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Neuromuscular strategies contributing to faster multidirectional agility performance

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ABSTRACT

The aim of this study was to first determine differences in neuromuscular strategy between a faster and slower agility performance, and second compare differences in muscle activation strategy employed when performing two closely executed agility movements. Participants recruited from an elite female basketball team completed an ultrasound to determine quadriceps muscle-cross sectional area; reactive isometric mid-thigh pull to determine the rate of muscle activation, rate of force development, pre-motor time and motor time; and multidirectional agility tests completing two directional changes in response to a visual stimulus. Peak and average relative muscle activation of the rectus femoris, vastus medialis, vastus lateralis, biceps femoris, semitendinosus and gastrocnemius were measured 100 ms prior to heel strike (pre-heel strike) and across stance phase for both directional changes. Faster agility performance was characterized by greater pre-heel strike muscle activity and greater anterior muscle activation during stance phase resulting in greater hip and knee extension increasing propulsive impulse. Differences between directional changes appear to result from processing speed, where a greater delay in refractory times during the second directional change resulted in greater anterior muscle activation, decelerating the body while movement direction was determined.

1. Introduction

Performance during agility maneuvers is determined by an athlete's ability to identify relevant cues within their environment, make the correct decision and rapidly accelerate out of the directional change (Spiteri et al., 2013; Spiteri and Nimphius, 2013). During such a maneuver, efficient neuromuscular control is essential to execute a coordinated motor response through the integration between cortically-programmed and reflex-mediated muscle actions. It is therefore contingent to maintain dynamic restraint during these high velocity dynamic movements (Swanik et al., 2007), reducing the amount of external distractions to produce a faster performance. Compared to closed environment motor skills such as sprinting and change of direction; agility requires greater attentional focus to filter irrelevant information and simultaneously execute a complex motor program (Landers et al., 1985; Swanik et al., 2007). As a result, slower agility performances are often characterized by a subsequent delay in processing speed, resulting in a longer decision-making time, affecting both neuromuscular control and compromising performance outcomes (Dault et al., 2001; Woo et al., 2006).

Producing a faster response to a stimulus when changing direction, can result in muscle pre-activation, which has been shown to protect against injury and increase subsequent movement execution (Bencke and Zebis, 2011; McBride et al., 2008). Increasing preparatory muscle activation through a faster reaction time can increase rate of force development (RFD) and muscular stiffness during the early phase of movement, enabling more force and impulse to be applied throughout the movement (Aagaard, 2003; Aagaard et al., 2002; Sleivert and Taingahue, 2004). Greater force production during both the braking and propulsive phase of agility movements has been observed when athletes produce a faster decision-making time, which subsequently increases exit velocity out of the directional change due to the higher net impulse (Spiteri et al., 2014a). Currently, a majority of research investigating muscle activation strategies during agility movements have situated from an injury prevention perspective, reporting decreased neuromuscular control as a result of insufficient time for the

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central nervous system to implement appropriate postural adjustment strategies (Besier et al., 2001a), and decreased lower body strength reducing the amount of structural support during the movement (Spiteri et al., 2014a). Therefore, it appears both the nervous and muscular systems can influence performance outcomes as a result of insufficient control (Aagaard, 2003; Aagaard et al., 2002; Hakkinen et al., 1998; Narici et al., 1996), however the relative involvement and functional significance of these neuromuscular factors to achieve a faster agility performance has yet to be examined.

Cerebral performance is indirectly measured during reaction time tasks by quantifying the time between stimulus presentation and the onset of movement execution providing a measure of processing speed (Swanik et al., 2007). Reaction time can be further dichotomized into pre-motor and motor time. Pre-motor time is the time between stimulus identification and the onset of electromyographic activity, and is reflective of cognitive processes (Van Donkelaar and Franks, 1991). Motor time is the time between initial muscle activity and movement execution, therefore encompassing electromechanical delay and is often considered to be the neuromuscular component of processing speed (Van Donkelaar and Franks, 1991). Many factors can affect processing speed and movement execution including speed of movement execution, number of response alternatives and location of the stimulus within the visual field (Brisswalter et al., 2002). During competition, athletes are required to perform multiple directional changes in close proximity, which requires a rapid response to successive stimuli to pursue opponents. When responding to two closely spaced stimuli a delay in processing speed is often observed; subsequently termed the psychological refractory period (Knott, 1970). While a delayed response to a stimulus has been shown to compromise performance outcomes, a greater delay in processing speed to a second stimulus may result in a greater decrease in neuromuscular control further affecting performance.

Therefore, the primary purpose of this study was to first quantify differences in decision-making time, pre-motor time, motor time, muscle cross-section area (CSA), RFD and muscle activation strategies between faster and slower agility performances. The second purpose was to compare differences in muscle activation strategies between two closely executed agility movements.

