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Anthropometrics and maturity status: A preliminary study of youth football head impact biomechanics

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A R T I C L E I N F O

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A B S T R A C T

Context: There is a paucity of head impact biomechanics research focusing on youth athletes. Little is known about how youth subconcussive head impact tolerances are related to physical size and maturation.
Objective: To examine the effects of age, anthropometric and maturational status variability on head impact biomechanics.
Design: Cross-sectional.
Setting: Outdoor youth football facilities in South Carolina.
Participants: Thirty-four male recreational youth football players, 8 to 13 yrs.
Interventions: Categorized by CDC standards, independent variables were: age, height, mass, BMI, and estimated peak height velocity (PHV). Participants wore a designated head impact sensor (xPatch) on their mastoid process during practices and games.
Main outcome measures: Linear acceleration (g) and rotational acceleration (rad/s^2).
Results: Boys in the older age category had a greater linear ($F = 17.72$; $P < 0.001$) and rotational acceleration ($F = 10.74$; $P < 0.001$) than those in the younger category. Post-PHV boys had higher linear ($F = 9.09$, $P = 0.002$) and rotational ($F = 5.57$, $P = 0.018$) accelerations than those who were pre-PHV. Rotational, but not linear acceleration differed by height category with lowest impacts found for the tallest category, whereas both linear and rotational accelerations by mass differences favored average and heavy categories. BMI overweight boys, had the greatest linear ($F = 5.25$; $P = 0.011$) and rotational acceleration ($F = 4.13$; $P = 0.260$) means.
Conclusion: Post-PHV boys who were older, taller and had longer legs, but who were not heavier, had higher impacts perhaps due to the type of impacts sustained. Taller boys' heads are above their peers possibly encouraging hits in the torso region resulting in lower impact accelerations. Obese boys did not have sequential results compared to boys in the other BMI categories probably due to league rules, player position, and lack of momentum produced.

1. Introduction

American youth football is one of the most popular sports in the United States but yields numerous injuries, from contusions to concussions (Nation et al., 2011). A concussion is defined as a brain injury resulting in a complex pathophysiological process caused by biomechanical forces (McCrory et al., 2017). Concussions compose almost 10% of all injuries in youth football with injury rates ranging from 2.38 to 6.16 per 1000 athlete-exposures in games and 0.24 to 0.59 in practices (Dompier et al., 2015; Kontos et al., 2013). Concussions affect the youth population differently than older populations. For example, youth patients require longer to recover from a concussion and for symptoms to resolve compared to older patients (Field et al., 2003).

Not all head impacts result in a concussion; however, athletes may experience hundreds of subconcussive—non-injurious—head impacts during regular participation in practices and games. It is believed

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repetitive subconcussive head impacts may have negative cumulative long-term neurological effects, but the physiological underpinning for this theory remains unknown to date (McCrory et al., 2017; McAllister and McCrea, 2017). To address a growing social concern surrounding short- and long-term implications of concussion, head impact biomechanics research has offered some interesting insights into head impact prevalence and severity, concussion risk factors, and injury prevention strategies, at all levels of football participation (Kontos et al., 2013; Broglio et al., 2010; Pellman et al., 2003; Crisco et al., 2010; Guskiewicz et al., 2007; Duhaime et al., 2012; Urban et al., 2013; Schnebel et al., 2007; Daniel et al., 2012; Cobb et al., 2013; McCaffrey et al., 2007; Mihalik et al., 2007). Notwithstanding, the topic of subconcussive head impacts in youth football still remains understudied. This is surprising given youth football represents the largest cohort (~3 million) (National Council of Youth Sports, 2008), greater than all other levels of football combined, with the least medical coverage, and likely a greater proportion of parent volunteer coaches who may not possess the requisite technical knowledge to effectively teach safe football techniques. Moreover, critical periods of growth and maturation, marked by variability in anthropometric characteristics within age groups, coincide with player skill development. Although preliminary descriptive research found youth football players have lower head impact exposure than high school and collegiate football players, their impact severity is near identical to their older counterparts (Munce et al., 2014). In contrast to traditional age-based divisions, some youth football leagues use weight-based categorization for player placement as a strategy to circumvent, or at least reduce injuries related to size.

