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Investigation of Reaction Time Usinga FIGUR8 Sensor Network

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Table of Contents

Introduction

Responding quickly to a visual cue and initiating subsequent motion is key for optimal sporting performance. In overhead throwing sports such as baseball and softball, quick reaction time is essential for activities from fielding to base running. In response to a visual cue like a line drive ball, a signal is sent out from the brain to muscles throughout the body causing each to activate a contraction. The muscles must first contract in order to physically move the skeleton for tasks like running and jumping. Most current assessment methods of reaction time are only able to detect the last step of this process once a subject has executed a large, easily distinguishable starting movement that can be registered by visual analysis with a stopwatch, force plate, or laser-based timing gate. However, there is interest in evaluating the actual efficiency and timing of muscle contraction that is responsible for movement initiation to improve sport performance.

The purpose of this study was to investigate a novel method for evaluating muscle activation reaction time during a dynamic task. This study investigated a sensor network's detection of quadriceps muscle activation and movement initiation during a shuttle run activity. The surface-Mechanomyography (sMMG) component of the sensor system has demonstrated successful detection of muscle activation.[1] Whereas, the inertia measuring unit (IMU) part of the sensor system can be used to assess initial acceleration of body segments corresponding to skeletal movement. Through use of a sensor network with both sMMG and IMU components, the study sought to compare reaction times calculated based on the timing of muscle contraction versus the timing of actual skeletal movement during a task frequently used in sports combine testing.

Study hypotheses included:

1. Detected quadriceps muscle contraction will occur slightly before the start of movement (initial pelvis acceleration) measured during the shuttle run.
2. Faster quadriceps activation times will be associated with faster overall shuttle times.
3. There will be differences between total shuttle run times right compared to the left.

Methods

Participants

Nineteen high school aged softball players (15.1 ± 1.2 yrs) underwent a functional assessment that included 4 shuttle runs (Figure 1). sMMG sensors (FIGUR8 Inc) were applied bilaterally across the largest portion of subjects' quadriceps muscle bulk. An inertia measuring unit (IMU) sensor (FIGUR8 Inc) was applied to the pelvis (representative of center of mass) via a waistband clip. Sensor data was recorded at 50 hz and streamed via Bluetooth Low Energy to a mobile device. A mobile device iOS app simultaneously recorded sensor data and was connected to a time-synced time stamper push-button device (FIGUR8 Inc). The iOS app also emitted a visual flash signal 2 seconds after the start of recording to emulate a visual sporting start cue.

Data Collection Activity: 5-10-5 shuttle run

The subject began standing in the middle of 3 cones each spaced 5 yards apart, facing the tester (Figure 1). Upon a flash visual cue, subjects were instructed to turn and run to the cone 5 yards to their right. Subjects were instructed to break the plane and touch the ground with their hand before reversing direction and sprinting 10 yards to the left. Upon reaching the farthest cone, subjects touched the ground, and then reversed direction to sprint the 5 yards back to the starting point. A time stamper was pressed the instant the subject ran past the starting point to record completion of the activity and the total shuttle run time. Each participant performed two shuttle runs starting to the right and two shuttle runs starting to the left.

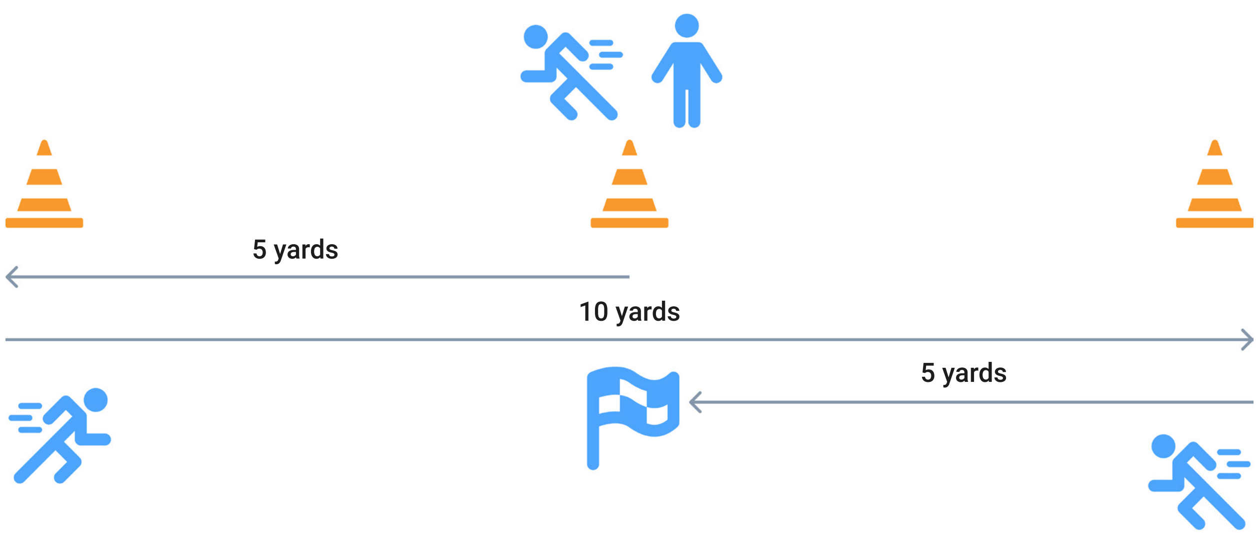

Figure 1. *Depiction of a right shuttle trial. The subject would run for a total of 20 yards for each shuttle, changing directions twice. Left shuttles followed the same procedure, and began in the opposite direction.*

Figure 2. *Example of initial run direction for a left shuttle (left) and a right shuttle (right) both starting from a neutral starting position (center). Note that right shuttles require initial ground push-off from the left leg, and left shuttles require initial push-off from the right leg.*

