Contraction speed influence the neural activation of m. Tibialis Anterior during submaximal dynamic contractions

Anders Juul Christensen[a], Simon Spanggaard Kristoffersen[b]

[ab] *Aalborg University, Sports-science, 10th Semester, June. 2020*

Abstract:

BACKGROUND AND AIM: It is well understood that neural strategies considerably differ when performing eccentric contractions compared to both concentric and isometric contractions. Most studies indicate a lowered EMG amplitude when performing maximal eccentric contractions than maximal concentric contraction. Consequently, there is a reduction of the fine motor control in eccentric force production. This implicates that fine control of eccentric movements are more difficult as fewer motor-units are involved. Several studies have demonstrated that type II (fast) muscle fibers are more prone to strain injury than type I (slow) muscle fibers. Neale et al, 2018, concludes that there is an increasing reliance on the fast-twitch fibers when contractions are performed at high-speeds. However, little is known about the influence of contraction speed, including different types of contractions (eccentric & concentric) when performing dynamic bouts with controlled speed and load. Therefor this study aimed to investigate effects of contraction speed on the amplitude and barycenter of EMG signals recorded at different contraction types and ranges of motion, using high-density surface EMG.

METHODS: Eleven healthy men (age; 26,4±4,2. height; 183,1cm±12,9; weight; 85,9kg±12,9) performed bouts of dynamic ankle dorsiflexion contractions in a dynamometer. Dynamic contractions were performed with two different contraction speeds: 5°/s and 20°/s. Both contractions were performed with 10% and 25% of their submaximal MVC. Two HD-sEMG 64 channel, matrices (i.e.d. 8mm) were placed over the m. tibialis anterior. The RMS value was calculated by normalizing to the lower isometric phase of the contraction, and the Barycenter position of RMS was tracked throughout the dynamic contractions. The dynamic contractions were divided in two phases, concentric and eccentric phase. A three-way ANOVA was used to test for statistical significance.

RESULTS: During dynamic contractions at 25% of MVC, the RMS differ significantly between the two speeds (,05>p; p=,036; F=4,521). The interaction between the factors; contraction speed and contraction type, were also significant in terms of the RMS (p=,003; F= 9,935), however the 10% intensity did not reveal a significant change in this interaction. The interaction between the position of the muscle (i.e. Lengthened, middle and shortened) and the contraction speed was significant in both in intensities (10%; p=,000; F =12,613) (25%; p=,000; F=13,373). The changes in the barycenter was significantly different in terms of the position (10%; p=,000; F= 24,103) (25%; p=,044; F 3,200). The contraction type showed a significant difference in 10% (p=,022; F=5,352). No interactions between the factors was significant.

CONCLUSIONS: An increase in contraction speed will affect the neural recruitment depending on the range of motion and contraction type. It was discovered that a more lengthened muscle requires lower neural recruitment during a low-speed contraction regardless of the contraction type. However, an increase in speed did not change the spatial distribution of neural activity, indicating that the CNS maintains the recruitment pattern for dorsiflexion despite substantial changes in EMG amplitude.

Keywords; Isometric; Dynamic; HDSEMG; Contraction Speed

Introduction

It is well understood that neural strategies considerably differ when performing eccentric contractions compared to both concentric and isometric contractions using surface electromyography (sEMG). Most studies indicate a lowered EMG amplitude when performing maximal eccentric contractions than maximal concentric contraction. (Hody et al, 2019; Kallio et al, 2013; Moritani et al, 1987) Consequently, there is a reduction of the fine motor control in eccentric force production. This implicates that fine control of eccentric movements are more difficult as fewer motor-units are involved. (Hoppeler et al, 2016).

The movement of muscles can be divided into three different types of contractions; Concentric (muscles are shortened), Eccentric (muscles are elongated) and Isometric (muscles are activated but maintain the same length) (Marri K et al, 2016; Søgaard K, 1995). Studies have furthermore suggested that muscular injuries are affected by the contraction type. Injuries in sports is a common phenomenon, where a typical injury is muscle strains (Liu et al, 20112). A muscle strain primarily occurs due to eccentric contractions. Moreover, it can be affected by the muscle strength and contraction speed (Liu et al, 20112). This indicates that intensity, contraction speed and contraction type are all variables, which affects the risk factor for a muscle strain (Liu et al, 20112). The argument that contraction speed affects the risk of a muscle strain, has been proved throughout several studies, which demonstrated that type II (fast twitch) muscle fibers are more prone to strain injury than type I (slow twitch) muscle fibers. (Liu et al, 2012). Neale et al, 2018, concludes that there is an increasing reliance on the fast-twitch fibers when contractions are performed at high-speeds. This indicates that faster contraction speeds, may increase the chance of a muscle strain injury.

The study of isometric contractions is well acknowledged in the literature(Søgaard K, 1995; Kallio et al, 2013; Holobar A & Glaser V, 2018), however dynamic contractions are more translatable to everyday activities (Marri K et al, 2016; Nurhazimah N, 2016), but has not been investigated as much as the isometric condition (Farina D, 2006). This is due to challenges in interpreting bipolar sEMG signals in dynamic conditions. These challenges are caused by three main factors; the nonstationarity of the signals, electrode shift, and the changes in conductivity properties of the tissue that separates the electrodes and muscle fibers (Farina D, 2006). These challenges can be solved using high-density surface electromyography (HD-sEMG) which has the potential of adding up to hundreds of electrodes and cover a larger area of the muscle - thus establishing a spatial representation of muscular activity in a two dimensional space (Negro et al, 2016). With this spatial representation it is possible to identify and track a barycenter of muscle activity (Farina et al, 2008). A barycenter is a centroid location of the distribution of the root mean squared (RMS) amplitude of muscle activity. (Hamilton et al, 2018) RMS barycenter can be used to investigate whether changes in the motor unit recruitment or de-recruitment occurs or remains the same, by examining the spatial distribution of motor units in the muscle. (Samani A. et al, 2016). A shift in the barycenter may also imply heterogeneous muscle activation during dynamic contractions (Gallina & Botter, 2013). Studies have investigated the RMS barycenter shift in upper trapezius in sustained isometric contractions. Farina et al, 2008 concluded that the subjects with the largest shift in activity, could sustain the isometric contraction the longest amount of time. This leads to the assumption that a higher recruitment pattern is sufficient to avoid fatigue (Farina et al, 2008). Therefore, the analysis of RMS and its barycenter might give insights about risk factors, that causes a muscle strain.

