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The practical use of surface electromyography during running: does the evidence support the hype? A narrative review

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ABSTRACT

Background/aims: Surface electromyography (sEMG) is a commonly used technique to investigate muscle activation and fatigue, which is non-invasive and can allow for continuous measurement. Systematic research on the use of sEMG in the sporting environment has been on-going for many years and predominantly based on cycling and rowing activities. To date there have been no reviews assessing the validity and reliability in sEMG exclusively in running activities specifically during on-field testing. The purpose of this review is to evaluate the use of sEMG in the practical context and whether this be translated to on-field testing.
Methods: Electronic literature searches were performed using the Cochrane Library, PUBMED, CINAHL and PeDro without restrictions on the study date to identify the relevant current English language literature.
Results: 10 studies were relevant after title and content review. All the studies identified were all level three evidence based. The general trends of the sEMG activity appear to correlate with running velocity and muscle fatigue seems almost always the consequence of prolonged, dynamic activity. However, these changes are not consistently measured or statistically significant throughout the studies raising the question of the accuracy and reliability when analysing sEMG measurements and making assumptions about the cause of fatigue.
Conclusions: An agreed consensus when measuring and analysing sEMG data during running activities particularly in field testing with the most appropriate study design and reliable methodology is yet to be determined and further studies are required.

What is known

- Surface electromyography (sEMG) is widely used in the sporting environment to assess for muscle fatigue.
- A number of methods and techniques are available to measure changes in EMG signals.

What this review adds

- This is the first review of the use of sEMG exclusively to running exercises with on-field testing.
- Multiple techniques and methods are being used with inconsistent results.
- Caution is required when interpreting the reliability of the recorded results.
- Further research is necessary.

INTRODUCTION

Muscle surface electromyography (sEMG) is a commonly used technique for measuring muscle activation. Systematic research on the use of sEMG in the sporting environment has been on-going for many years[1] and predominantly based on cycling activities.[2] To date there have been no reviews assessing the validity and reliability in sEMG exclusively in running activities. The purpose of this review is to evaluate the use of sEMG in the practical context and whether this can be translated to on-field testing.

EMG has been increasingly used to investigate muscle activity and fatigue as this is non-invasive and can allow for continuous measurement. By investigating changes occurring in the EMG signal, muscle activation can be inferred by certain EMG signal changes; either in the time and/or amplitude of the EMG signal or in frequency domains.[3] A number of parameters have been used to investigate changes in the amplitude and frequency domains of the EMG signal. These include mean and median frequency to investigate changes in the frequency spectrum of the EMG signal as well as root mean square and integrated EMG to determine amplitude changes.[4] Muscle fatigue developed during isometric contractions increases the EMG signal amplitude and the power spectrum towards lower frequencies.[5–7]

Surface v fine wire EMG

EMG can be categorised into either surface or fine wire. Fine wire EMG (fEMG) involves placing electrodes and recording electrical activity intramuscularly, whereas sEMG measures the electrical signal of the muscle recorded from the surface of the skin overlying the muscle. Intramuscular recording of muscle electrical activity using fEMG is appropriate for the study of the physiology and pathology of individual motor units, whereas sEMG is better suited for investigation of the temporal pattern of activity and fatigue of whole muscles or muscle groups.[8] sEMG is non-invasive making it is more appropriate than fine wire in the sporting environment. This may minimise discomfort, risk of infection, and allows for frequent and even live repetition of assessments. Various types of expensive sEMG measuring equipment have been developed often without clarity of their exact use or reliability during on field-testing. This is a review of sEMG activity literature related exclusively to running exercises.

METHODS

Electronic literature searches were performed using the Cochrane Library, PUBMED, CINAHL and PeDro without restrictions on the study date to identify the relevant current English language literature. One reviewer (RW) conducted the literature search and retrieved the abstracts. The methodological quality of the studies included and the abstracts of the reviews identified using this search were inspected by two authors (RW, RS). Those meeting the inclusion criteria were retrieved and read in full. A low number of studies relevant to the research question were identified.

The inclusion criteria and related MeSH terms searched were adult human studies, athletes, running, sport, exercise, endurance, exhaustion, fatigue, training, fitness, track, treadmill testing, EMG and sEMG. Exclusion criteria included cycling, rowing, static, resistance, isometric, concentric, eccentric and isokinetic exercises. Fifty-five papers were identified from PubMed. Ten studies were relevant after title and content review. Key words included runner, run, sport, exercise, endurance, fatigue, exhaustion, treadmill, training, fitness, fit long distance, EMG and surface EMG. The outcome measures included impulse, electrical potential, muscle motor unit, motor unit action potential, electrophysiological activity, EMG signal and mean power frequency.

RESULTS

Two reviewers (RW and RS) independently identified studies to be included in the review, with no disagreements. Fifty-five papers were identified. Following application of the inclusion criteria, 10 studies were found to be eligible for appraisal. Using the Oxford Centre of Evidence-Based Medicine, all the studies identified were of levels 3a and 3b.

