DOES MATURATION AFFECT THE RELATIONSHIP BETWEEN HIP STRENGTH DIFFERENCES AND LOWER EXTREMITY ASYMMETRY IN ADOLESCENT LONG-DISTANCE RUNNERS?

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The purpose of this study was to investigate the influence of maturation on the relationship between joint asymmetry and side-to-side hip strength differences in adolescent runners. Uninjured adolescent runners (n = 63) were recruited for the study. Participants completed hip strength and three-dimensional testing and were stratified by maturity level. Results demonstrate inconclusive results of the effect of maturation on the relationship between side-to-side joint asymmetry and hip strength differences. This lack of clarity highlights the need for prospective study on running patterns in maturing adolescent runners.

KEYWORDS: adolescent running, hip strength, asymmetry.

INTRODUCTION: Running as an endurance sport continues to grow in popularity amongst middle and high school athletes, with nearly 500,000 young athletes participating in cross-country during 2017-2018 (Associations, 2018). Unfortunately, the literature on pediatric running related injuries (RRIs) is sparse and often contradictory. Currently, pediatric clinicians apply adult literature on both running mechanics and treatment techniques to children of differing maturational statuses. The potential confounding effects of growth, gender, and maturation on mechanics and injury in children and adolescents may limit the generalizability of the adult literature to this population.

To our knowledge, the relationship between maturation and adolescent running mechanics has not been studied. However, differences in landing kinematics, isometric strength, and joint laxity have been reported to be related to maturation (DiStefano et al., 2015; Quatman, Ford, Myer, Paterno, & Hewett, 2008). Hip and knee musculature weakness have been measured in injured high school and adult runners (Luedke, Heiderscheit, Williams, & Rauh, 2015). Additionally, inverse relationships have been reported between hip strength and joint range of motion (ROM), specifically at the hip (Ford, Taylor-Haas, Genthe, & Hugentobler, 2013; Souza & Powers, 2009; Taylor-Haas et al., 2014). Injured runners have also been found to have greater hip internal ROM than uninjured runners (Zifchock, Davis, Higginson, McCaw, & Royer, 2008). Coupled together, these findings suggest a relationship between muscle weakness and lower extremity asymmetry.

Normal gait is often assumed to be symmetrical in healthy populations while asymmetry is commonly associated with pathology (Bredeweg, Buist, & Kluitenberg, 2013; Zifchock, Davis, & Hamill, 2006; Zifchock et al., 2008). However, side-to-side lower extremity biomechanical asymmetries have been reported in uninjured adolescent and adult runners (Furlong & Egginton, 2018; Garcia, Taylor-Haas, & Long, 2019; Radzak, Putnam, Tamura, Hetzler, & Stickley, 2017; Zifchock et al., 2008).

Therefore, the purpose of this study is to investigate the influence of maturation on the relationship between joint asymmetry and hip strength differences in long-distant adolescent runners. It is hypothesized that immature adolescents will demonstrate stronger relationships between joint asymmetry and neuromuscular asymmetry.

METHODS: 63 adolescent runners (M = 30; F = 33, Age = 14.23 ± 2.73 years) who were free from injury over the past six months and participated in long-distance running activities were recruited for the study. Participants completed a modified Pubertal Maturational Observation Scale (PMOS; (Davies & Rose, 1999)) and were stratified by as either immature (pre- and pubertal) or mature (post-pubertal). Subjects completed a single visit to the Motion Analysis Lab and underwent hip strength and three-dimensional motion analysis testing.

Hip Strength: Side-lying isometric hip abduction strength (Dalton et al., 2011) was measured via a hand-held dynamometer (microFET2; Hoggan Health Industries; West Jordan, UT). Two trials were collected for each limb and peak torque (Nm) was recorded. Hip abduction strength was measured as the average peak torque between the two trials.
Isokinetic hip extension strength was measured via Biodex System 4 dynamometer (Biodex Medical Systems, Inc.; Shirley, NY) at 60º/s. Participants laid prone on an exam table with the greater trochanter of the tested side aligned with the axis of rotation of the dynamometer while the contralateral limb was rested on a bench posterior to the participant. The hip attachment cuff was secured proximally to the knee. While maintaining a flexed knee, the participant was instructed to kick his/her leg up as forcefully and far as possible then allow the hip to relax and return to a flexed position. Five repetitions were completed for each leg. Continuous torque and position data were recorded throughout the set ROM and exported to MATLAB (MathWorks, Inc.; Natick, MA) for further analysis. To exclude the initial torque impulse, peak torque was assessed only during the functional hip sagittal plane ROM measured during three-dimensional motion analysis. Hip extension strength was then measured as the average peak torque between the five repetitions.

Three-Dimensional Motion Analysis: Subjects were instrumented with reflective markers and tested using a 12-camera Raptor 4 (Ford et al., 2013) system (Motion Analysis Corp.; Santa Rosa, CA). Following a 5-minute warmup and treadmill familiarization period, kinematics were measured during self-selected running speeds on a non-instrumented motorized treadmill (Biodex RTM 600). Foot contact and toe-off events were determined based on previously established algorithms (Maiwald, Sterzing, Mayer, & Milani, 2009; O'Connor, Thorpe, O'Malley, & Vaughan, 2007).

Analysis: Using previously described methods, trunk endurance and hip strength were non-dimensionalized to body size (Hof, 1996). Neuromuscular asymmetries were calculated as the absolute difference between sides for the hip abduction and extension measures.
Three-dimensional joint side-to-side symmetry was measured using the Average Symmetry Index (ASI) during stance phase (Garcia & Long, 2019):

$$ASI = \frac{\sum|Xleft(i) - Xright(i)|}{n\ waveform\ points}$$

for every i^{th} waveform point. An ASI value of 0 represents perfect symmetry.