The muscle length is an interesting factor when investigating the neural behaviour of muscles during dynamic contractions. Previous studies on dynamic contractions using sEMG, have divided the contractions

into phases depending on the joint angle. They reported that the normalized root mean square (RMS) increases significantly during concentric contraction, with no significant changes in the eccentric contraction. (Oliveira F, et al 2009; Potvin J, 1997). The contraction speed is another interesting factor, even though it has been reported that the contraction speed did not reveal any effects on muscle architecture in m. Tibialis Anterior, when examined with ultrasound imaging. (Reeves et al, 2013; Chino et al, 2009). However, there is a limited number of studies about contraction speed when examined with sEMG. This might be due the difficulties of recording bipolar sEMG during dynamic contractions, reasoned by the nonlinear motor unit firing, recruitment pattern and synchronisation of motor units (Farina D, 2006) (Marri K et al, 2016). Although, a comparison between concentric and eccentric contractions has been established in earlier research, there is an assumption that the faster the contraction, the eccentric contraction utilizes more on the fast twitch fibers, who are more prone to muscle strains. (Liu et al, 2012; Neale et al, 2018) The aim of this study is to investigate effects of contraction speed on the amplitude and barycenter of EMG signals recorded at different contraction types and ranges of motion, using high-density surface EMG.

Methods

Eleven healthy physical active men (age; 26,4±4,2. height; 183,1cm±12,9; weight; 85,9kg±12,9) participated in this study. The subjects with no previous lower limb injuries provided written informed consent. Subjects were requested not to ingest anti-inflammatory drugs or nutritional supplements, and not to perform unaccustomed exercise five days prior to the experiment. Subjects all had no pain/soreness before the first trial, to ensure optimal conditions.
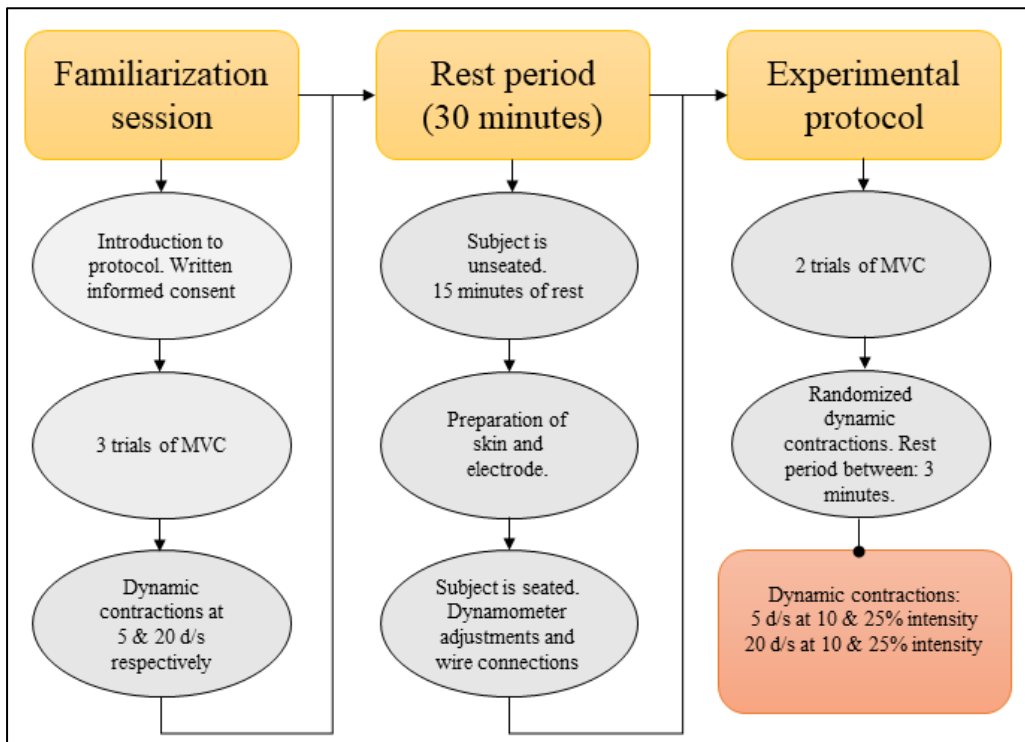
Figure 1, full overview of the experimental period.

The experimental protocol consisted of one session lasting approximately two hours. The session initiated with a familiarization session (FS). The participants were introduced to the measurement devices and experienced the performance of maximal voluntary isometric contractions and dynamic ankle dorsiflexion. The protocol was repeated until the subject could average at least 95% on the error margin inside of the Humac-software (HUMAC NORM Extremety System, CSMi Solutions, Stoughton, Massachusetts). After the FS, the subject received a 30-minute rest period, to recover and avoid potential fatigue.

The setup up for supine ankle dorsiflexion was proposed by the dynamometers software and adjusted accordingly to the subject's physical limitations. The following video-guide from YouTube was used (https://youtu.be/bxxa6nGjf6U). To ensure subjects safety, anatomical zero and range of motion (ROM) was calculated on the Humac Norm dynamometer before tests. The anatomical zero was set according to the subject's own perception of their foot. They were informed that the degrees in the ankle joint should be approximately 90 degrees. In both familiarization and experimental protocol, the procedure is performed without shoes. After the foot is placed correct, and the anatomical zero is found, the range of motion was fixated. The range of motion was 2 degrees above the anatomical zero, and 22 degrees below, which was a ROM of 24 degrees. The subjects were instructed in only to move in 20 degrees. 2 degrees in both directions was added to avoid reaching the mechanical limitations, that could create artifacts in the EMG-signal. Protocols was setup using the software, to automate and streamline the process.

