HOPPING AND LANDING PERFORMANCE IN MALE YOUTH SOCCER PLAYERS: EFFECTS OF AGE AND MATURATION

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ABSTRACT

Quantifying hopping and landing performances can assist coaches in identifying young male soccer players who may be at increased risk of injury. The influence of chronological age and maturation on these measures in this population are unknown. Single leg hop for distance (SLHD) and 75% horizontal hop and stick landing force (75%Hop) were examined in a cross-sectional sample (N = 400) of elite male youth soccer players. Between group differences for both chronological age (U11-U18) and stage of maturation (pre-, circa- or post-peak height velocity (PHV)) were analyzed. Absolute 75%Hop increased with both age and maturation. Apart from the U18s, pre-PHV and U11-U12 players displayed the greatest relative landing forces compared to all other groups ($p < 0.001$; $d = 0.56 – 0.93$). Absolute and relative SLHD were greatest in the U18s and post-PHV players ($p < 0.001$; $d = 0.35 – 2.04$). A trend showed increased SLHD with each consecutive age group although a reduction in performance was identified in the U13s ($d = 0.50$ to 0.59). High volumes of accumulated soccer participation in the U18s may lead to altered landing strategies indicative of high injury risk. A temporary reduction in hop performance in the U13s may also be linked to a period of adolescent awkwardness.

Key words

Injury risk, jumping, kinetics,

INTRODUCTION

Recent data indicate that male youth soccer players are a target group who would benefit from injury risk-reduction strategies (30), with periods of heightened risk associated with rapid growth (34). Dynamic movements that underlie injury in male youth soccer include running, decelerating, over-stretching for a ball or when tracking an opponent, regaining balance after a kicking action and landing from a jump (24, 35). In adult male (10, 32), and female soccer players (5, 22), altered neuromuscular control has been shown as a predictor of injury. Less information is available in youth and there is currently a paucity of literature that has specifically examined the effects of chronological age and maturation on measures of neuromuscular control in elite male youth soccer players.

Due to the physical demands of elite male youth soccer (2), the associated injury risk (24), and the number of children and adolescents who participate in the sport (7), there is a clear need for increased evidence within male youth soccer players to identify age and maturation specific injury risk factors (1, 26). A range of time efficient, non-invasive field-based methods have been developed to screen an athlete's level of movement skill and injury risk during jumping and landing tasks (6, 20). Unilateral landing forces that are greater than three times body weight (19) and reduced single horizontal hop distances (11) have previously been reported as risk factors for injury. Recent data also indicate that jumping tasks using force plate diagnostics can be reliably used with elite male youth soccer players and easily implemented in the field setting (27). However, the relative influence of chronological age and maturation on these measures in this population is currently unknown.

Previous research investigating the effects of age on maximal jump performance has demonstrated a general trend of performance increases associated with age (8, 16, 23). This indicates that youth will naturally enhance performance during growth and maturation; however, variation may be evident with various peaks and declines based on performance level and stage of maturation (16, 23). Research in youth populations has primarily used jumping tasks and included outcome variables that are biased towards performance and power derivatives (3, 8, 17, 23). Less age and maturation specific research is available that have examined kinetic data during landing.

The available literature shows a concomitant reduction in relative landing forces with maturation in male youth (14, 25). Increases in jump height, reductions in normalized landing forces and an enhanced ratio of landing to take off force has also been shown with each stage of maturation in young male athletes (14). These data indicate that males concomitantly enhance their ability to attenuate force and develop power as they mature (14). However, the majority of studies have utilized bilateral drop vertical jump landing tasks (9, 13, 14, 25) with less information available to examine unilateral landings which may be more ecologically valid for soccer players (27). The effects of age and maturation on landing forces during single leg jumping tasks requires further investigation.

Quantifying jumping and landing forces during single leg tasks can assist coaches in identifying young players who demonstrate high risk kinetics and developmental trends associated with chronological age and maturation. The current study aims to examine possible age and maturation-related differences in performance during practically viable screening assessments using a large cross-sectional sample of elite male youth soccer players.

