THE CONTRIBUTION OF HIP STRENGTH TO HIP ADDUCTION DURING RUNNING IS INFLUENCED BY STEP RATE, ANKLE DORSIFLEXION AND INJURY STATUS

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Peak hip adduction angle is frequently associated with running related injuries. The purpose of this study was to identify how clinical assessment measures interact to determine the presence of high or low peak hip adduction angles during running. A mixed sex sample of runners (n=125) comprising both injured and healthy controls were assessed for hip abduction strength and range of movement of the hip and ankle. Each runner then ran on a treadmill whilst 3D kinematic data was recorded, with peak hip adduction angles isolated from the data. All interest variables were analysed using a classification and regression tree procedure. This produced a model which was able to classify runners with either high or low peak hip adduction angles with an accuracy of 83.2%. The contribution of hip abductor strength to peak hip adduction angles was influenced by step rate, ankle dorsiflexion range of movement and injury status. This adds to our understanding of the relationship between hip strength and peak hip adduction.

KEYWORDS: Hip abduction strength, peak hip adduction, ankle dorsiflexion, step rate.

INTRODUCTION: Peak hip adduction angle (HADD) is frequently associated with running related injuries (Bramah et al., 2018, Ceyssens et al., 2019). Several investigations have examined the relationship between hip abduction muscle strength (HABDs) and peak HADD, however there appears to be conflicting evidence as to whether a relationship exists. Some studies have shown no correlation between HABDs and peak HADD (Baggaley et al., 2015, Zeitoune et al., 2020), while others have shown a significant inverse relationship (Hannigan et al., 2018, Taylor-Haas et al., 2014).
Due to dynamic coupling between the hip, knee, and ankle, it is possible that additional clinical assessment measures may influence peak HADD beyond HABDs. In studies investigating single leg loading activities, ankle dorsiflexion (ADF) range of movement, as well as hip internal (Hip IR) and external rotation (Hip ER), have all shown correlations to dynamic knee valgus (Bell-Jenje et al., 2016, Wyndow et al., 2016). Similar variables may influence peak HADD during running.
In a seminal paper, Bittencourt et al. (2016) highlighted a need to explore complex interactions between variables using methods such as classification and regression trees (CART). This approach has proven useful in highlighting interactions influencing frontal plane projection angles (Bittencourt et al., 2012) and injury (Mendonca et al., 2018).
This retrospective study aimed to explore possible interactions between clinical assessment measures and their influence upon peak HADD during running. The first objective was to investigate whether there are significant relationships between clinical assessment measures (HABDs, Hip IR, Hip ER and ADF) and peak HADD. A secondary objective was to explore the interaction between variables and their influence upon classification of runners as either high peak HADD or low peak HADD with the use of CART analysis.

METHODS: A mixed sex sample of 125 (72 male) runners volunteered for the study. Participants comprised of both injured (36 male, 29 female) and non-injured (36 male, 24 female) individuals; matched for age, body mass, and height. Diagnosis of a running related injury was confirmed by an experienced chartered physiotherapist in accordance with the consensus definition reported by Yamato et al. (2015). For inclusion in the study, injured participants must have been able to run for up to 10 minutes before the onset of pain. Non-injured participants must have reported no history of injury for the 6 months prior to participation and be running a minimum of 15 miles per week. Participants in either group were excluded if they described a history of lower limb surgery, joint dislocation, or instability.
HABDs was assessed isometrically using a handheld dynamometer (Lafayette instruments, Lafayette, IN) and normalised using participants' body mass and limb length (Bazett-Jones et al., 2011). Range of movement (ROM) at the hip and ankle were recorded using a smartphone

tilt-app (iphone, Apple Inc). HIP rotation was measured in prone following the same procedure as Kouyoumdjian et al. (2012). ADF was measured during a weight bearing lunge test following the same procedure as Williams et al. (2013). All participants ran on a treadmill in their own running shoes at a standardised speed of 3.2 m/s. Kinematic data were collected at 240 Hz using a 12-camera motion capture system (Qualisys, Gothenburg, Sweden). Inter segmental kinematics were calculated using a nine segment six degree of freedom model using Visual3D (C-Motion Inc., Maryland, USA) (Mason et al., 2016).
Step rate (SR) and peak HADD at midstance were isolated from the kinematic data. Pearson product-moment correlation coefficients were first used to test the relationships between peak HADD and SR, and then between peak HADD and one of the four clinical assessment measures: HABDs, ADF, Hip IR and Hip ER. For peak HADD, individuals were then dichotomised into one of 2 categories: high or low, based on prior work by Bramah et al. (2018) using the same laboratory equipment, who defined 13.2 degrees or above as high peak HADD. All variables of interest, along with additional potential confounding variables of injury status, running status, step rate, and gender, were then entered into the CART (Figure 1). Tree depth was limited to a maximum of 3 levels and a pruning procedure was applied to avoid overfitting the data (Mendonca et al., 2018). Cross-validation was used to assess the generalisability of the CART.

