Effects of maturation on countermovement jump waveform: An exploratory study using functional component analysis

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PURPOSE

Recent studies have applied temporal phase analysis to compare the characteristics of the countermovement jump (CMJ) force-time data between groups of athletes (McMahon et al., 2017a, 2017b). Whilst these studies have provided valuable contributions to our understanding of (for example) sex, maturation and sport-specific differences in neuromuscular function, they have been limited by the fact that pre-selection of discreet data points is dependent on knowledge of the movement which may lead to abandoning potentially relevant data (Parker & Lundgren, 2018); and that these discreet data points do not explicitly account for the multidimensional nature of the data (Wu et al. 2019).

Functional principal component analysis (fPCA) can be applied to temporal waveforms without *a-priori* selection of important features, and has been proposed as a useful method to gain greater insight into human motion data (Brandon et al. 2013).

The aims of this study were therefore to investigate the variance in CMJ waveform data between academy soccer players, and to compare the first few principal components (PC) between maturation groups

METHODS

Ninety-nine football players aged 9 - 18 from a Cat. 2 soccer academy in the UK volunteered to take part. Players were categorised as pre, circa or post peak height velocity according to maturational offset prediction equations (Mirwald et al. 2002) Following a RAMP warm up, participants performed three CMJ's with their hands on their hips, with 1-min recovery between jumps.

All jumps were performed on a portable force plate sampled at 1000hz. Participants were instructed to jump as high as they could, and countermovement depth was self-selected. The time series of data were normalised to body mass on the magnitude axis, and to 0-100% of the movement cycle of the time axis.

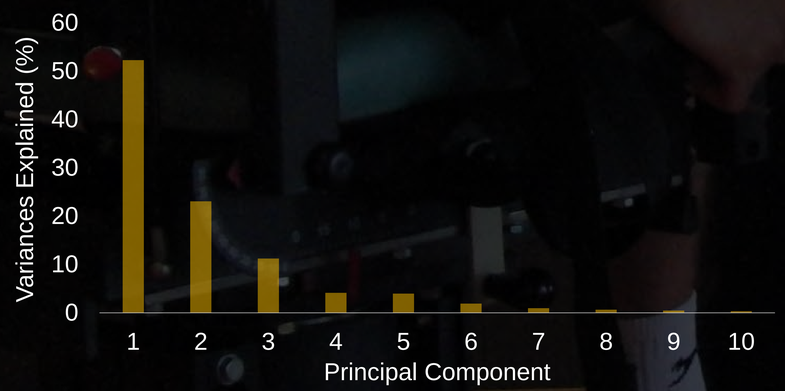

Figure 1: Screed plot showing the percent variances accounted for by each of the first ten principal components. The first four accounted for >90% and were selected for analysis

All data was used as input for the variance matrices and the mean waveform of the three jumps represented a row in the matrix. *f*PCA resulted in PC scores and time-series loading vectors for each PC. A one-way ANOVA was conducted to investigate between group differences in loading scores, and significant main effects were followed with Bonferoni adjusted (98.3%) confidence intervals. Linear regression was performed to investigate relationships between jump height and PC scores.

RESULTS

The first four PC's explained more than 90% of the variance in force parameters (Figure 1) and were characterised by magnitude, (PC1), phase shift (PC2) and difference features (PC3 and PC4) (Figure 2) (Brandon et al. 2013)

A one-way ANOVA revealed a significant between-group main effects for PC1 ($F_{2,96} = 3.85$, $p = 0.02$) and PC3 ($F_{2,96} = 9.62$, $p < 0.001$). Specifically, PC1 loadings for CIRCA were between 0.5 – 15.5 units lower than pre PHV players, and PC3 loadings for pre were between 1.5 – 9.8 and 2.8 – 12.7 lower than circa and post, respectively. Linear regression showed that PC3 ($r=0.77$, $p<0.001$), PC4 ($r=0.28$, $p=<0.01$) and PC5 ($r=0.38$, $p=<0.001$) were significantly related to jump height.

CONCLUSIONS

Around PHV, soccer players begin to adopt a CMJ technique which is characterised by a longer period of unweighting and shorter propulsion-acceleration, and both circa and post PHV players generate greater relative peak force between 85-90% of the movement cycle, compared with pre-PHV

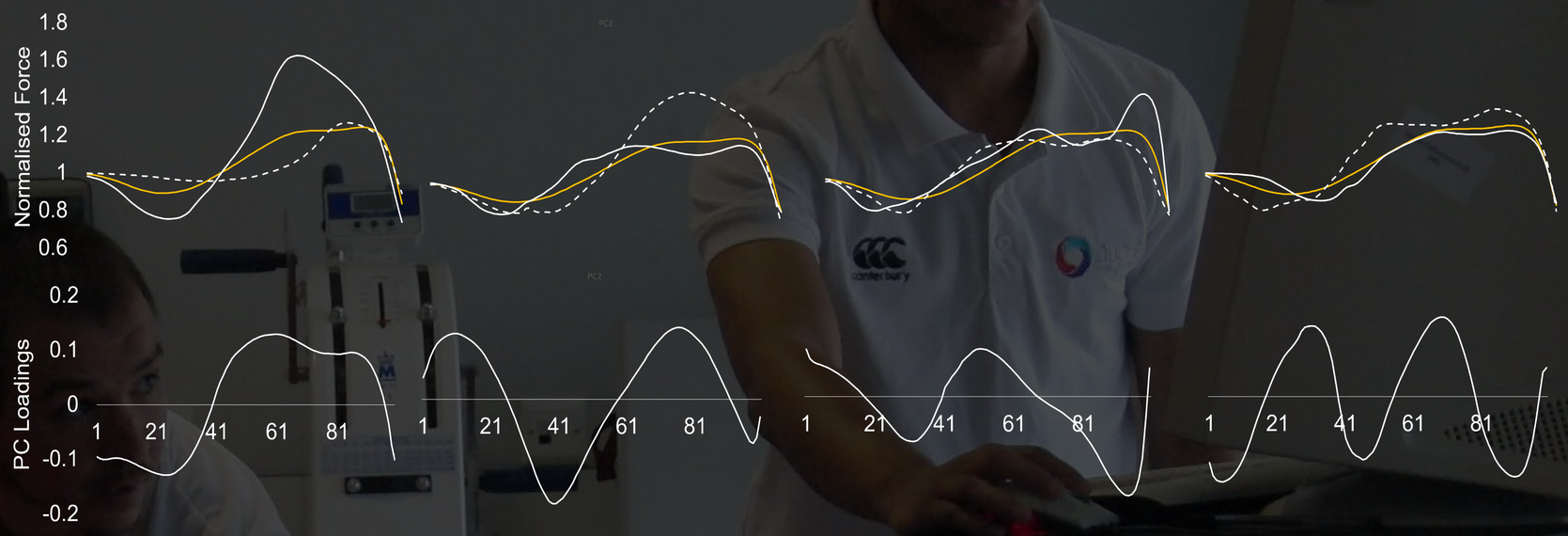

Figure 2. The panels show data from the first four principal components (left to right, respectively). The bottom row shows the loading vectors for each principal component, and the top row shows the mean (yellow), upper (solid white) and lower (dashed white) extreme cases.

PRACTICAL APPLICATION

These data provide greater insight into differences in jump technique and variables affecting jump performance in youth soccer players at different stages of maturation, and could be used to inform age-specific training interventions and inform interpretation of changes in jumping performance throughout adolescence

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