METHODS

Participants

Four hundred elite male youth soccer players from the academies of six English professional soccer clubs volunteered to take part in the study. Descriptive statistics for each chronological age and maturation group are displayed in tables 1 and 2 respectively. Predicted maturational status was calculated using a previously validated regression equation (18). None of the players reported injuries at the time of testing and all were participating regularly in football training and competitions. Parental consent, participant assent and physical activity readiness questionnaires were collected prior to the commencement of testing. Ethical approval was granted by the institutional ethics committee in accordance with the declaration of Helsinki.

***** *insert tables 1 and 2 near here* *****

Experimental design

A cross-sectional design was used to examine the effects of chronological age and stage of maturation on single leg jumping and landing performance. Participants were required to attend their respective club's training grounds on two occasions separated by a period of seven days. The first session was used for familiarization and the second session was used for data collection. Standardized procedures were replicated at each test session including the warm up, test set-up and participant instructions. This included eating according to their normal diet, not drinking substances other than water one hour prior to each test session and refraining from strenuous exercise at least 48 hours prior to testing. Three trials of each test were performed with the mean score reported. One minute of recovery was allowed between trials based on previous recommendations (6).

Procedures

Biological Maturity: Stage of biological maturation was assessed using a previously validated and non-invasive regression equation (18), comprising measures of chronological age (yrs), body mass (kg), standing height (cm) and sitting height (cm).

Single leg hop for distance (SLHD). Hop distances were recorded using a tape measure marked out to a length of 3 m. Players began by standing on the designated test leg with their toe on the marked starting line, the hip of the free leg flexed at 90° to avoid contralateral propulsion, and their hands on their hips. Participants were instructed to hop forward as far as possible, landing on the same leg with the hands remaining on their hips throughout. For each test to be recorded, players had to stick the landing and hold for three seconds without any other body part touching the floor in accordance with previous guidelines (11). The test was performed on both legs and the distance in line with the heel was recorded to the nearest 0.1 cm using a ruler stick to increase accuracy of the measurement. The reliability of maximum hop distance during this test has previously been shown as acceptable (28).

Single leg 75% horizontal hop and stick (75%Hop). A tape measure was marked out to a 3 m distance and taped to the floor on a horizontal line with the 0 cm mark positioned in line with the centre of a force plate (Pasco, Roseville, California, USA). Participants began by standing in line with the force plate on the designated test leg, hands on their hips and toe in line with a distance marker on the tape measure representing 75% of their predetermined maximal single leg hop and stick performance. Previous literature has utilized similar testing protocols and standardized the hop distance based on either an arbitrary figure (19) or leg length; however, it was the goal of the current study to devise a test that was representative of the individual's level of physical performance. Pilot testing indicated that 50% and 100% of maximum hop distance were too easy and difficult respectively. Thus, 75% provided a sufficient challenge to examine the participants landing kinetics while maintaining adequate reliability (27). Participants were instructed to hop forward onto the force plate, landing on the same leg with the hands remaining on their hips throughout. For each test to be recorded, players had to stick the landing and hold for three seconds, remaining as still as possible without any other body part touching the floor. Peak landing vertical ground reaction force (pVGRF) was measured for each jump. The initial ground contact was defined as the point when vertical ground reaction force first exceeded 10 N. Both absolute pVGRF and values normalized to body weight were calculated. All data were recorded at a sampling rate of 1000 Hz and filtered through a fourth-order Butterworth filter at a cut-off frequency of 18 Hz.

Statistical analysis

Descriptive statistics for each test were calculated for each sub-group. A one-way analysis of variance (ANOVA) was performed to determine the existence of between group differences for all outcome measures. The level of significance was set at alpha level $p \leq 0.05$. Homogeneity of variance was tested by Levene's statistic, and where violated Welch's adjustment was used to calculate the F-ratio. Post-hoc analysis to determine significant between group differences was assessed using Gabriel's or Games-Howell tests when equal variance was or was not assumed respectively. Separate analyses were performed to examine between group differences for a range of chronological age groups that are representative of those used in an elite soccer academy (U11-U18). A secondary analysis was also employed, grouping players by maturation (pre-, circa- or post-PHV). To account for the reported error (approx. 6 months) in the equation (18), players were grouped into discrete bands based on their maturational offset (pre -PHV = <-1, circa-PHV = -0.5 to 0.5, post-PHV = >1). Players who recorded a maturational offset between -1 to -0.5 and 0.5 to 1 were subsequently removed from the data set when players were analysed by stage of maturation. Cohens *d* effect sizes (ES) were calculated to interpret the magnitude of between group differences using the classifications as proposed by Cohen (4): standardized mean differences of 0.2 (small), 0.5 (medium), and 0.8 (large). Paired samples t-tests were also used to assess differences in performance between limbs. All data were computed through Microsoft Excel® 2010, while ANOVAs and t-tests were processed using SPSS® (V.21. Chicago Illinois).