Experimental Protocol

Subject was seated and fixated to the dynamometer and the protocol initiated with two measurements of MVC, where the highest value is the chosen MVC. The contraction time was at five seconds, with three minutes rest between the two sets. The contraction was performed slow at start and peaked the contraction in the middle of the five seconds. The MVC was used for calculating submaximal contractions in the test. Subsequently the dynamic contractions were performed with the following protocol: Protocol consists of 4 randomized trials of submaximal contractions with two different intensities; 10% and 25% of the MVC. The dynamic contractions involved two different contraction speeds. 5 degrees/second(°/s) and 20 °/s. This was performed with one trial each at the two intensities 10% and 25%. (Figure 2). Four cycles of 5 °/s were executed, with a 4 second(s) concentric phase, 1 second isometric hold, and then 4 seconds of eccentric phase. 20 °/s had 10 cycles of 1s concentric phase, 1s isometric hold, 1s eccentric phase. Each contraction had a 2s isometric hold between them,

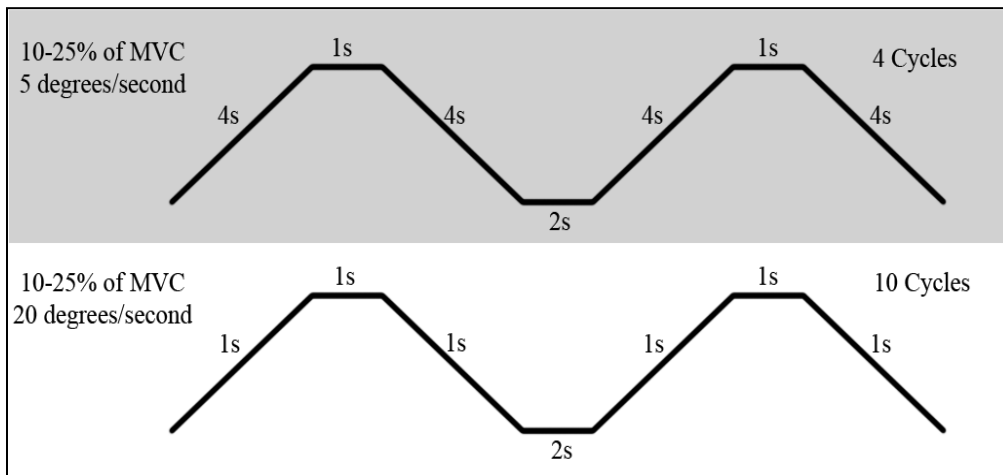where the subject was not allowed to rest, to ensure constant torque being produced. (Figure 2).

Figure 2, Illustrates the dynamic contractions that the subject performed at 10 and 25% of their MVC.

To ensure acceptable results, the subject was requested to notify the researcher, if any discomfort was experienced during the test. With this, the researcher immediately could release the subjects from the dynamometer. If no notifications from the subject would occur, they would be released every thirty minutes to reassure optimal conditions. Furthermore, the reference bands were rewetted during the release. During this experimental session precautions was taken to insure homogeneity in the measurements. Two researchers conducted this experiment, and certain roles were applied, and procedures was trained individually before applying into the experiment. The protocol has been developed through an extensive amount of pilot-testing.

Data Acquisition & Treatment

The software OT-Biolab v. 2.0.6 (OT Bioelettronica, Italy) was used for EMG data acquisition. Software was run on the same PC as the Humac Norm software with a duo screen setup.

Subjects m. Tibialis Anterior on the right leg is shaved, cleaned (Alcoswaps (MEDIQ, Denmark), and mildly scraped with fine sandpaper to ensure clean contact between the electrode and the skin. Two HD-sEMG 64 channel, matrices (ELSCH064R3S, i.e.d. 8mm) was prepared with adhesive foam (KITAD064, OT Bioelettronica, Italy), and conductive gel (AC-Cream, OT Bioelettronica, Italy). Electrodes is placed parallel to the tibia bone, starting from the soft tissue below patella. Cables (AD1x16, OT Bioelettronica, Italy) were labeled and connected to the 8 channels on the multichannel amplifier (EMG-USB, OT Bioelettronica, Italy). The multichannel amplifier, set in monopolar mode, had a sampling frequency at 2048 hertz and the gain was adjusted accordingly to each trial, to get the maximum amount of resolution without saturating the signal output. Furthermore, position and torque output were measured during the trials. This was connected from the dynamometer to the auxiliary input channels on the amplifier, and had a gain set 6144. Reference bands are wetted and applied to the subject's right ankle and wrist. Subsequently connected to the Driven Right Leg-in (DRL) port, and right wrist was connected to DRL-out on the amplifier. Furthermore, another cable was connected to the patient reference with an Ambu Neuroline 720 electrode placed firmly on the dynamometers crank arm, to help with grounding and ensure minimal noise on the signal output. Full setup is shown in appendix (B)

One researcher acquired all data from the software to ensure the process to be similar, while the subject focused on the feedback provided on the second screen. After acquiring the data from OT-Biolab, the files are unpacked and processed in MATLAB (The MathWorks, Inc.)

The raw EMG signal is visually and manually cleaned for bad channels. The decision was based upon channels that was clearly saturating or did not look comparable to the other channels.