Data Analyses

The total time to complete each shuttle trial was recorded using a time stamper that was timesynced with the sensor network. Reaction time, or the time required for the subject to respond to the visual start cue was assessed via 2 methodologies. The first peak in accelerometer data from the sensor applied to the pelvis (approximate center of mass) was used to identify when the subject began to initiate lower extremity translational movement (start of movement). The time of initial deviation from baseline of the quadriceps muscle for the first leg to push-off the ground of each trial was used to identify the time point of initial quadriceps contraction required for push-off to initiate sprinting. Time of muscle activation and start of movement were calculated relative to the time of the flash start cue. The flash cue was automatically initiated 2 seconds after the beginning of sensor recording. Paired T-tests and Pearson correlation statistical analyses were performed with the level of statistical significance established at $p<0.05$.

Results

There was a significant difference in the fastest overall quadriceps activation time (0.333 ± 0.076 s) and fastest start of movement time (0.469 ± 0.104 s) across all subjects ($p<0.001$). Start of movement time was slightly more correlated with overall shuttle time for all trials ($r=0.349$, $p=0.001$) compared to quadriceps activation time ($r=0.212$, $p=0.052$). The mean time difference between quadriceps activation and start of movement was

0.141 ± 0.128 s and 0.149 ± 0.117 s for all left and right shuttle runs respectively, with detection of quadriceps activation occurring prior to detection of start of movement on average. No significant differences were observed for either the fastest quadriceps activation times (p=0.258) or fastest start of movement times (p=0.919) between shuttle runs beginning to the right compared to those beginning to the left. There were no significant differences in fastest quadriceps activation times between trials beginning with push-off from the dominant versus non-dominant limbs (p=0.910). Average quadriceps activation and start of movement times for all right and left shuttle runs are displayed in Table 1.

An analysis was performed to see if the fastest quadriceps activation time for a subject corresponded to the subject's fastest total shuttle time. 50% of the time this result was found to be true, while 80% of the time the quickest quadriceps activation corresponded to either the 1st or 2nd fastest shuttle for each subject.

Table 1: *Average time values for shuttle runs beginning to the left and the right for all subjects.*

Measurement	Left Shuttle	Right Shuttle
Total Shuttle Time(s)	6.450 ± 0.460	6.421 ± 0.529
Start of Movement Time(s)	0.585 ± 0.202	0.568 ± 0.137
Quadriceps Activation Time(s)	0.43 ± 0.112	0.39 ± 0.116
Average Quadriceps Reaction Time/Total Shuttle Time (%)	6.62% ± 1.7%	6.13% ± 1.7%

Conclusions

Use of a sensor network to examine two methodologies for calculation of reaction time were successful. Study findings confirmed sensor network ability to simultaneously evaluate muscle activation and movement initiation during a common agility and athletic screening task. Use of a sensor network with both sMMG and IMU components facilitated a unique look into multiple factors possibly influencing overall shuttle performance. Evaluation of study hypotheses help to confirm the validity of sensor network calculations and suggest possible utility for future clinical and sports performance applications.

Study results support the first hypothesis that muscle contraction will occur before skeletal body movement. Our findings reveal that, on average, the quadriceps muscle of the first push-off leg begins to contract 0.145 ± 0.122 seconds before the pelvis begins to accelerate. Results are consistent with physiological expectations that concentric quadriceps contraction is necessary for initiation of ground push-off prior to the subject beginning to demonstrate forward movement. The alignment of study findings with physiological expectations increases confidence in successful sMMG sensor detection of quadriceps muscle contraction. However, subjects leaning or shifting their center of mass to begin the shuttle run could serve as a confounding factor. The difference in timing between the two methodologies for assessing reaction time is expected and represents two potential sites for assessment and intervention to optimize shuttle performance: 1) the time required to engage muscle groups and 2) the time required to coordinate and initiate forward movement.

Study findings also partially support the second hypothesis that a shorter reaction time results in a faster shuttle time. Eighty percent of all trials were consistent with the idea that the fastest quadriceps reaction time was associated with a subject's first or second fastest shuttle run. Other factors including consistent subject effort across trials and human error in timestamping fast movements could also play a role in these results.

In this study sample, limb dominance and shuttle direction does not appear to significantly influence shuttle reaction or total time, further suggesting that other biomechanics in addition to reaction time may play a major role in dictating overall shuttle performance. While reaction time is associated overall shuttle time, the study results may be due to variation in biomechanical techniques such as body posture and initial step positioning. Shuttle motion elements like inefficient turning may be disguising a more direct relationship between reaction time and total shuttle time.

This study supports the use of a FIGUR8 sensor network for providing quantitative information on neuromuscular control in fast reaction situations. Reaction time, a key indicator of neuromuscular control, is important to clinicians and coaches for injury prevention and rehabilitation assessment. In particular, for fast-paced sports like softball and baseball the time to which a muscle is activated relative to when movement occurs is important. The FIGUR8 platform's capability to assess both measures of reaction time evaluated in this study could be key for agility performance improvements. For training purposes, a FIGUR8 sensor network could provide feedback to improve the efficiency of muscle activation and movement initiation biomechanical patterns. Coaches and trainers may benefit from this technology to monitor and provide feedback to their athletes during commonly repeated movements (ie. running the bases) or game situations that require fast reactions (ie. fielding) to optimize performance.

References

1. Linderman S, Scarborough DM, Eckert MC, Berkson EM, Gong N. Wearable Contour Sensors to Assess Neuromuscular Control During Repeated Unilateral Partial Squat Task. 31 May. 2018. Poster session at American College of Sports Medicine Annual Meeting, Minneapolis, MN.

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