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PRACTICAL APPLICATIONS AND FUTURE DIRECTIONS OF ELECTROMYOGRAPHY USE IN TACTICAL POPULATIONS

INTRODUCTION

Tactical personnel perform unique movements while on the job. To initiate movement in the body, the brain sends an electrical signal to the spinal cord (via neurons), which discharges an action potential and creates a muscle contraction. When the contraction of the muscles is sufficient, they pull on the bony landmarks to which they are attached (typically via tendons), and movement is generated. When an individual wants to produce more force (e.g., when lifting a heavier load), motor neurons discharge action potentials more rapidly or activate additional motor units (24). The size principle is in effect where the smallest motor units are recruited first, eventually leading to the recruitment of the largest motor units (24). This recruitment pattern should lead to greater muscular force production (15). The summed action potentials result in muscle activation that can be measured via electromyography (EMG).

EMG measures the electrical signals from the action potentials of motor units (15). This involves the use of specific sensors being placed on, or within, certain muscles to determine the amount of electrical activity that occurs during movement. EMG research is useful to the tactical facilitator in several ways, including allowing to measure the following (13,15):

- Technique analysis by illustrating the sequence and magnitude of muscle activation and how contributions can vary between different muscles.
- The relationship between muscle activation and force output within a specific movement.
- Changes in muscle activation over time due to treatment or training.
- Fatigue during a particular movement.

More recently, EMG data have been used to infer physiological training load during exercise (9). Numerous publications have outlined the science behind EMG data analysis and best practice for data collection (10,33). Therefore, this article will review EMG procedures as well as provide examples of how EMG data analysis has been used in tactical populations. Lastly, the use of EMG for the extrapolation of training load in tactical populations will be discussed.

EMG MEASUREMENT METHODS

There are two primary EMG methods that have been used in the scientific literature; intramuscular EMG and surface EMG (sEMG). Intramuscular EMG is invasive and requires fine wire or needle electrodes to be inserted into the muscle by trained personnel. These methods are often used to assess individuals that have neurological disorders, but due to their nature can restrict movement (25). Accordingly, sEMG tends to be more practical and common among strength and conditioning practitioners who wish to measure muscle activation. The sEMG process involves electrodes being placed appropriately on the skin surface above the muscles of interest (13). These electrodes can then measure the electrical activity occurring in the muscles below the skin surface.

There are limitations associated with sEMG use, which the tactical facilitator should note (15). Incorrect electrode placement can result in crosstalk, which is where muscles other than the muscle of interest contribute to the electrical signal. Other tissues, such as subcutaneous fat, can also affect the electrical signal received from the muscle by the sEMG sensor by acting as a barrier. Deeper muscles cannot be measured by sEMG, so the analysis is limited to surface muscles (e.g., the deltoids, rather than the muscles in the rotator cuff). Additionally, sEMG data cannot discriminate between the types of muscle fibers being recruited (e.g., Type I versus Type II fibers). Nonetheless, within the context of these limitations, tactical facilitators can elicit a lot of useful information from sEMG data.

TACTICAL TASKS AND sEMG

Numerous studies have used sEMG to measure muscle activation and tactical tasks. The investigations have often centered on the analysis of specific movements for a particular tactical population, the effects of equipment and load carriage, and how this could affect performance and ergonomic design. Although it is outside the scope of this article to analyze all tactical population research

FIGURE 1. EXAMPLE OF SEMG SIGNAL

that has utilized sEMG analysis, specific examples for police, firefighter, and military personnel will be presented. These will demonstrate the practical application for sEMG in tactical populations, and help govern why future research in this topic is required, especially for evidence-based-applications.

Load carriage is a necessary challenge for most tactical populations (14). In Royal Marine recruits, marching with a load of 35.5 kg (78.3 lb) led to an increase in maximum vastus lateralis amplitude ($p = 0.004$, moderate effect size = 0.66) relative to unloaded walking (27). Rice et al. further asserted this change in activity was linked to the greater eccentric work required during stance when under load (27). Additionally, Rice et al. noted that the significant increase ($p < 0.001$, moderate effect size = 0.70) in gastrocnemius lateralis activity was necessary during push-off to overcome the greater external load while walking (27). Army-issue footwear can also influence muscle activation for soldiers, and this could contribute to stress-related injuries (28). Schulze et al. found that in German soldiers, combat boots increased peak muscle activity in the rectus femoris and tibialis anterior relative to barefoot walking, by greater than 40% and approximately 10%, respectively (28). It was postulated by Schulze et al. that these changes in muscle activity could be linked to patellofemoral pain and shin splints (2,26,28).