After cleaning the channels, the analyzer chose the regions of analysis in the contractions, this is done by dividing the concentric-, eccentric- and lower isometric contraction using the position of the ankle joint as feedback (Figure 3). The lower isometric contraction is used as a normalization value in root mean square. The RMS value is normalized by $\frac{Concentric\ or\ eccentric}{Lower\ isometric\ contraction}$, so an RMS value of 1 is equal to the isometric lower contraction.
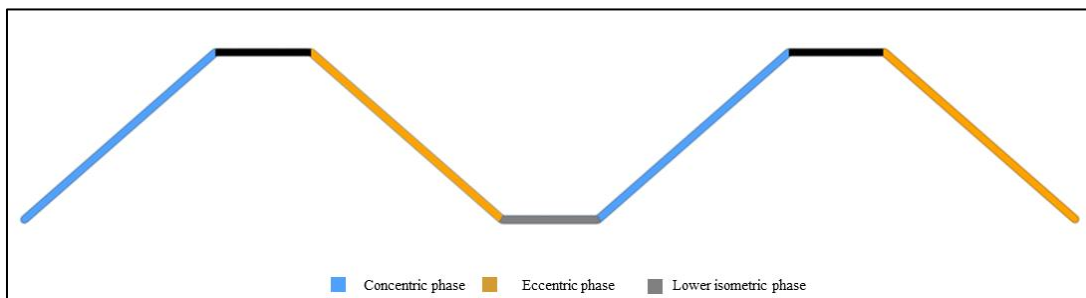

Figure 3, shows the different regions during a dynamic contraction, and how they were divided during multiple dynamic contractions.

The signal was divided into concentric and eccentric phases, and further broken down into five different percentages of the contractions, The 0-20% is the lengthened position in the concentric- and shortened position in the eccentric contraction and the opposite for the 80-100%. The barycenter in the proximal/distal direction is a spatial representation of the peak RMS between channels in the matrix. The unit is millimeters calculated by the distance between channels. The barycenter investigation is made one-dimensional, in the proximal-distal direction, this is due the muscle architecture of m. Tibialis anterior, which consists of parallel muscle fibers.

Statistical Analysis

The normality of the dependent variables (RMS and BarycenterY) was confirmed using a Shapiro Wilk test. A correlation analysis was used to investigate the relation between the changes in RMS during a concentric- and eccentric contraction. A three-way analysis of variance (ANOVA) was conducted to assess the significance levels for the variables: muscle length (i.e. Lengthened(L), middle(M) and shortened(S)), contraction type(Concentric, Eccentric) and contraction speed (5°/s, 20°/s) and the interaction between these three independent variables (contraction speed × contraction type, contraction speed × ROM, contraction type × ROM). This three-way ANOVA was conducted in both Root mean square and barycenter for both 10%- and 25% intensity. The ANOVA also calculates the estimated size of effect was measured as the partial eta squared(η^2), this was to analyze the interaction between the variables. An effect size between independent variables provides knowledge on the efficiacy of different factors' treatment effect, which means the factors influence on the outcome (McGough,J & Faraone S, 2009). This is relevant because the p value is not adequate for readers to fully understand a result section, as the η^2 is independent of the sample size and is

measured as $\frac{SSeffect}{SSeffect+SSerror}$. The effect size contributes to understanding the direction and strength of a relationship between two factors (Berben et al, 2012). Effect size can furthermore be used as a comparison variable between studies, if the design is similar, and will not be restricted due to a limited sample size (Berben et al, 2012). The interpretation of a η^2 value, is be referring to Cohen's rule of thumb being (Cohen, J, 1988)

Table 1, Shows how this study categorizes the estimated size of effect, using the Cohen's rule of thumb

Small size effect	Medium size effect	Large size effect
,01	,059	,138

This is important to understand why a potential change in neuromuscular behavior occurs, when adding three independent variables. The α level was set to (α=,05).

Results

Root Mean Square

The three-way ANOVA conducted on RMS, revealed the main effects for contraction speed (5°/s, 20°/s) in 25% intensity is significant (25%; p=,036. F 4,521. η^2=,036). The main effects for contraction type (concentric, eccentric) in both intensities (10%, 25%) were significant (10%; p=,000. F 26,701. η^2=,308) (25%; p=,000. F 52,956. η^2=,469). The main effects for ROM (S, M, L) in both intensities (10%, 25%) were also significant (10%; p=,000. F 26,701. η^2=,308) (25%; p=,000. F 52,956. η^2=,469).

There was a significant interaction contraction speed × contraction type for 25% intensity (p=,003 F= 9,935. η^2=,073). The increase in RMS is larger for both contraction types in 5°/s, compared to 20°/s. However, this interaction revealed no significance for 10% intensity. (p=0,59) (Figure 5)

There was a significant interaction contraction speed × ROM for both intensities (10%; p=,000 F =12,613, η^2=,174) (25%; p=,000 F =13,373 η^2=,182), where an increase in RMS was observed in 5°/s from lengthened position compared to middle- and shortened position (figure 4, 5).