RESULTS

Absolute SLHD scores for each chronological age and maturation group are displayed in figures 1a and 1b, depicting a trend of increasing hop distance with advanced age and maturation. A significant increase in hop distance was reported between consecutive age groups from the U14s onwards with medium to large effect sizes (d = 0.65 – 0.84). Hop distances were lower in the U13 age group in comparison to both the U12s and U14s on both legs; however, this reduction was statistically significant compared only to the U14s ($p < 0.05$) (d = 0.65 to 0.84). Effect sizes for all other age group comparisons ranged from small to very large (d = 0.23 – 2.58). When analyzed by maturation, significantly greater hop distances were shown in the post-PHV participants than all other maturation groups on both legs ($p < 0.001$), corresponding to a large effect size (> 1). Circa-PHV players displayed significantly greater hop distances than those in the pre-PHV group on the right leg only ($p < 0.05$; d = 0.56). Within-group analysis showed no significant difference between limbs.

Hop distances normalized to leg length are displayed in figures 3 and 4. Scores were lower in the U13 age group in comparison to the U12s and U14s (d = 0.50 to 0.59). A significant increase in hop distance was present from the U13s to U14s on both legs ($p < 0.05$; d = 0.52-0.58). The U18 age group achieved significantly greater hop distances relative to leg length than all other groups on both legs ($p < 0.001$; ES range d = 0.57 to 1.71) apart from the U16s on the right leg. Maturation analyses showed that relative hop scores were significantly higher in post-PHV players on both legs with small to medium effect sizes ($p < 0.001$; d = 0.35 to 0.54). No other group comparisons were statistically significant and displayed trivial effect sizes. Within-group analysis showed no significant difference between limbs.

***** insert figures 1 a - d near here ******

Absolute pVGRF experienced by each chronological age and maturation group during the 75%Hop are displayed in figures 2a and 2b. A trend of increased landing forces with advances in both chronological age and maturation were evident. The youngest age groups

(U11 and U12) had significantly lower absolute landing forces than the oldest four age groups (U14 – U18) ($p < 0.001$; $d = 0.62 – 3.18$). When analyzed by maturation, significantly greater landing forces were displayed on both legs in the post-PHV players than all other groups ($p < 0.001$; $d = 1.10 – 1.40$). Within group analysis showed that right leg landing forces were significantly greater than the left ($p < 0.001$).

Relative to body weight, 75%Hop landing forces were highest in the U11 and U12 age groups and then displayed a trend of reductions with age (figure 2c); however, an increase was present in the U18 age group who experienced significantly greater relative forces than the U15s and U16s ($p < 0.001$; $d = 0.71 - 1.05$). The lowest relative landing forces were shown in the U16s on both legs and this was statistically significant from all other age groups except the U15s. Maturation analyses indicated that pre-PHV display the greatest landing forces relative to body weight which were significantly greater than all other groups (figure 2d), corresponding to medium and large effect sizes ($p < 0.001$; $d = 0.56 – 0.93$). Within-group analysis showed landing forces were significantly greater on the right leg ($p < 0.001$).

***** insert figures 2 a - d near here ******

DISCUSSION

The current study examined the effects of chronological age and maturation on single leg jumping and landing performance in elite male youth soccer players. Results showed that absolute peak landing forces increased with both age and maturation. When normalized to body weight, a more variable pattern was evident across different chronological age groups and maturational stage, with pre-PHV players displaying the highest relative forces. Single leg hop distances also increased with each consecutive chronological age group apart from the U13s where a reduction in performance was identified. The same pattern of heightened performance with maturation was also shown. After adjusting the scores relative to leg length, the U18s still achieved the greatest hop distances; however, more variability was noted in respective age group comparisons, particularly around periods of rapid growth. Post-PHV players were also still the most effective performers with nominal to no differences between those in the pre and circa PHV groups.