Szasz et al. used sEMG to highlight limitations in the two-minute sit-up test (part of the Army Physical Fitness Test [APFT]) performed by Reserve Officer Training Corps (ROTC) cadets (31). The data indicated that the activity of the hip flexors (rectus femoris) increased to a greater extent than the abdominals (rectus abdominus) over the progression of the two minutes. Due to the greater increase of hip flexor activity, Szasz et al. suggested that the two-minute sit-up test may not be a valid assessment of abdominal endurance (31). This is noteworthy, especially considering the United States Army's shift to the new Army Combat Fitness Test that does not include sit-ups (32). The measurement of sEMG during basic training could be of great value for the tactical facilitator, especially if it can provide some measure of the training load being experienced by the tactical athletes (9).

Specific to training, Lane et al. compared the performance of 13 firefighters in the Candidate Physical Ability Test (CPAT) to traditional weightlifting exercises (18). The CPAT incorporates eight tasks, which have been described in detail by Sheaff et al. (29). Briefly, the tasks include a stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry with a sledgehammer, crawl through a tunnel maze, body drag, and ceiling breach and pull. The resistance training exercises consist of the back squat, Romanian deadlift, overhead press, bent-over row, banded Romanian deadlift, glute hyperextension, and kneeling rotational throw. Each exercise was performed for one set of 10 repetitions. Lane et al. found there were no differences between the weight training exercises and CPAT in the sEMG recorded from the deltoid, trapezius, lumbar multifidus, gluteal, and biceps femoris (18). However, activation of the abdominal obliques was significantly higher in the CPAT tasks compared to the resistance training exercises. This led Lane et al. to suggest that exercises targeting the abdominal obliques should be incorporated into the training for firefighters (18). This article highlights the value of using sEMG to measure the muscle's response during training activities for tactical populations.

Police work can feature a high amount of sedentary activity, (e.g., seated in a car during patrol) (1). This has led to the use of sEMG to analyze the stress experienced in upper-body muscles (e.g., trapezius, deltoids, supraspinatus, infraspinatus, triceps brachii, biceps brachii) when using a mobile data terminal in a police cruiser (20,21). A simulated environment was used in both of these studies. McKinnon et al. detailed that a self-selected mobile data terminal positioning within the police cruiser led to a significant ($p < 0.001$) reduction in muscle activity measured as a percentage of maximal voluntary isometric contraction (MVIC) for the posterior deltoid (up to 1.6%) and supraspinatus (up to 3.1%) compared to set positioning (20). This change in muscle activity was associated with a 68% reduction in perceived discomfort measured by a visual analogue scale. Utilizing similar procedures in a different study, McKinnon et al. also found up to 3.4% decreases in shoulder muscle activity (e.g., left anterior and middle deltoid, right middle deltoid, infraspinatus, and supraspinatus) that contributed to a 55 – 65% reduction in perceived shoulder discomfort (21). dos Santos et al. analyzed the effects of wearing bulletproof vests on male Brazilian military police (11). This involved measuring a trunk extension maximal voluntary isometric contraction (MVIC) prior to and after two 12-hr shifts with a 24-hr break in between. The results indicated there was a 1.4% reduction of the sEMG median value relative to MVIC in the right rectus abdominus—the side of the body where most officers carried their primary weapon. dos Santos et al. linked these results to fatigue of the muscles on the right side of the body as a result of the load carriage, which has potential implications on low back pain (11). This is important, given the propensity for officers to report low back pain (19). Further applications could include the use of sEMG equipment that could be used while an officer is on-duty, thereby illustrating the muscle activation changes that could occur with the onset of fatigue.

sEMG AS A MEASURE OF TRAINING LOAD

Wearable technology has rapidly increased in popularity, and there are many different devices that can measure a range of physiological responses to physical activity (23). For example, recent research analyzing the sEMG wearable technology (compression garments with built-in sensors) concluded that the measure of training load provided did indicate fatigue during exercises, such as running or cycling (3,4). For example, Balfany et al. observed changes in the quadriceps training load across

