV. The elite group did not increase MVF as a consequence of the 8-week training intervention. This would seem to suggest that the training undertaken was not effective in developing isometric strength across this time period. Taken together this data demonstrates that while strength may be important in youth soccer greater consideration may need to be given to training programmes used to develop strength in young players.

The differences observed in MVF at baseline in elite and control groups supports the hypothesis that elite youth soccer players have greater MVF capabilities than non-elite counterparts. Isometric MVF, using IMTP, is linked to functional performance in sport (Wang et al., 2016). This can be evidenced by the observed correlations between MVF and various dynamic performance measures (i.e. speed (r =-0.539) and agility (r =-0.523)). While no research currently exists that investigates these specific relationships between MVF and dynamic performance measures in elite youth soccer players it seems logical to assume that the relationships are relevant in a broader group of athletes than included in specific research papers (e.g. Wang et al., 2016). This would suggest that MVF, as assessed using IMTP, is a potentially relevant assessment tool in evaluating strength in elite players despite its inability to reflect dynamic muscle contractions. Our observations of strength differences between groups could be indicative of beneficial physiological and morphological differences (that underpin strength) in the elite players compared to the control. It is probable that such differences may be a result of the repeated exposure to both a general and a specific (resistance) physical training stimulus completed by the players. This may be a function of their involvement in a specific talent development programme at the club in question. At the time of testing the elite population will have been chronically exposed to a systematic training stimulus around 4-5 times per week for a period of between 2-12 years (depending on their specific chronological age). This advanced training age will undoubtedly have resulted in physiological changes that would facilitate force production (Wrigley et al. 2014) among other performance attributes. It is these changes that are likely to underpin the superior performance in the elite players observed here.

Unfortunately, this study provides no data in respect to the underlying physiology that may help explain the differences in MVF. Beyond differences in genetics, the available research would suggest that typically, neural adaptations are responsible for underpinning the increases in strength observed in pre-pubertal and novice athletes (Schoenfeld 2010). These ideas are supported by Legerlotz *et al*. (2016) who described neural adaptations (e.g. modifications in motor-unit coordination, recruitment and firing frequency) in youths that were accompanied by non-significant changes in muscle cross-sectional. The data of Schoenfeld (2010) and Marcotte et al. (2015) would indicate that the adaptations that underpin strength development may vary as a function of maturation status (e.g. primarily neural in those with low training and biological ages with morphological differences occurring later). As a consequence, it may be important to adopt a multi-factorial approach to the investigation of the underpinning physiological characteristics associated with strength across a broad age range in future investigations. Such research projects would provide detailed data on the adaptive processes that underpin the effectiveness of long-term athlete development (LTAD) models in soccer.

The investigation of a controlled period of training in this study demonstrated that the activities programmed by the club did not seem to elicit increases in MVF in the elite youth players. This would seem unexpected, especially in the POST ESP group, who were undertaking a systematic specific resistance training programme during this time (see Table 2). A more detailed consideration of the trends observable in the entire data set collected here may, however, suggest that such changes in strength were in fact unlikely across such a relatively short time period. For example, training that is not focussed on the technical and tactical ability of players (e.g. non-soccer training) is not introduced until the U11 age groups and specific resistance training is not completed systematically until U15 (see Table 2). These limited exposures to a specific resistance training stimulus, or a more general stress that has the potential to lead to increases in the force generating capacity of the muscle (e.g. jumping, kicking etc) may therefore limit the opportunity for the adaptations that may facilitate isometric strength development in such a time period across the age groups. As a result, it would seem that the training completed by the players in these programmes seemed to provide an insufficient stimulus to elicit increased muscular strength. Studies that have employed greater and more specific resistance training loads (e.g. plyometric training (Thomas et al. 2009), strength training involving squats (Sander et al. 2013) and velocity based training (González-Badillo et al. 2015)) in youth soccer players have found increases in elite soccer player strength. This suggests that such populations have the potential to increase their strength if the stimulus is appropriate. Future studies, may look to assess training practices, alongside LTAD Position Statements to determine whether adjustments should be considered.

Some limitations are inevitable when conducting a study such as this one that includes multiple age groups within elite sport. The inferences that may be made around the data collected in this study, and its potential relevance to soccer performance, as a consequence of using the mid-thigh pull to determine MVF, has been highlighted earlier in the discussion. As with the majority of the tests that can be used to quantify muscular force production, the relevance of the outcome into the exact context of sports performance is difficult to quantify. For example, the ability to maximally produce bilateral isometric force in a mid-thigh pull on a force platform may not be a specific enough assessment of the dynamic muscular strength that is required by an elite youth soccer player during a soccer match. Beyond such conceptual considerations other limitations also relate to the specifics of the methodological approach used to operationalise these tests. Firstly, an Olympic weightlifting bar was used throughout testing, which provided a uniform bar diameter. Such an approach did not account for participant hand size. Issues with the ability to grip the bar may have affected some individual’s potential to produce a true MVF. Previous research has also suggested that the use of weightlifting straps and/or taped the participants hands to the bar (Haff et al. 2015; James et al. 2015), may be important in obtaining peak force. These de-limitations were thought to introduce small error while optimising the efficiency of testing. Recent research has proposed that a specific hip angle of 145° may be optimal during IMTP in order to elicit greater IMTP kinetics when compared to 175° (Dos’Santos et al. 2017; Beckham et al. 2017). Our approach in the current data collection was to use a self-selected knee and hip angle. This is more in line with recommendations made by earlier researchers (Comfort et al. 2015) that emphasised reduced learning effects. The hip angle in this study (around 138°) was however close to the new recommendations and as such may suggest that our approach was appropriate for the production of peak forces.