Peak vertical landing forces increased linearly with age and maturation, which is likely due to increases in body weight and muscle mass. Conversely, pre-PHV players displayed significantly greater normalized landing forces than all other maturation groups, and a trend was shown of younger players (U11-U13s) experiencing higher ground reaction forces relative to body weight. Conflicting data has shown a reduction in normalized landing forces with each advancing maturation stage indicating that force attenuation improves with maturation (14). However, it has been suggested that younger children land with different kinematic strategies to adults, characterized by reduced knee and hip flexion angles (33). The described landing position is indicative of a stiffer landing in which ground reaction forces and joint torques may increase (33). In-spite of this, injury risk is reportedly low in this group (24), and intuitively higher relative ground reaction forces may be offset by lower body mass, shorter statures and slower intensities of play in comparison to older players.

Absolute single leg hop distances generally increased concomitantly with age and maturation on both the right and left legs. These findings are consistent with previous literature using jumping tests in male youth soccer players (8) and may be due to rises in muscular strength as a result of growth and maturation. This notion is supported by research showing that the standing long jump test has demonstrated strong relationships with lower body muscular strength in youth athletes (3).

Between the U12s and U13s, a reduction in both absolute and relative hop distances was evident, with significant increases in performance subsequently shown in the U14s. This could be attributed to a period of ‘adolescent awkwardness’ due to rapid increases in limb length, which can lead to young soccer players experiencing temporary decrements in motor skill performance and neuromuscular function approximately 12 months prior to PHV (23). Large percentage changes in leg length were evident between the U12s and U13s, indicating that the U13s were at the start of the growth spurt. Significant increases in relative hop distances between the U13 - U14 age groups may suggest the presence of an adolescent spurt, characterized by gains in muscular strength and power, occurring shortly after PHV (17, 23). This is supported by the maturational analyses, whereby, small and largely non-significant differences were shown between pre and circa-PHV players in both absolute and relative hop distances. This was followed by larger and significant increases by those in the post-PHV group, indicating that horizontal jump performance shows greater improvements that could be attributed to a more advanced training age, increased strength and motor control in the later stages of maturation.

Poor attenuation of ground reaction forces upon landing in-spite of improvements in jumping performance may heighten injury risk in youth players. In the current study, the presence of a neuromuscular spurt leading to enhanced jump performance (as evidenced by significant increases in single leg hop distances between the U13s and U14s) is plausible. However, age group comparisons showed no reductions in relative landing forces between the U13-U14 and small increases on the left leg. Significant reductions in landing force were then observed in the U15 and U16 age groups. These data may indicate a developmental lag in the ability of players to attenuate ground reaction forces upon landing following enhancements in jump performance. This could increase the risk of injury and highlights the need for training interventions that focus on developing appropriate landing mechanics during periods of rapid growth that may result in heightened force production.

Relative landing forces in the 75%Hop revealed significant reductions between the U14s, U15s and U16s respectively. This may be due to the post-PHV cohort adopting a more hip-dominant landing strategy, demonstrated by greater ankle and hip joint stiffness which enables more effective force absorption (9). Greater hip flexion upon ground contact provides a mechanical advantage to the hamstring musculature, heightening their activation and concomitantly reducing quadriceps activation (31). When analyzed by maturation a trend of reductions in relative landing force were shown on the left leg although a minor increase was present between the circa and post PHV players on the right leg. This could be attributed to significant increases in landing force reported in the U18s, which may in part be explained by greater jump distances; however, the increase between the U16-U18s was proportional to other between group comparisons and only statistically significant on the left leg. Thus, altered landing mechanics during single leg tasks appear to be present in U18 players which may predispose them to a heightened risk of injury. The majority of participants in the current study were right footed, and as such, their preferred stance limb would be their left. Therefore, it is plausible to suggest that due to the repeated exposures of soccer training and competitions that their left limb may have developed heightened neuromuscular control.