Participants were stratified by maturation status. Pearson's correlation coefficient was calculated between ASI and side-to-side absolute differences in hip abduction and extension strength.

RESULTS:
Hip Abduction Strength Deficiency: Immature adolescent runners were found to have a significant positive relationship with knee flexion/extension asymmetry (**Figure 1**; r = 0.394, p = 0.023) and a negative relationship with trunk rotation asymmetry (r = -0.393, p = 0.024). Though not significant, a positive trend was also measured with ankle dorsi/plantarflexion asymmetry (r = 0.314, p = 0.075). No relationships were found in mature runners.

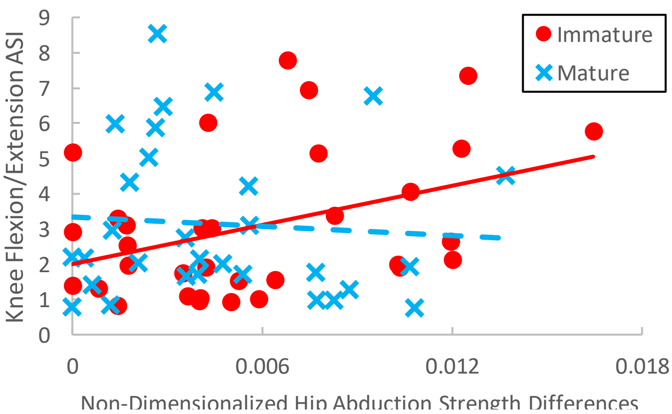

Figure 1: Effect of maturation on the relationship of non-dimensionalized hip abduction strength differences and knee flexion/extension ASI

Hip Extension Strength Deficiency: No relationships were found with immature adolescent runners. Mature runners were found to have significant positive relationships with pelvic obliquity (r = 0.370, p = 0.045) and hip flexion/extension (r = 0.425, p = 0.019) asymmetries. Though not significant, positive trends were also measures with hip rotation (r = 0.325, p = 0.08) and knee varus/valgus (r = 0.352, p = 0.057) asymmetries.

DISCUSSION: The purpose of this study was to investigate the influence of maturation on the relationship between joint asymmetry and hip strength differences in long-distant adolescent runners. It was hypothesized that immature adolescents would demonstrate stronger relationships between hip strength differences and joint asymmetry. Overall, the findings indicate that maturation likely factors into the relationship between side-to-side hip strength differences and joint asymmetry. However, the exact nature of this effect is not entirely clear. While immature runners demonstrated stronger relationships between hip abduction differences, mature runners demonstrated stronger relationships between hip extension differences and join asymmetries.

A previous report on adolescent male distance runners reported reduced hip extension strength was related to increased hip rotation ROM (Taylor-Haas et al., 2014). Increased hip rotation ROM has also been associated with running injury (Zifchock et al., 2008). In the current study, mature runners demonstrated a non-significant trend that increased side-to-side hip extension strength differences were related to increased hip rotation ROM. In addition, increased hip extension strength differences were related to increased hip flexion/extension asymmetry in mature runners. Further investigation is necessary to determine if the weaker limb demonstrated a consistently more flexed or extended position than the stronger limb. These insights could provide clarity on if the weaker limb has inadequate strength to support the demands during stance phase, potentially placing more demand on the stronger limb. Prospective study is warranted to determine if these side-to-side strength differences and greater joint asymmetries are related to injury risk and running performance. Additionally, the incorporation of a strength training program targeted at equivalent limb strength profiles may provide valuable information if strength improvements are related to more symmetrical running mechanics.

The study design imposed several limitations that may factor into the variable results. Runners ran on a treadmill, under the assumption that any deficits present during overground running would manifest identically during treadmill running. This assumption, however, must be considered against evidence that there are differences between treadmill and over-ground running patterns in children (Rozumalski, Novacheck, Griffith, Walt, & Schwartz, 2015). Additionally, some of the younger members of the cohort did not have extensive prior experience running on a treadmill. All participants were provided a brief acclimation period at the beginning of testing, and all indicated feeling safe and confident with running on the treadmill prior to the start of data collection. Nevertheless, a longer acclimation period (or a criterion-based screening for experienced treadmill runners) may result in more consistent running patterns that are more typical of overground patterns.

The effect of gender differences was not considered in the current study as males and females were grouped together. The cohort was limited by the number of participants in the pre- and mid-pubertal groups, such that pre- and mid-pubertal adolescents were stratified together for the immature group. Prospective study that separates participants into groups of pre-, mid-, and post-pubertal will better represent the significant physical changes that occur with puberty. A final limitation to this study involves the means of calculating joint symmetry. Recent (unpublished) work has indicated that the ASI is strongly correlated with previously established symmetry measures. However, the ASI represents the average difference between the waveforms throughout a time series, which may mask larger differences in peak values or position at important events. Refinement of this measure may be necessary to best understand side-to-side symmetry.

CONCLUSION: Although the findings from the current study are inconclusive, the results indicate hip strength differences and joint asymmetry may be related to maturation. The sparsity of adolescent-specific running related literature indicates the necessity for prospectively tracking adolescent runners. Longitudinally tracking running patterns, strength profiles, and training regimens can provide valuable information on the effects of maturation on running performance and injury.

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