Factors affecting head impact biomechanics during a subconcussive head impact include impact anticipation, cervical muscle strength, rule infractions, and behavioral modifications (Cantu, 1992; Mihalik et al., 2010a; Schmidt et al., 2014; Mihalik et al., 2010b; Martini et al., 2013). It stands to reason that all of these factors may be affected by physical maturity; therefore, we believe variability in body size associated with maturational timing is a contributing factor during head impacts that has not yet been explored. Forty-five percent of American youth football players are considered overweight or obese, which is almost double that of other American boys the same age (Malina et al., 2007). The variability in biological growth among boys of the same chronological age is large and especially accentuated around peak height velocity (i.e., the adolescent growth spurt) which typically occurs around 13 years of age among boys (Malina et al., 2004). Peak weight velocity generally occurs about 3–10 months after growth spurts in height, and is influenced by the amount of muscle and fat tissue. The timing and tempo of height and mass related changes can impact the size and shape of the body (Malina et al., 2004) and perhaps translate to head impact acceleration and force variability when receiving or initiating collisions on the field. There are a variety of ways to account for growth related variability in research and practice.

Considering the dynamic and varying timing of children's growth, the Centers for Disease Control and Prevention provide tools to track child growth. These tools include Body Mass Index (BMI) categories and growth chart percentiles for height and mass commonly used in health care settings (Age-based Pediatric Growth Reference Charts, 2010; About BMI for Children and Teens, 2011). Maturity offset, or the estimated time around peak height velocity (PHV) is an additional derived measure that captures variability in maturational timing related to relative leg length to height (Moore et al., 2015). Therefore, the purpose of this study was to compare linear and rotational acceleration across traditional age- and weight-based categories with BMI and maturity offset categories in healthy youth football players.

2. Materials and methods

2.1. Design

A cross-sectional research design was utilized for this study. The independent variables were participant's anthropometric and derived characteristics divided into categorical levels: height (short, average, tall), mass (light, average, heavy), age (older, younger), BMI (underweight, healthy weight, overweight, obese) and maturity offset (pre-PHV and Posts PHV). The dependent variables included linear acceleration (g) and rotational acceleration (rad/s^2).

2.2. Participants

Thirty-four male youth football players enrolled in local youth football programs volunteered for the study. Based on the assumption that 25 g provides a clinically meaningful difference for linear magnitude and the median youth football impact is 19 g (Cobb et al., 2013; Cobb et al., 2014), 32 participants were needed to detect a difference at 95% power with an alpha level of 0.05 as calculated by G*Power software (Faul et al., 2007). All of the athletes enrolled in the study were recruited from age restricted leagues, leagues that separate athletes by age ranges only (not body size). Two leagues' teams were divided into 8–9 year olds, 10–11 year olds, and 12–13 year olds. The third leagues' teams were divided into 8–10 year olds and 11–13 year olds. Assent and informed consent forms were signed by the participants and their parent or legal guardian, respectively. Athletes were excluded from the research if there was an allergy to the adhesive used to adhere the head impact sensor (xPatch) in place, or if the child could not fully participate in practices and games.

2.3. Instrumentation and measurements

2.3.1. Age

Participants self-reported their birthdate. Age (in years) was then determined relative to the beginning of the youth football season, and subsequently categorized using a median split: "younger" (8–10 years old) and "older" (11–13 years old).

2.3.2. Height

Height was collected with standardized markings from a single tape measure on a sitting/standing height board (ShorrBoard Weight and Measure, LLC). Participants were instructed to remove their shoes and any head wear before measurement. Height was taken in centimeters to the nearest tenth. Height percentiles were calculated with the CDC growth percentile charts (Age-based Pediatric Growth Reference Charts, 2010). Boys were placed in three groups using a tertiary split of height percentiles labeled: "short" (18.2%–44.9%), "average" (45.0%–71.7%), and "tall" (71.8%–98.4%).

2.3.3. Mass

Mass was collected by using the same digital scale (BWB-800S, Tanita CO., Arlington Heights, IL) for each participant. The participants wore only shorts or padded football pants for the weighing process. It was noted if the athlete was wearing shorts or football pants on the data collection sheet and the corresponding mass was subtracted (pants 0.5 kg, shorts 0.2 kg). If uncomfortable with not wearing a shirt in public, the child was allowed to wear a light t-shirt during weighing. The mass of a standard t-shirt was also subtracted (0.2 kg). Mass was reported in kilograms to the nearest tenth. Mass percentiles were calculated with the CDC growth percentile charts (Age-based Pediatric Growth Reference Charts, 2010). A tertiary split was also used to categorize the boys into the following groups based on mass percentiles: "light" (16.9%–44.6%), "average" (44.7%–72.3%), and "heavy" (72.4%–100%).

2.3.4. Maturity offset

Maturity offset was calculated using the sitting height inclusive formula for boys in Moore et al. (Moore et al., 2015) derived from height, mass and leg length (stature – sitting height). According to Mirwald et al. (Mirwald et al., 2002 #26), the maturity offset formulas