The interaction contraction type × ROM was also significant (10%; p=,001 F=7,77, η^2=,115) (25%; p=,000 F=13,373, η^2=,131), where the concentric contraction RMS in both speeds and intensities increase from lengthened position to middle- and shortened position. However, the RMS during eccentric contractions is lower in both speeds compared to concentric contractions. For 20°/s the RMS increases during the concentric contractions in both intensities, but for 5°/s eccentric contraction there is a decrease during the contraction at 10% intensity. This is not observed at 25% intensity.
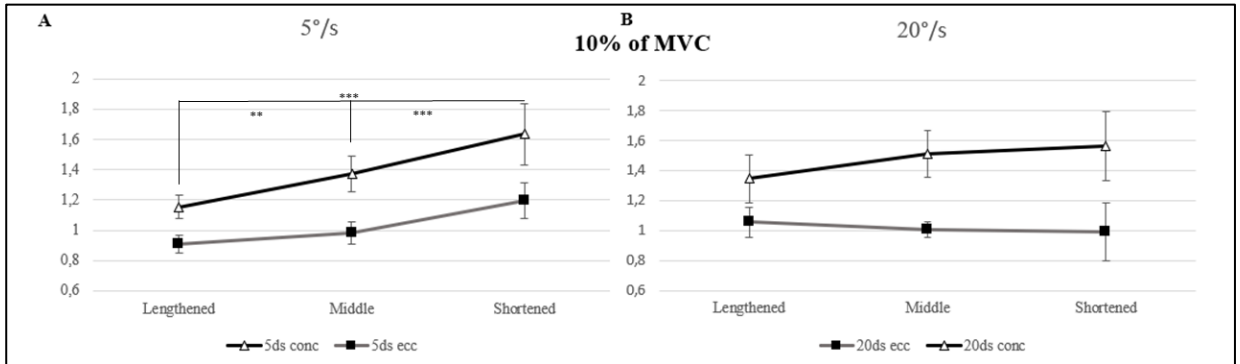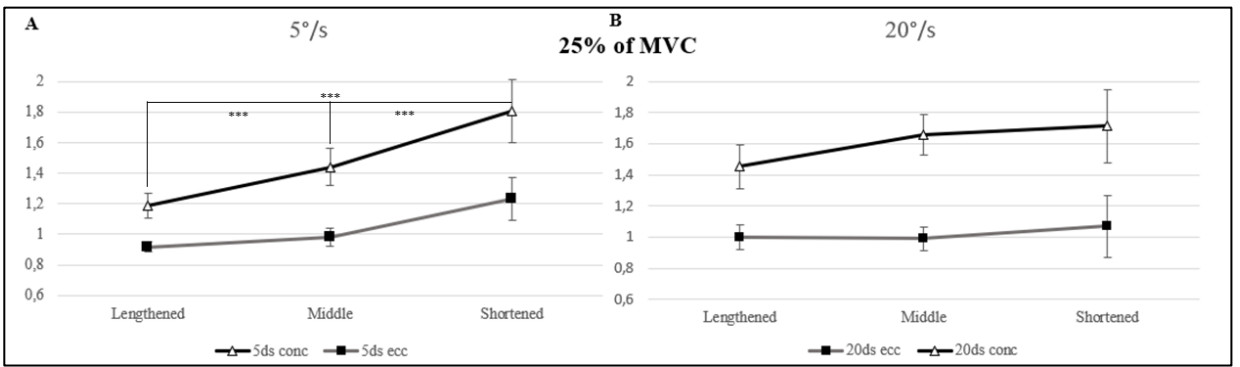
FIGURE 4 A, B. Comparison of the two contraction speeds at 10% intensity, in terms of RMS, 5°/s (left) and 20°/s (right). The Y axis is a normalized RMS value. The X axis is the muscle length (***=p<,001; **=p<,01).

FIGURE 5 A, B., Comparison of the two contraction speeds at 25% intensity, in terms of RMS, 5°/s (left) and 20°/s (right). The Y axis is a normalized RMS value. The X axis is the muscle length (***=p<,001; **=p<,01).

The correlations between the RMS in concentric and eccentric contractions.

The inverse correlation between the RMS changes from shortened- to lengthened position, in concentric and eccentric contraction is highly correlated in the 20d°/s in both intensities with 10% being R^2 0,9174 and the 25% intensity being R^2 0,8386. The scatterplot of 5°/s has a lower correlation with 10% being R^2 0,5859 and 25% being R^2 0,3817.
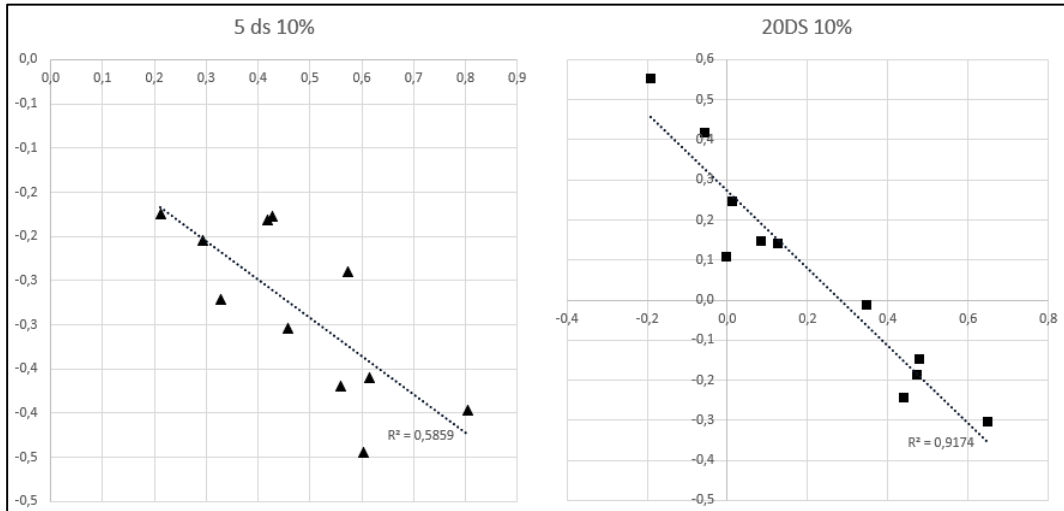
Figure 6 shows a scatterplot of the RMS changes in concentric (X axis) and eccentric (Y axis) for 10% of MVC.
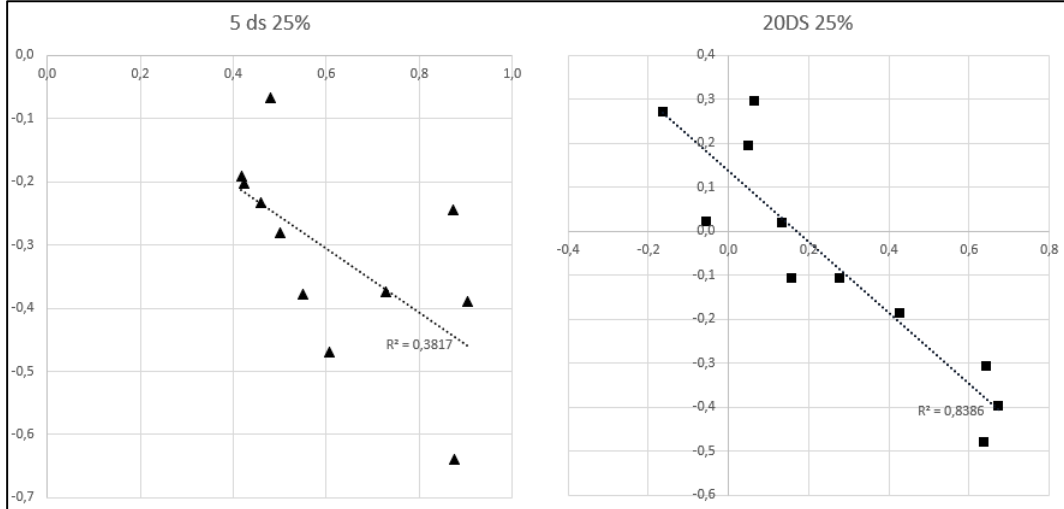

Figure 7 shows a scatterplot of the RMS changes in concentric (X axis) and eccentric (Y axis) for 25% of MVC.