2. Methods

2.1. Participants

Twelve (N = 12) female basketball athletes (age: 24.25 ± 2.55 yrs; height: 177.69 ± 7.25 cm; body mass: 75.56 ± 14.55 kg) playing for a professional basketball team within the Women's National Basketball League (WNBL) in Australia were recruited for this study. All participants were recruited from the same WNBL team consisting of three guards, six forwards and three centers. To be included for participation within the study, participants were required to have played basketball for a minimum of five years and partake in a minimum of one competitive game and two structured skills training sessions each week. All participants were required to be injury free (of the lower limbs) at the time of testing, and report no previous history of major lower limb injuries (e.g. anterior-cruciate ligament injuries). Ethics approval was obtained from the University Human Research Ethics Committee prior to testing and procedures were explained and informed consent was obtained prior to testing. Participants were separated into faster and slower groups based on their total running time achieved during the agility test. Participants above the 50th percentile were assigned to the faster group and those below the 50th percentile were assigned to the slower group, similar to previous research (Spiteri et al., 2013). A priori power analysis was performed using results that allowed detection of a significant difference in quadriceps muscle activity in men and women (Padua et al., 2005). Using G*Power (Faul et al., 2007) for independent means analysis (α = 0.05; β = 0.80; d = 1.54) from previously mentioned results it was determined at least 12 total participants (6 in each group) were required to achieve an actual power of 0.83. Participant characteristics of the faster (n = 6) and slower (n = 6) groups are displayed in Table 1.

2.2. Procedures

2.2.1. Measurement of muscle cross-sectional area (CSA)

Images were captured using a B-mode axial-plane ultrasound machine (Aloka SSD-a 10, 6.1.0, Aloka Co., Ltd., Tokyo, Japan), with a 10 MHz linear-array probe (60-mm width) in extended field of view mode (gain: 79, constraint: 13, sampling frequency: 24 Hz). Participants were instructed to relax their leg and rest in a supine position for 20 min to allow fluid shifts in the lower body to stabilize (Noorkoiv et al., 2010). A continuous single image of the quadriceps was taken from 50% on the line between the greater trochanter and the lateral epicondyle of the femur (Noorkoiv et al., 2010). During the imaging, minimal pressure was applied to the skin to avoid compressing the muscle and transmission gel was used to improve acoustic coupling and image quality (Narici et al., 1996; Noorkoiv et al., 2010). Cross-sectional area of the quadriceps (rectus femoris, vastus lateralis and vastus medialis) of the participant's dominant leg was measured using ImageJ digitising software (1.41, Wayne Rasband, National Institutes of Health, USA), with the average muscle CSA of the three scans used for analysis. Limb dominance or "preferred limb" was defined as the limb that participants used as their preferred takeoff foot when performing a lay-up.

2.2.2. Determination of pre-motor and motor time

Participants were instructed to assume an isometric mid-thigh pull position, with both legs positioned shoulder width apart on the center of a force plate sampling at 2000 Hz (AMTI, BP12001200, Watertown, USA). Hip and knee angles of both legs were positioned at 140° (Haff and Dumke, 2012). Participants were instructed to pull on a bar attached to tension removed adjustable straps, driving their feet into the ground "as hard and as fast as possible" for 5 s, in response to a visual stimulus (light stimulus). The light stimulus was positioned at chest height, 3 m in front of the participant. Participants completed a total of three trials, with a 30-s rest interval between trials. Reliability of this protocol to obtain a measure of peak force was performed in a separate study prior to testing (ICC = 0.88, CV = 3.0%).

Electromyography (EMG) activity of the rectus femoris, vastus medialis, vastus lateralis, biceps femoris, semitendinosus and medial gastrocnemius of the dominant leg was recorded using wireless pre-amplified active surface electrodes sampling at 1000 Hz (Wave Cometa, Milano, Italy). Prior to electrode placement, area was shaved and skin cleaned with alcohol swabs. Two monopolar Ag–AgCl surface electrodes were then placed on the muscle belly in the direction of the muscle fibers, in accordance to SENIAM guidelines (Hermens et al., 2000). All force, EMG signals and timing data was collected and synchronized using Powerlab A/D system (ADInstruments, Colorado Springs, CO, USA) and LabChart 5.0 software (ADInstruments, Colorado Springs, CO, USA). The variables examined include, pre-motor time (ms), motor time (ms), rate of EMG rise (RER) across 30, 50 and 75 ms time intervals for each muscle (Aagaard, 2003), relative RFD across 30, 50, 90 and 100 ms time intervals (Aagaard, 2003), and relative peak force.