FIGURE 2A. MANUAL MUSCLE TESTING FOR THE QUADRICEPS

FIGURE 2B. MANUAL MUSCLE TESTING FOR THE HAMSTRINGS

FIGURE 2C. MANUAL MUSCLE TESTING FOR THE GLUTEALS

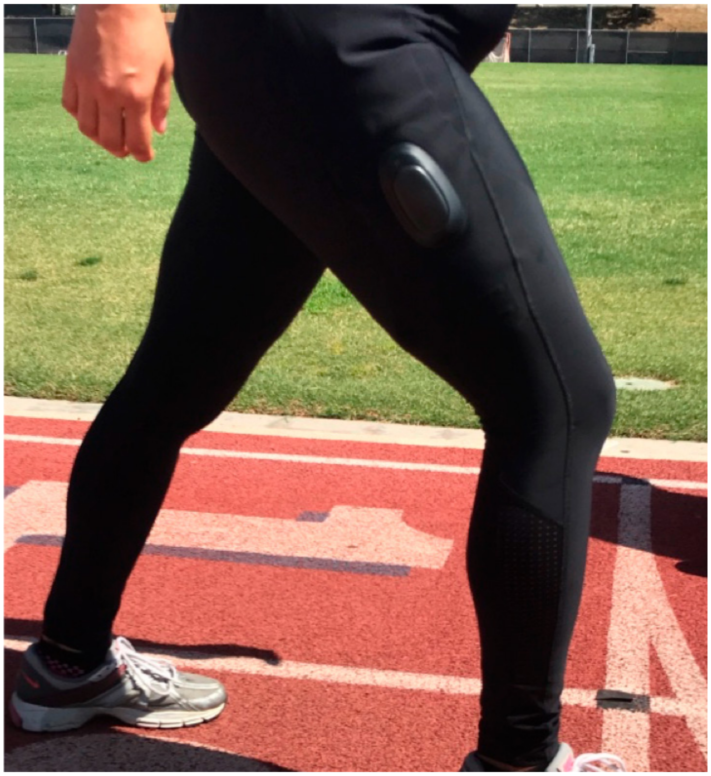

FIGURE 3. EXAMPLE OF LEGGINGS WITH SEMG WEARABLE TECHNOLOGY

a fatiguing exercise, indicating modifications in the muscles contributing to the performance of movement and potential shifts in movement strategy (4). In tactical populations, a greater understanding of the muscle's response to fatigue could deliver insights into an individual's ability to handle the stressors of physical training, work tasks, and/or compensatory muscle strategies adopted (whether consciously or subconsciously) to complete work tasks despite fatigue. Particularly in tactical populations who experience repetitive stress injuries, insights regarding an individual's ability to respond and adapt to external stressors could influence training modalities, equipment, or mechanisms for performing work-specific tasks (12).

When considering implementation and observation of muscle activation within tactical populations, the potential for utilizing wearable technology with sEMG measures could offer acute and longitudinal insights into an individual's muscle stress response to external loads. Additionally, wearable technology fulfills the non-invasive ease of use via compression garments, commonly worn by active populations for ergogenic benefits, while providing valuable data into the physiological response to external stressors (6).

FUTURE DIRECTIONS

There are several future directions for research involving sEMG analysis specific to tactical populations. There has been some research in this area for firefighters (30,34) and police (11,20,21), but more detailed investigations are required, especially as it pertains to movement efficiency and safety for personnel. This is notable for police, as even though officers tend to carry a lighter load compared to soldiers and firefighters, the location of the load may be different (e.g., via a duty belt) (5). Previous research has suggested that the location of the duty belt load may not adversely influence pathologies such as low back pain, but this research was conducted nearly 20 years ago (7). Importantly, the load carriage requirements of tactical personnel have tended to increase over the years, which demands further analysis of the muscular demands of these tasks (8).

Future research should investigate the use of wearable technology that incorporates sEMG to provide a measure of training load, as this could have a great practical use to tactical personnel. This equipment could be worn under training uniforms of physical training sessions to indicate the load being experienced by a recruit or cadet. As long as research documents the validity and reliability of this technology, this could provide very useful information as studies that have linked an inappropriate application of load and injury risk in tactical populations (16,17,22). The use of sEMG wearable technology could have applications in police, firefighter, and military personnel. If the validity and reliability of sEMG wearable technology can be detailed, tactical populations could use this equipment to measure the demands associated with work-related tasks.