For the first time, the IMTP has been used to illustrate the potential importance of muscular strength in elite youth soccer by determining greater baseline MVF data in PRE and MID academy players compared to controls. Subsequently, investigation into training practices are suggested as no further effect of systematic training on MVF was observed following 8-wks. training. It is recommended that future work might investigate specifics around training undertaken and strength profiling following training more aligned with LTAD Position Statements. It may also consider whether the IMTP might be useful as a tool to describe more granular differences within elite populations (e.g. U18 *vs.* first team). In conclusion, elite PRE and MID MVF has been shown to be greater in the sample examined in this study compared with controls. Although strength training specific programming should not come at the detriment of technical or tactical development, it is proposed adequate appropriately programmed strength training leading to increased MVF, may be advantageous for soccer performance purposes.

**Practical Applications**

This study provides some indication that isometric MVF may have an impact on elite youth soccer status. This seems to further support the idea that some importance should be placed by practitioners on increasing the attribute in young players. Typical training methodologies, as observed in this instance may need refining in order to optimise these adaptations, which may ultimately aid on-pitch performances.

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**List of Tables**

**Table 1** Characteristics of participant’s (mean ± SD) for elite and control for the pre-peak height velocity (PHV), mid-PHV and post PHV groups in Part 1 and 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Phase** | **Group** | **Maturation****Group (*n*)** | **Age (years)** | **Stature (m)** | **Body Mass (kg)** |
| Part 1 |  | Pre-PHV (88) | 11.0 ± 1.5 | 1.45 ± 0.08 | 36.6 ± 5.8 |
| Elite | Mid-PHV (13) | 14.1 ± 0.5 | 1.61 ± 0.07 | 48.6 ± 5.9 |
|  | Post-PHV (54) | 16.8 ± 1.7 | 1.79 ± 0.06 | 69.0 ± 8.5 |
|  | Pre-PHV (44) | 11.2 ± 1.3 | 1.45 ± 0.08 | 37.5 ± 5.8 |
| Control | Mid-PHV (15) | 13.7 ± 0.6 | 1.63 ± 0.05 | 51.2 ± 8.1 |
|  | Post-PHV (34) | 16.2 ± 1.8 | 1.75 ± 0.05 | 67.1 ± 9.3 |
| Part 2 |  | Pre-PHV (83) | 11.0 ± 1.5 | 1.45 ± 0.08 | 36.9 ± 5.9 |
| Elite | Mid-PHV (13) | 14.2 ± 0.6 | 1.60 ± 0.06 | 46.9 ± 5.3 |
|  | Post-PHV (46) | 16.8 ± 1.8 | 1.79 ± 0.09 | 69.0 ± 8.4 |
|  | Pre-PHV (27) | 11.2 ± 1.3 | 1.45 ± 0.08 | 37.5 ± 6.1 |
| Control | Mid-PHV (14) | 13.7 ± 0.5 | 1.63 ± 0.05 | 51.2 ± 4.9 |
|  | Post-PHV (21) | 16.2 ± 1.3 | 1.75 ± 0.05 | 67.1 ± 8.6 |

**Table 2** Frequency oftraining type (mean ± SD) for Under 9 (U9) to Under 21 (U21) age groups in the elite soccer players (sessions/week).

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **U9** | **U10** | **U11** | **U12** | **U13** | **U14** | **U15** | **U16** | **U18** | **U21** |
| **Matches** | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 | 1 ± 1 |
| **Soccer Training** | 3 ± 1 | 3 ± 1 | 3 ± 1 | 4 ± 1 | 4 ± 1 | 3 ± 1 | 4 ± 1 | 4 ± 1 | 3 ± 1 | 4 ± 1 |
| **Resistance Training** | N/A | N/A | N/A | N/A | N/A | N/A | 0 ± 1 | 1 ± 1 | 2 ± 1 | 1 ± 1 |
| **Non-Resistance Training**  | N/A | N/A | N/A | 0 ± 1 | 2 ± 1 | 2 ± 1 | 2 ± 1 | 3 ± 1 | 3 ± 1 | 4 ± 1 |

**Table 3** Overview of baseline isometric mid-thigh pull maximum voluntary force in elite youth soccer players (ESP) and control group (CON) comparing whole cohorts, and grouped in reference to their time from peak height velocity ((PHV); pre-PHV (PRE), mid-PHV (MID) and post-PHV (POST)).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **ESP (N)** | **CON (N)** | **Magnitude based inference** |
| **Whole Cohort** | 115.42 ± 21.96 | 109.36 ± 29.90\* | Possibly Small |
| **PRE** | 101.34 ± 12.75 | 91.49 ± 11.09\* | Likely Moderate |
| **MID** | 115.08 ± 12.39 | 101.71 ± 12.15 | Possibly Moderate |
| **POST** | 138.44 ± 15.18 | 135.88 ± 27.76 | Unclear |

**Note: Data displayed as mean ± SD. \* represents a significant effect of condition (p < .1)**

**List of Figures**

**Figure 1.** Isometric mid-thigh pull positioning schematic.

**Figure 2.** Isometric maximum voluntary force (MVF) normalised to body mass (BM) for elite youth soccer players (ESP) and control participants (CON) at pre- (PRE), mid- (MID) and post-peak height velocity (POST). (\*PM indicates a possibly moderate increase in MVF between PRE and MID *P* = 0.002, \*LL indicates a likely large increase in MVF between MID and POST, *P* < 0.001).

**Figure 3**. Isometric maximum voluntary force (MVF) normalised to body mass (BM) for elite youth soccer players (ESP) and control participants (CON) at pre- (A), mid- (B) and post-peak height velocity (C) at week 0 and week 8.