Barycenter shift

The three-way ANOVA conducted on RMS barycenter shift, revealed a significant main effect for ROM in both intensities (10%; p=,000 F= 24,103. η2=,287) (25%; p=,044 F 3,200. η2=,012). Additionally, a significant main effect of contraction type in 10% intensity was also observed (10%; p=,022 F=5,352. η2=,043). However no other significant main effects or interactions between the factors was reported.

Figure 8 A, B. Comparison of the two contraction speeds in terms of RMS, 5°/s (left) and 20°/s (right). The Y axis is millimetres and the X axis is the muscle length.
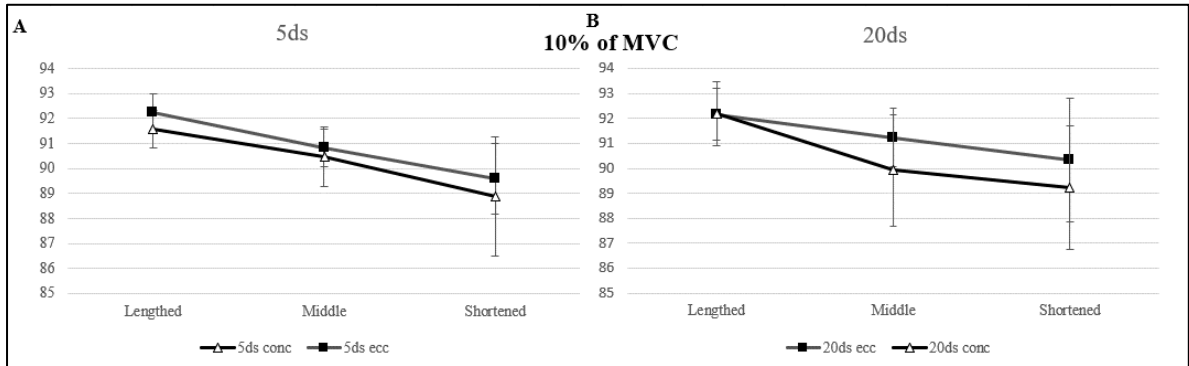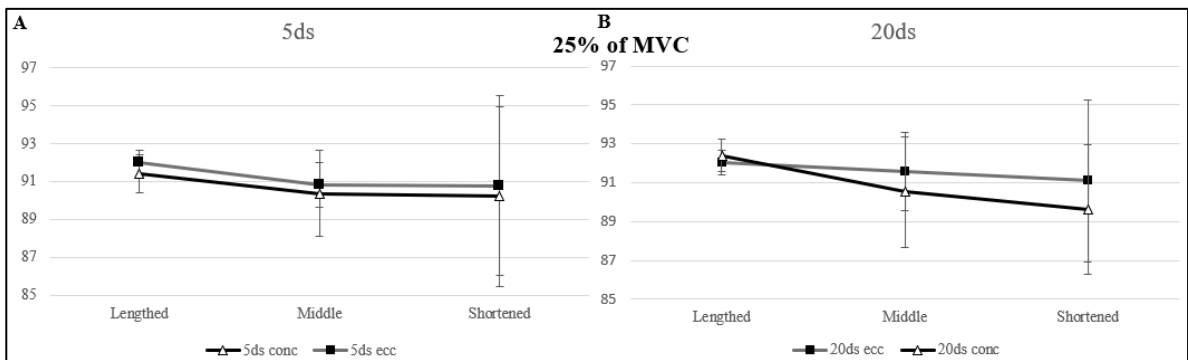

Figure 9 A, B. Comparison of the two contraction speeds in terms of RMS, 5°/s (left) and 20°/s (right). The Y axis is millimetres and the X axis is the muscle length.

Discussion

Root mean square

The present study showed a correlation between the changes in RMS during concentric- and eccentric contractions. The correlation revealed that the changes in RMS in 20°/s, in both contraction types and intensities, had a higher correlation compared to 5°/s. The Y axis in the 20°/s shows that some subjects had a decrease in the RMS during the eccentric contraction where others had an increase (Figure 6, 7 This can be

explained by the subjects' increase in eccentric contraction that has a decrease, or small increase, in the concentric contraction. This is opposite to subjects with a decrease in the eccentric contractions, who had a larger increase in the concentric contraction. This indicates a strong relationship between the changes in concentric and eccentric RMS. As reported by previous literature, faster contraction speeds utilize a larger amount of type II muscle units (fast twitch) compared to slower contraction speeds (Liu et al, 2012; Neale et al, 2018). This implies that a neuromuscular change occurs when changing the contraction speed (Neale et al, 2018). The difference in morphological fiber composition, might contribute to explain the difference between the subjects.