RESULTS: Only two interest variables had a statistically significant correlation with peak HADD; ADF (p=0.012) and HABDs (p=0.003) both demonstrated significant negative relationships. All interest variables along with additional potential confounding variables of injury status, running status, and sex were then entered into the CART.
Details of the cut-off values, established by the CART analysis, and the number of subjects classified into the main outcome groups are shown in figure 1. The model was able to correctly classify 14 of 28 runners (50%) with high peak HADD, and 90 of 97 runners (92.8%) with low peak HADD. This produced an overall classification accuracy of 83.2%.
To test classification accuracy a 10-fold cross-validation was performed. The cross-validation resulted in a risk error (SD) of 0.224 (0.037) indicating classification accuracy of 78%.

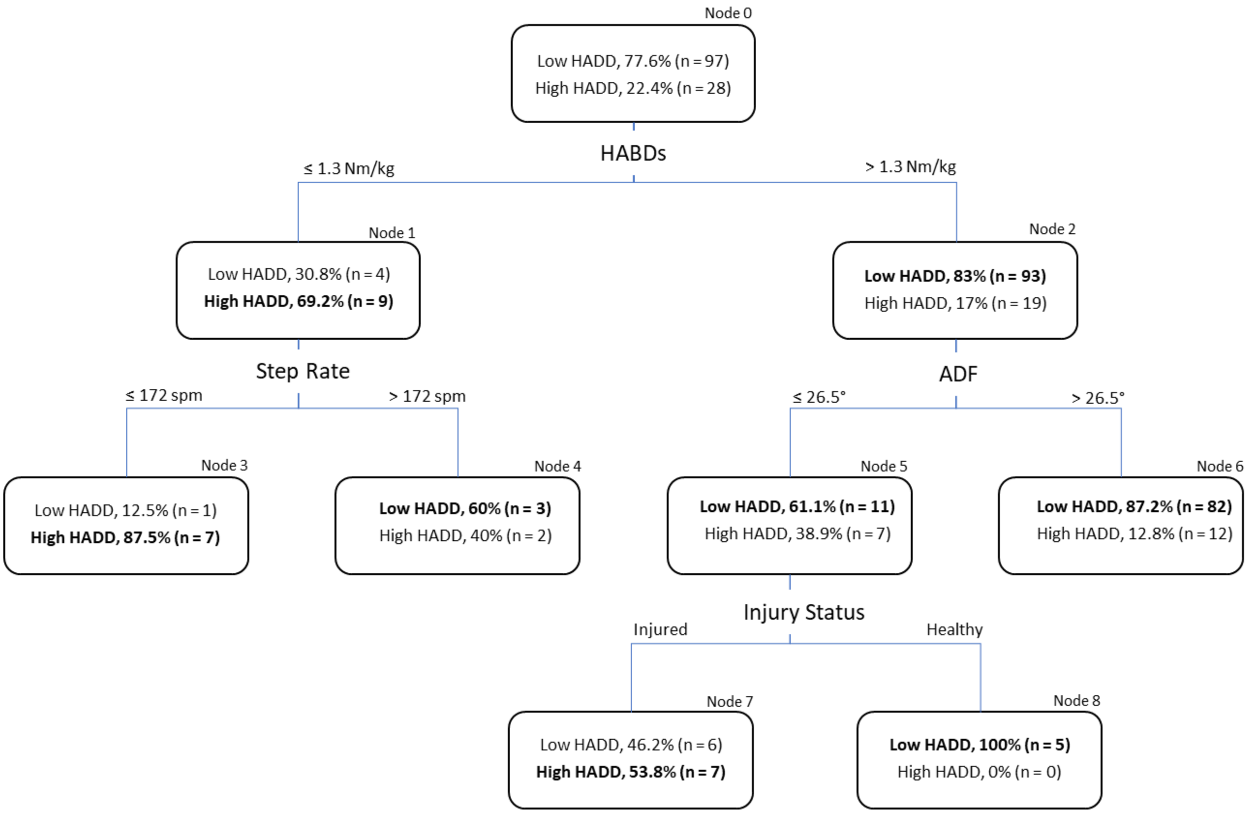

Figure 1 - CART classification of 125 participants (node 0) using interactions of the interest variables. The CART selected HABDs as the strongest determinant to group classification, specifically HABDs ≤1.3 Nm/kg (node 1) or >1.3Nm/kg (node 2). Node 3 represents HABDs ≤1.3 Nm/kg combined with SR ≤172 steps/min. Node 4 represents HABDs ≤1.3 Nm/kg combined with SR >172 steps/ min. Node 5 represents runners with HABDs >1.3 Nm/kg and ADF ≤26.5°. This was split further for nodes 7 and 8 based on injury status. All remaining participants were placed into node 6 which represented HABDs >1.3 Nm/ kg and ADF >26.5°.

DISCUSSION: The results of this study identified a significant negative relationship between HABDs and peak HADD during running, suggesting runners with weaker hip abductors demonstrate greater hip adduction angles. This is in agreement with previous studies (Hannigan et al., 2018, Taylor-Haas et al., 2014), yet in contrast to others (Baggaley et al., 2015, Zeitoune et al., 2020). One explanation is the smaller sample sizes in previous studies may have limited the available range of hip adduction angles, resulting in non-normalised data. To our knowledge this is the first study to identify a significant correlation between decreasing ADF and increasing peak HADD during running. However, restricted ADF has been associated with peak HADD during a variety of other tasks (Bell-Jenje et al., 2016, Wyndow et al., 2016, Sigward et al., 2008). This relationship may be explained by kinematic coupling between lower limb segments. Restricted ADF may lead to compensatory frontal plane motion at the subtalar joint producing internal rotation of the tibia and a medial deviation of the thigh. This relationship has been supported by studies which have found a significant correlation between peak ankle eversion and peak HADD during running (Zeitoune et al., 2020, Luz et al., 2018).