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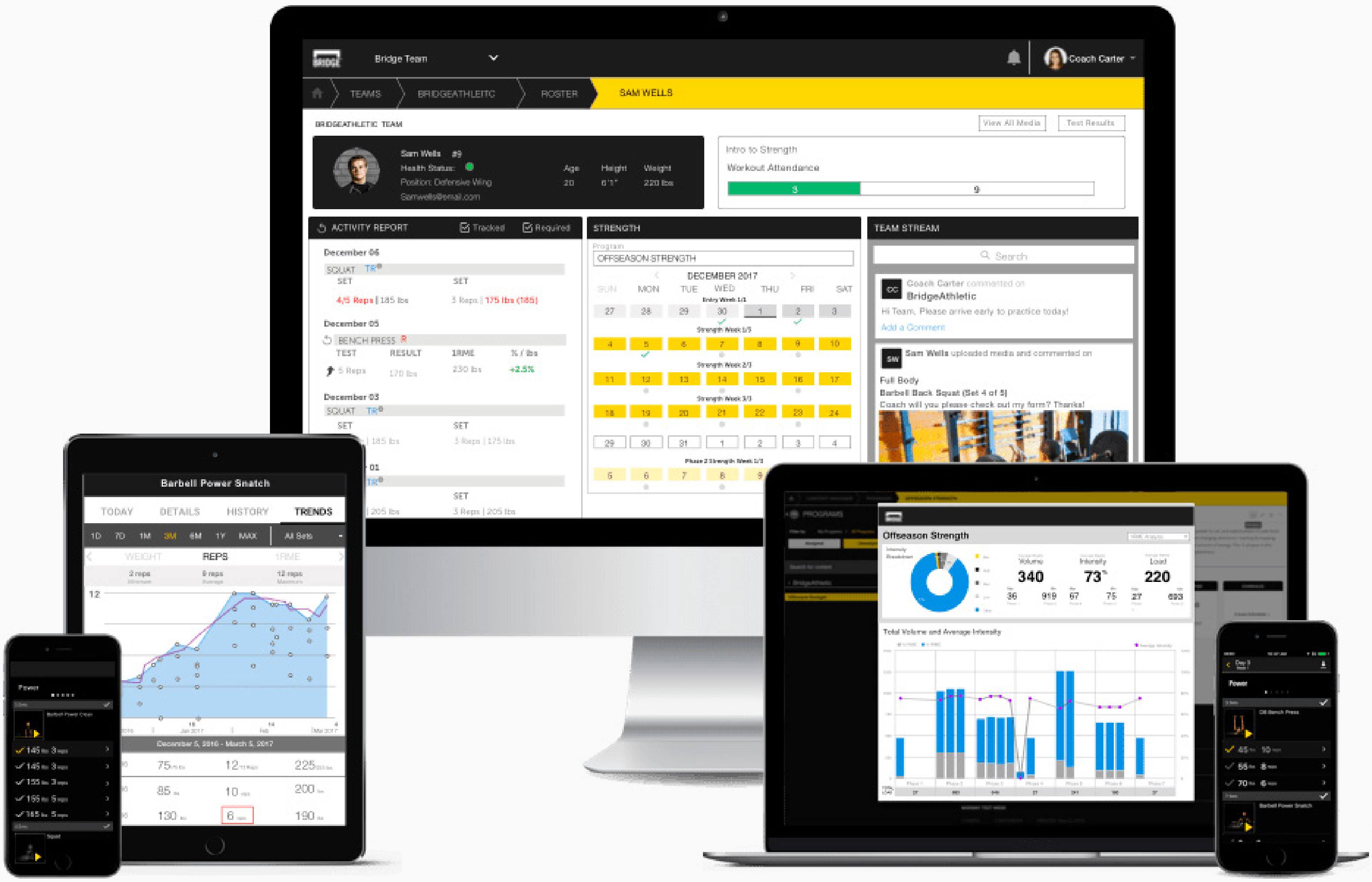

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