When increasing the contraction speed, the recruitment pattern in different ranges of motion changes. The muscle activation in the lengthened muscle position, is lower in slower contraction speeds, compared to faster contraction speeds (Figure 4, 5). The shortened muscle position has a higher muscle activation in slower contraction speeds compared to faster contraction speeds. This suggest an agreement with the results F. Oliveira et al, 2009 presents. They found a significant change during concentric contractions; however, they did not find a significant change during eccentric contractions. This study states, there is a significant difference between the speeds and ROM in eccentric contractions in both intensities. This might be due to the change in fiber type activation in faster contraction speeds (Liu et al, 2012; Neale et al, 2018). This can be the reason, why this study suggests another view on the eccentric contractions. Another reason for the different results between the two studies, might have been a methodological reason. This study investigated m. Tibialis Anterior using a HD-sEMG, whereas F. Oliveira et al, 2009, used a bipolar configuration on the m. biceps brachii. This may have contributed to the different findings as well.

Furthermore, when increasing the contraction speed, the RMS behaviour in contraction type changes. The eccentric contractions have a higher increase from lengthened- to shortened position in slower contraction speeds, compared to faster contraction speeds. In fast contraction speeds, they either have a small decrease or a small increase from lengthened- to shortened position. Fine motor control is lower in the eccentric contraction, due to less EMG amplitude (Hoppeler et al, 2016). The increase in contraction speed might contribute to further loss of fine motor control in eccentric contractions (Hoppeler et al, 2016). This loss, in addition with the faster contraction speed, might contribute to a higher chance of causing a muscle strain injury.

RMS Barycenter shift.
The spatial pattern of activity over the tibialis anterior proved to be different during a dynamic contraction. When performing submaximal contractions of 10 and 25% of MVC, the position of the RMS barycenter shifts in a distal direction from the lengthened position of the concentric contraction, and then shifts in a proximal direction when the eccentric contraction begins. However, an increase in speed and intensity did not change the RMS barycenter position, indicating that the central nervous system maintains the shape of the m. tibialis activation pattern for dorsiflexion's despite substantial changes in EMG amplitude. This indicates that the muscle activation pattern of tibialis anterior is maintained at different contraction speeds and contraction types, which implies that it is the length of the muscle that imposes the need to change the recruitment strategy. To our knowledge, no studies have tested whether the alteration in RMS barycenter shifts is associated with the contraction speed of a muscle. However, J. Cohen et al, 2019 reported that the RMS barycenter shift preferentially towards mechanical advantageous positions, during a unilateral standing

balance task with external perturbations. This supports the suggestion that muscles are organized into neuromuscular compartments, which can be independently controlled by the CNS (Windhorst et al, 1989). This might be able to explain that it is the length of the muscle which imposes the need to change the recruitment strategy.

Due the muscle architecture of Tibialis anterior, it was decided for this study to exclude the barycenter x position. The Tibialis muscle consists of parallel muscle fibers in the proximal – distal direction. If this method were applied to a different muscle e.g. trapezius (Samani et al, 2016; Farina et al, 2006), the barycenter x position would be highly relevant to describe the shift in the RMS barycenter.

Limitations

Some limitations of the study need to be discussed. In the current study a limitation on the equipment was the use of the electrode. This study used two 64 channel HD-sEMG electrodes to give a full representation of the m. tibialis anterior muscle. This provides a total of 128 channels covering the nearly the full innervation zone of the muscle. By using two electrodes it leaves a gap, of approximately 1.5 cm between the proximal and distal electrode, where no activity is measured. This can be solved by using a 128-channel electrode, specifically designed for the tibialis muscle. It is reasonable to believe that the RMS barycentre could have appeared in this gap, and therefore be undetectable.

The experimental protocol consisted of one session lasting approximately two hours. During this session it may be plausible that the subject experienced some degrees of fatigue. Fatigue can affect the motor unit recruitment, as mentioned in the introduction of this study; Within motor units one can find different types. The motor units which produces the most force, are also the units which are most susceptible to fatiguing (Potvin J & Fuglevand A, 2017). This means that fatiguing can change the motor unit recruitment strategy (Potvin J & Fuglevand A, 2017). This study tried to accommodate the fatiguing issues by giving the subjects three minutes of rest between trials. Furthermore, all the trials were performed in a randomized order.

Conclusion

In this study, the effects of contraction speed on amplitude and barycenter of EMG signals at different contraction types and ranges of motion was investigated. The results show that increases in contraction speed of m. Tibialis anterior will affect the neural recruitment depending on the range of motion and contraction type. It was discovered that a more lengthened muscle requires a lower neural recruitment during a low-speed contraction regardless of the contraction type. Additionally, proof of a reduction in RMS during eccentric contractions at faster speeds were found, which implies, the central nervous system is reducing the recruitment if speed is increased but load is maintained. Moreover, an increase in speed did not change the spatial distribution of neural activity, indicating that the central nervous system maintains the shape of the m. tibialis activation pattern for dorsiflexion's despite substantial changes in EMG amplitude. However, it was discovered that the length of the muscle is imposing the need to change the recruitment strategy. Based upon these conclusions this study suggests, that at faster contraction speeds, the less activation for the eccentric phase of the movement, which consequently increases the risk for muscle strain injuries in a clinical setting.

Acknowledgements

References

Berben, L., Sereika, S. M., & Engberg, S. (2012). Effect size estimation: Methods and examples. *International Journal of Nursing Studies, 49*(8), 1039-1047. doi:https://doi.org/10.1016/j.ijnurstu.2012.01.015

Chino, K., Mitsukawa, N., Kobayashi, K., Miyoshi, Y., Oda, T., Kanehisa, H., . . . Kawakami, Y. (2009). The influence of fascicle behavior on the lack of velocity dependence in eccentric joint torque in humans: In vivo observation. *Journal of Applied Biomechanics, 25*(2), 111-118. doi:10.1123/jab.25.2.111 [doi]

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.) Hillsdale, NJ: Lawrence Erlbaum.