Reduced relative ground reaction forces in older and more mature have been reported previously in drop jumping (14, 25), with data suggesting that athletes are better able to attenuate landing forces with advanced age and maturation (33). Conversely, literature has reported that resultant forces are significantly greater in post-PHV than pre-PHV subjects during a single leg stride jump task (12) which may be more representative of the 75%Hop performed during this study. Hass et al. (12) suggested that with increased age, a more extended knee position on landing is adopted, whereas greater knee flexion in younger subjects is a strategy to protect internal joint structures. The results of the current study do not support this notion due to the youngest (pre-PHV and the U11-U12) and oldest (U18) age group players displaying higher relative landing forces. The significant increase in landing forces in the U18 age group may therefore be a result of the increased training loads required as a full time academy scholar, altering their landing strategy. Specifically, alterations in the functional hamstring: quadriceps ratio have been shown in male youth soccer players due to muscle loading patterns that asymmetrically strengthen the quadriceps during training and competitions (15). This alters the reciprocal balance of strength and dynamic stabilization around the knee as indicated by compromised function of the hamstrings during high velocity actions (15). Increased exposures in the U18 group could have resulted in a more quadriceps dominant landing strategy and higher ground reaction forces (13, 14).

SUMMARY AND PRACTICAL APPLICATIONS

This study provides cross sectional data for single leg jumping and landing performance in a large sample of elite male youth soccer players. Our findings may assist practitioners by providing normative data for a range of players grouped according to chronological age groups or maturation, from which reduced performances and potential injury risk factors can be identified.

A trend of increased absolute peak landing forces was observed with each incremental age group and stage of maturation, whereas relative landing forces demonstrated a more variable pattern. Single leg maximum hop distances increased linearly with age and maturation, but relative to leg length, a reduction in performance was reported in the U13 age group. This could be linked to a period of adolescent awkwardness during which motor control is compromized. Following improvements in hop performance as indicated by heightened jump distances in the U14, a developmental lag may exist in the attenuation of landing forces and this could increase the risk of injury during periods associated with rapid growth. High volumes of accumulated soccer training and competitions may also lead to altered landing strategies in older athlete's that are indicative of high injury risk and this risk may be further magnified by increases in body mass, limb lengths and velocities of play. Whilst integrated neuromuscular training (INT) is recommended at all stages of a young player's development to enhance strength and motor control (21), targeted programs to enhance landing mechanics are advised during periods associated with rapid growth. However, to validate these inferences, further research is warranted to examine the measures included in this study as potential risk factors for injury and the effects of training programs which include resistance training, dynamic balance and plyometrics in this cohort.

