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Can Achilles tendon moment arm be predicted from anthropometric measures in pre-pubescent children?

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ABSTRACT

Muscle–tendon moment arm magnitudes are essential variables for accurately calculating muscle forces from joint moments. Their measurement requires specialist knowledge and expensive resources. Research has shown that the patellar tendon moment arm length is related to leg anthropometry in children. Here, we asked whether the Achilles tendon moment arm (MA_{AT}) can be accurately predicted in pre-pubescent children from surface anthropometry. Age, standing height, mass, foot length, inter-malleolar ankle width, antero-posterior ankle depth, tibial length, lower leg circumference, and distances from the calcaneus to the distal head of the 1st metatarsal and medial malleolus were determined in 49 pre-pubescent children. MA_{AT} was calculated at three different ankle positions (neutral, 10° plantarflexion, and 10° dorsiflexion) by differentiating tendon excursion, measured via ultrasonography, with respect to ankle angle change using seven different differentiation techniques. Backwards stepwise regression analyses were performed to identify predictors of MA_{AT}. When all variables were included, the regression analysis accounted for a maximum of 49% of MA_{AT} variance at the neutral ankle angle when a third-order polynomial was used to differentiate tendon excursion with respect to ankle angle. For this condition, foot length and the distance between calcaneus and 1st metatarsal were the only significant predictors, accounting for 47% of the variance ($p < 0.05$). The absolute error associated with this regression model was 3.8 ± 4.4 mm, which would result in significant error (mean = 14.5%) when estimating muscle forces from joint moments. We conclude that MA_{AT} cannot be accurately predicted from anthropometric measures in children.

1. Introduction

Muscular strength, which can be defined as the maximum torque developed by a muscle group about a joint during a voluntary contraction, increases during childhood (Blimkie, 1989). The mechanisms underpinning the development of age-related gains in muscular strength include neuro-maturation (Savelsbergh, 2003), increases in muscle size (Kanehisa et al., 1995; Morse et al., 2008), changes in muscle architecture (Binzoni et al., 2001) and increases in moment arm length (Wood et al., 2006; Morse et al., 2008; O'Brien et al., 2009).

The moment arm of a muscle–tendon unit is defined as the perpendicular distance between the line of muscle/tendon force action and the rotational centre of the corresponding joint (Spoor and van Leeuwen, 1992). Its measurement is vital for quantifying changes in muscle force production (Wood et al., 2006), where the changing moment arm impacts on joint moment magnitude. In addition, to moment arm length is both an essential parameter in many musculoskeletal models (Delp et al., 1990) and is also used in the calculation of other important parameters such as tendon stiffness and Young's modulus (O'Brien et al., 2010). Muscle moment arms can be obtained using imaging techniques such as magnetic resonance imaging (Spoor and van Leeuwen, 1992; Maganaris et al., 1998; Reeves et al., 2003; Sheehan, 2007), X-ray videofluoroscopy (Baltzopoulos, 1995; Kellis and Baltzopoulos, 1999) and ultrasonography (Ito et al., 2000; Fath et al., 2010). Given that such techniques require specialist knowledge and resources, it is not always feasible for researchers to use them to obtain accurate moment arm lengths. As a result moment arms of various muscles such as the knee or (Kubo et al., 2001) elbow extensors (Kanehisa et al., 1995) have been previously estimated in children by scaling them to surface anthropometry. This practice is based on the assumption that moment arm length scales proportionally with stature or the geometry of the corresponding segments, and that these relationships are constant between children and adults. However, these assumptions have not been explicitly confirmed.

In adults, the strength of the relationship between moment arm length and body anthropometrics depends on the muscle or

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