Cohen, J. W., Gallina, A., Ivanova, T. D., Vieira, T., McAndrew, D. J., & Garland, S. J. (2020). Regional modulation of the ankle plantarflexor muscles associated with standing external perturbations across different directions. *Experimental Brain Research, 238*(1), 39-50. doi:10.1007/s00221-019-05696-8 [doi]

Farina, D., Leclerc, F., Arendt-Nielsen, L., Buttelli, O., & Madeleine, P. (2008). The change in spatial distribution of upper trapezius muscle activity is correlated to contraction duration. *Journal of Electromyography and Kinesiology : Official Journal of the International Society of Electrophysiological Kinesiology, 18*(1), 16-25. doi:S1050-6411(06)00107-6 [pii]

Farina, D. (2006). Interpretation of the surface electromyogram in dynamic contractions. *Exercise and Sport Sciences Reviews, 34*(3) Retrieved from https://journals.lww.com/acsm-essr/Fulltext/2006/07000/Interpretation_of_the_Surface_Electromyogram_in.6.aspx

Gallina, A., & Botter, A. (2013). Spatial localization of electromyographic amplitude distributions associated to the activation of dorsal forearm muscles. *Frontiers in Physiology, 4*, 367. Retrieved from https://www.frontiersin.org/article/10.3389/fphys.2013.00367

Glaser, V., & Holobar, A. (2019). Motor unit identification from high-density surface electromyograms in repeated dynamic muscle contractions. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 27*(1), 66-75. doi:10.1109/TNSRE.2018.2885283

Hamilton, L. D., Mani, D., Almuklass, A. M., Davis, L. A., Vieira, T., Botter, A., & Enoka, R. M. (2018). Electrical nerve stimulation modulates motor unit activity in contralateral biceps brachii during steady isometric contractions. *Journal of Neurophysiology, 120*(5), 2603-2613. doi:10.1152/jn.00235.2018 [doi]

Hody, S., Croisier, J., Bury, T., Rogister, B., & Leprince, P. (2019). Eccentric muscle contractions: Risks and benefits. *Frontiers in Physiology, 10*, 536. doi:10.3389/fphys.2019.00536

Hoppeler, H. (2016). Moderate load eccentric exercise; A distinct novel training modality. *Frontiers in Physiology, 7*, 483. doi:10.3389/fphys.2016.00483

Kallio, J., Søgaard, K., Avela, J., Komi, P. V., Selänne, H., & Linnamo, V. (2013). Motor unit firing behaviour of soleus muscle in isometric and dynamic contractions. *PloS One, 8*(2), e53425. doi:10.1371/journal.pone.0053425

Liu, H., Garrett, W. E., Moorman, C. T., & Yu, B. (2012). Injury rate, mechanism, and risk factors of hamstring strain injuries in sports: A review of the literature. *Journal of Sport and Health Science; Special Issue on Sports Injuries: Prevention and Rehabilitation, 1*(2), 92-101. doi:https://doi.org/10.1016/j.jshs.2012.07.003

Marri, K., & Swaminathan, R. (2016). Analyzing origin of multifractality of surface electromyography signals in dynamic contractions. *Journal of Nanotechnology in Engineering and Medicine, 6*(3) doi:10.1115/1.4032005

McGough, J. J., & Faraone, S. V. (2009). Estimating the size of treatment effects: Moving beyond p values. *Psychiatry (Edgmont (Pa.: Township)), 6*(10), 21-29. Retrieved from https://pubmed.ncbi.nlm.nih.gov/20011465 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2791668/

Moritani, T., Muramatsu, S., & Muro, M. (1987). Activity of motor units during concentric and eccentric contractions. *American Journal of Physical Medicine, 66*(6), 338-350.

Nazmi, N., Abdul Rahman, M. A., Yamamoto, S., Ahmad, S. A., Zamzuri, H., & Mazlan, S. A. (2016). A review of classification techniques of EMG signals during isotonic and isometric contractions. *Sensors (Basel, Switzerland), 16*(8), 1304. doi: 10.3390/s16081304. doi:10.3390/s16081304 [doi]

Negro, F., Muceli, S., Castronovo, A. M., Holobar, A., & Farina, D. (2016). Multi-channel intramuscular and surface EMG decomposition by convolutive blind source separation. *Journal of Neural Engineering, 13*(2), 026027. doi:10.1088/1741-2560/13/2/026027

Oliveira, L. F., Matta, T. T., Alves, D. S., Garcia, M. A. C., & Vieira, T. M. M. (2009). Effect of the shoulder position on the biceps brachii emg in different dumbbell curls. *Journal of Sports Science & Medicine, 8*(1), 24-29. Retrieved from https://pubmed.ncbi.nlm.nih.gov/24150552 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3737788/

Potvin, J. R. (1997). Effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. *Journal of Applied Physiology (Bethesda, Md.: 1985), 82*(1), 144-151. doi:10.1152/jappl.1997.82.1.144 [doi]

Potvin, J. R., & Fuglevand, A. J. (2017). A motor unit-based model of muscle fatigue. *PLoS Computational Biology, 13*(6), e1005581. doi:10.1371/journal.pcbi.1005581

Reeves, N. D., & Narici, M. V. (2003). Behavior of human muscle fascicles during shortening and lengthening contractions in vivo. *Journal of Applied Physiology, 95*(3), 1090-1096. doi:10.1152/japplphysiol.01046.2002

Samani, A., Srinivasan, D., Mathiassen, S. E., & Madeleine, P. (2017). Variability in spatio-temporal pattern of trapezius activity and coordination of hand-arm muscles during a sustained repetitive dynamic task. *Experimental Brain Research, 235*(2), 389-400. doi:10.1007/s00221-016-4798-y

Søgaard, K. (1995). Motor unit recruitment pattern during low-level static and dynamic contractions. *Muscle & Nerve, 18*(3), 292-300. doi:10.1002/mus.880180305

Tillin, N. A., Pain, M. T. G., & Folland, J. P. (2018). Contraction speed and type influences rapid utilisation of available muscle force: Neural and contractile mechanisms. *The Journal of Experimental Biology, 221*(24), jeb193367. doi:10.1242/jeb.193367

Windhorst, U., Hamm, T., & Stuart, D. (1989). On the function of muscle and reflex partitioning. *Behavioral and Brain Sciences, 12*, 629-645. doi:10.1017/S0140525X00024985