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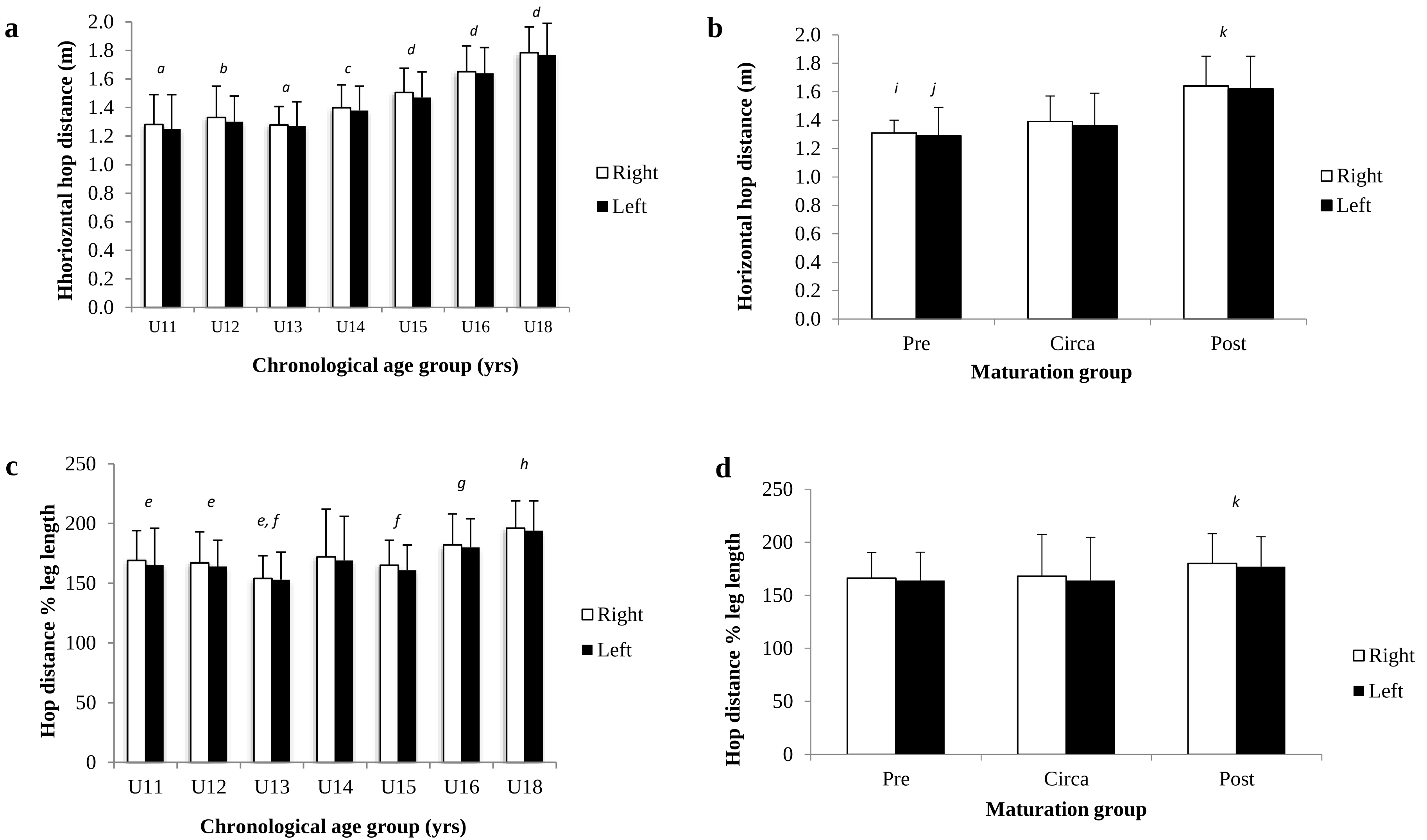
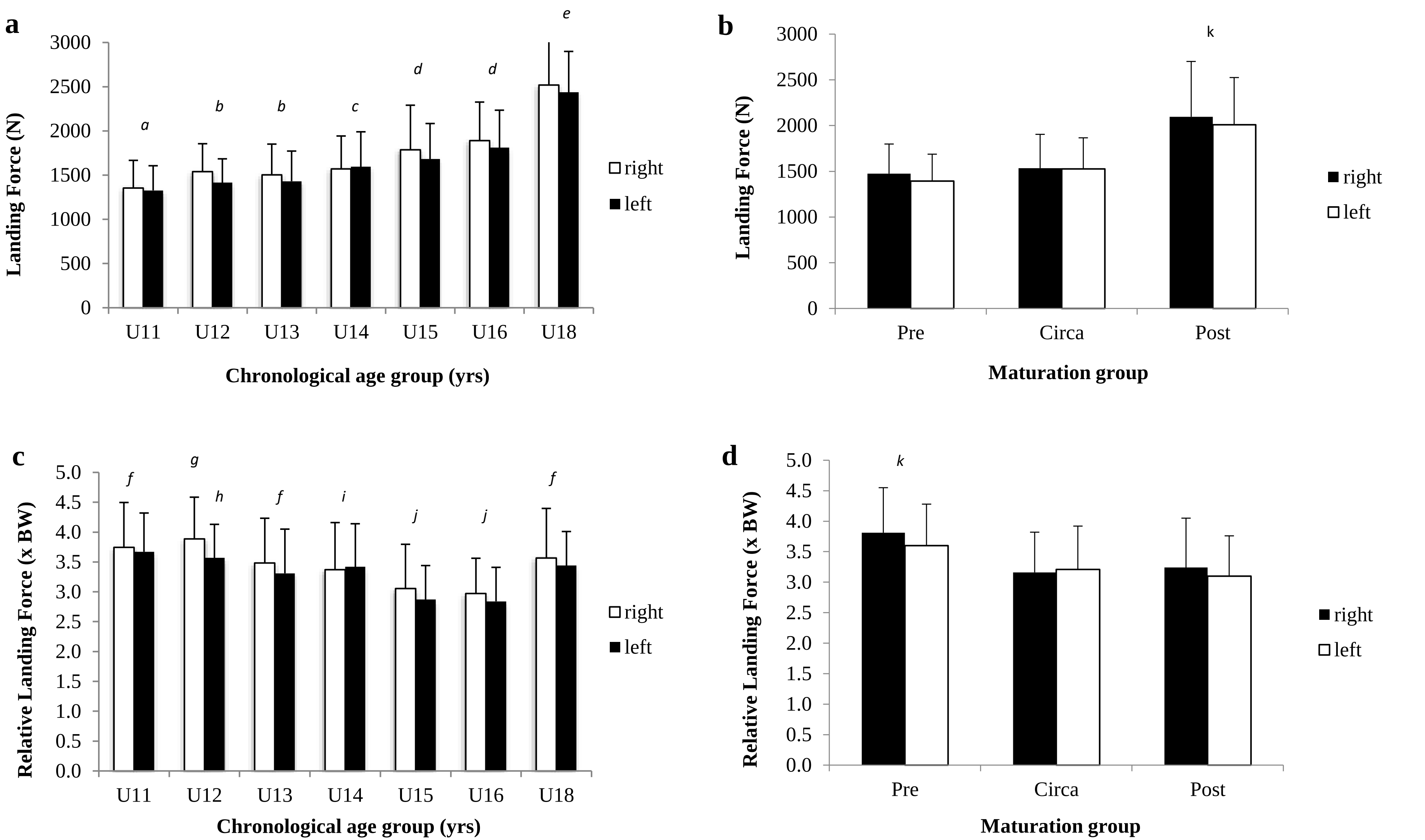