However, the use of statistical methods which capture only linear relationships between single variables has been questioned as they may fail to identify non-linear interactions between variables, which may influence peak HADD during running (Bittencourt et al., 2016). These authors emphasise the need to include more complex statistical analysis that can identify interactions between variables. Using CART analysis, interactions between HABDs, ADF, step rate, and injury status were identified. This method was able to classify runners with either high or low peak HADD, with a high degree of accuracy.

HABDs was identified as the main predictor of peak HADD during running. Only 5% of runners with low peak HADD had HABDs of ≤1.3 Nm/kg, compared with 32% of runners with high peak HADD (node 1). This suggests there may be a minimal strength required for controlling hip adduction during running that wouldn't have been identified by studies using linear models.

For those with HABDs <1.3 Nm/kg, runners with a SR ≤172 spm were seven-times more likely to be classified with high peak HADD (node 3). In contrast, participants with SR >172 spm had a greater chance of being classified as having low peak HADD (node 4). Increasing SR reduces peak HADD and external hip adductor moments (Heiderscheit et al., 2011, Lenhart et al., 2014). These findings suggest a mechanism whereby higher SRs may negate the kinematic effects associated with weak hip abductors, reducing the hip abductors requirements for controlling hip adduction.

For runners with HABDs >1.3 Nm/kg, runners with ADF >26.5° were seven-times more likely to be classified as having low peak HADD (node 6). ADF may be important in allowing absorption of impact forces in the sagittal plane, thus a reduced ADF may lead to compensatory kinematics in the frontal plane driving the hip into adduction. If this is the case HABDs above 1.3 Nm/kg may be insufficient to resist this movement.

It is worth noting however, those with HABDs >1.3 Nm/kg and ADF ≤26.5° were also classified as having low peak HADD 50% more often than having high peak HADD (node 5).

All runners with high peak HADD, with both HABDs >1.3 Nm/kg and ADF ≤26.5°, were injured (node 7), compared with just over half the runners with low peak HADD. This finding agrees with previous studies (Bramah et al., 2018, Noehren et al., 2007), which found increased hip adduction in several groups with common soft tissue running injuries.

CONCLUSION: The present study is the first to identify the existence of complex non-linear interactions between multiple variables influencing hip adduction during running. While peak hip abduction strength appears to play a significant role in controlling hip adduction, this measure in isolation appears to be influenced by step rate, ankle dorsiflexion range of movement and injury status. It is possible that additional variables beyond those considered in the present study may also influence hip adduction. The present results highlight the need for clinicians and researchers to consider non-linear interactions between multiple variables which may influence kinematic patterns commonly associated with injury.

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