CRITICAL APPRAISAL

The Critical Appraisal Skills Program for cohort studies was used to review all the studies.[9 10] Study design, methods and outcomes were extracted and tabulated in online supplementary table provided. All studies included running activities with participants being athletes and football players at a professional and amateur level. Running activities varied between each study with athletes being tested on different surfaces ranging from outdoor to indoor track surfaces over varying distances. The studies all measured different muscles groups in the lower limb using surface electrodes placed at different points on each muscle. One study included muscles of the foot and only two studies investigated both legs. All participants in each study were deemed physically fit at the time of testing with no associated injuries. The number of participants in each study was low with the mean number of 9.5 with sample sizes ranging from 4 to 19.

DISCUSSION

From the results outlined in this review, sEMG appears to provide inconsistent results when assessing neuromuscular activity during running. The general trends of the sEMG activity appear to correlate with running velocity and muscle fatigue seems almost always the consequence of prolonged, dynamic activity. However, these changes are not consistently measured or statistically significant throughout the studies raising the question of the accuracy and reliability when analysing sEMG measurements and making assumptions about the cause of fatigue.

Owing to the varying descriptive methodology of each study the results merely indicate that a pattern seems to exist when using sEMG measurements during different running exercises. With each study using participants of different capabilities at different times of the day with different technical equipment, the interpretation of sEMG data and comparison of findings between the different studies becomes very challenging, unreliable and statistically insignificant.

With regards to study design, a clear distinction should be made between running surfaces and the neuromuscular activity should be differentiated depending on whether the context allows changes in velocity and direction (eg, running on a track) or controlled speed and direction (eg, treadmill testing and gradient). Each treadmill study varied in terms of speed and gradient. Only four studies were identified with on-field testing, further indicating the difficulties in the practical and analytical use of this equipment

Responses may differ between muscles groups in each leg and the consideration of stride frequency with an increase in speed or onset of fatigue is a vital part of the assessment of muscular fatigue.[3] These are not consistently measured throughout each of these papers. Each study measures different muscle groups in the lower limb with no consistency in using both legs; only 2 of the 10 studies used both legs. Guidelines are available for the placement and preparation of the surface electrodes[11 12]; these are inconsistently followed in each paper; with recording failure and electrode connections frequently problematic. When interpreting results, the analysis must take into consideration the 'cross-talk' effect of detecting signals form more than one muscle leading to inaccurate signals. These differences and complications make comparable interpretation of data extremely difficult with questionable accuracy and reliability when interpreting results. The results further suggest that muscles may fatigue at different thresholds seen by decreasing, minimal or no sEMG activity, which may depend on athlete calibre, certain local muscle measurements, velocity, distance, mechanism and origin of the onset of fatigue, whether peripheral or central. This is inconsistently tested, measured and remains poorly understood in the literature.

The low number of studies identified reflects the logistical challenges of study methods involving participants running, particularly during field testing, the cost of expensive sEMG equipment, the rapid changes in technology of the equipment over the past 30 years and complexity of accurate analysis. Given the potential impact of previous injury on sEMG response, which is not clear in these studies, it seems prudent to initially measure uninjured legs, on a standardised flat surface while running in straight lines. Both limbs and major muscle groups would need to be measured with greater detail on each participant, such as measurements of muscle mass/volume, fitness for example, VO2 max or lactate threshold to account for confounders and bias.

These confounding factors make the measurement and mathematical analysis very challenging, leading to potentially inaccurate or false results. The low number of participants in each study makes them significantly underpowered. Furthermore, a very high number of participants are required to achieve sufficient power for conclusions to be made and this may restrict future research. These limitations make it difficult to determine fatigue measurements and have a relatively high risk of selection bias. No general consensus on a reliable and comparable methodology or optimal statistical analysis for assessing and analysing sEMG activity exists.

SUMMARY

Despite the commercial applications and use of expensive sEMG equipment in the sporting environment, there are many important limitations with this technique when it is used during running. The variety of methods and equipment for processing sEMG data limits the ability to interpret and compare data. sEMG measurements seem to demonstrate inconsistent, non-statistical changes in lower limb sEMG activity and much larger cohorts of athletes must be studied with comparable sEMG methods and statistical analysis to produce more reliable and valid results. This may be difficult to achieve in practice, especially when investigators wish to include professional athletes.

There is currently no consensus on how to measure and analyse the sEMG data produced during running activities. This technique may have the potential to predict fatigue, recovery and prevent injury but until these limitations are addressed and results better understood the commercial application of sEMG remains uncertain in this context.

Contributors All authors stated contributed to data collection, analysis and interpretation. RW initiated the idea and performed the first review of the literature with initial tabulated rests. RS performed another literature review and tabulated further results with analysis and write-up of the results providing concise discussion and conclusions. GW reviewed the tabulated results and provided further analysis of results.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

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