a
Hhorizntal hop distance (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
a
b
a
c
d
d
d
U11
U12
U13
U14
U15
U16
U18
Chronological age group (yrs)
Right
Left
b
Horizontal hop distance (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
i
j
k
Pre
Circa
Post
Maturation group
Right
Left
c
Hop distance % leg length
250
200
150
100
50
0
e
e
e, f
f
g
h
U11
U12
U13
U14
U15
U16
U18
Chronological age group (yrs)
Right
Left
d
Hop distance % leg length
250
200
150
100
50
0
k
Pre
Circa
Post
Maturation group
Right
Left

Figures 1 a - d. Absolute and relative single leg hop distances. [a] significantly different from U14, U15, U16, U18 ($P < 0.05$); [b] significantly different from U15, U16, U18 ($P < 0.001$); [c] significantly different from all other age groups except the U12s ($P < 0.05$); [d] significantly different from all other age groups ($P < 0.001$); [e] significantly different from U16 and U18 ($P < 0.05$); [f] significantly different from U14s ($P < 0.05$); [g] significantly different from all age groups except U14s ($P < 0.05$); [h] significantly different from all age groups ($P < 0.001$); [I] significantly different from circa and post PHV ($P < 0.05$); [j] significantly different from post PHV ($P < 0.001$); [k] significantly different from all maturation groups ($P < 0.001$)


a
Landing Force (N)
3000
2500
2000
1500
1000
500
0
a
b
b
c
d
d
e
U11
U12
U13
U14
U15
U16
U18
Chronological age group (yrs)
right
left
b
Landing Force (N)
3000
2500
2000
1500
1000
500
0
k
Pre
Circa
Post
Maturation group
right
left
c
Relative Landing Force (x BW)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f
g
h
f
i
j
j
f
U11
U12
U13
U14
U15
U16
U18
Chronological age group (yrs)
right
left
d
Relative Landing Force (x BW)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
k
Pre
Circa
Post
Maturation group
right
left

Figures 2 a - d. Absolute and relative lading forces. [a] significantly different from U14, U15, U16, U18 ($P < 0.05$); [b] significantly different from U15, U16, U18 ($P < 0.05$); [c] significantly different from U16, U18 ($P < 0.05$); [d] significantly different from the U18s ($P < 0.05$); [e] significantly different from all other age groups ($P < 0.001$); [f] *s*ignificantly different from U15 and U16 ($P < 0.05$); [g] significantly different from U14, U15 and U16 ($P < 0.05$); [h] significantly different from U14s ($P < 0.05$); [I] significantly different from U12, U15 and U16 ($P < 0.05$); [j] significantly different from U11, U12, U13, U14 and U18 ($P < 0.05$); [k] significantly different from from all maturation groups ($P < 0.001$)