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Influence of course type on upper body muscle activity in elite Cross-Country and Downhill mountain bikers during off Road Downhill Cycling

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Abstract

This study aimed to investigate upper body muscle activity using surface electromyography (sEMG) in elite cross-country (XCO) and downhill (DH) cyclists during off road descending and the influence of man-made (MM) and natural terrain (NT) descents on muscle activity. Twelve male elite mountain bikers (n=6 XCO; age 23 ± 4 yrs; stature 180.5 ± 5.6 cm; body mass 70.0 ± 6.4 kg and n=6 DH; age 20 ± 2 yrs; stature 178.8 ± 3.1 cm; body mass 75.0 ± 3.0 kg) took part in this study. sEMG were recorded from the left biceps brachii, triceps brachii, latissimus dorsi and brachioradialis muscles and expressed as a percentage of maximal voluntary isometric contraction (% MVIC). Both groups performed single runs on different MM and NT courses specific to their cycling modality. Significant differences in mean % MVIC were found between biceps brachii and triceps brachii (p=.016) and triceps brachii and latissimus dorsi (p=.046) during MM descents and between biceps brachii and triceps brachii (p=.008) and triceps brachii and latissimus dorsi (p=.031) during NT descents within the DH group. Significant differences in mean % MVIC were found between biceps brachii and brachioradialis (p=.022) for MM runs and between biceps brachii and brachioradialis (p=.013) for NT runs within the XCO group. Upper body muscle activity differs according to the type of downhill terrain, and appears to be specific to DH and XCO riders. Therefore, the discipline specific impact on muscle activation and the type of course terrain ridden should be considered when mountain bikers engage in upper body conditioning programmes.

Keywords: cycling, mountain biking, downhill, surface EMG, performance.

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Introduction

Mountain biking (MTB) is composed of several sub-disciplines, with Olympic Cross-Country (XCO) and Downhill (DH) being the most popular. Both XCO and DH can be characterised as high intensity, intermittent activities that require riders to compete over varied terrain, including rocky paths, technical single-track and open forestry roads; and also include frequent obstacles, such as jumps and vertical drops (Lee et al. 2002). Typically, elite DH races last between 2-5 min and 1.5-3.5 km with the emphasis being on technical skill, whilst elite XCO races last approximately 1.5-1.75 hrs, are competed over laps of between 4-6 km in length, and focus more on aerobic fitness (Union Cycliste Internationale, 2012).

Both specialist downhill courses and downhill sections of XCO courses can be classified as either natural (NT) or man-made (MM). Natural courses rely predominately on the geography and existing obstacles to provide a technical challenge; whilst MM courses are created using machinery to sculpt a track down the hillside that generally includes machine-built jumps and numerous smooth banked corners. Generally, MM courses also tend to be faster than NT courses due to the less rugged nature of these courses. The skills required to ride MM and NT courses differ, and riders will usually change their body position on the bike in response to the type of terrain. Therefore, course type may influence muscle activity during downhill cycling.

Elite XCO and DH cyclists generally compete in approximately twenty to thirty races per season with races often comprised of qualification rounds and a final (Sperlich et al. 2012). As a result cyclists are required to perform a high volume of downhill riding, both during the course of a weekend race and throughout the season, irrespective of discipline.

However, modern XCO and DH bicycles differ considerably, with DH bicycles having between 200-230 mm of front and rear suspension travel, whilst XCO bicycles have between 80-100 mm of suspension travel that can be front and rear or front only. These specificities in bicycle designs may lead to different upper body muscle activity in DH and XCO riders most likely linked to differences in force transmission to the upper body and differing body positions on the bicycles.

Whilst there is a plethora of research pertaining to the aerobic and anaerobic characteristics of XCO racing, with comparisons often made to road cycling (Wilber et al. 1997; Stapelfeldt et al. 2004; Impellizzeri et al. 2005; Prins et al. 2007), there is a clear paucity of data on the performance characteristics of elite DH mountain bikers.

Currently, the only study to use elite level DH cyclists is Sperlich et al. (2012), who investigated the psycho-physiological stresses of DH racing. Hurst and Atkins (2006) investigated the power, cadence and heart rate responses to DH riding; however, their study used well trained amateur DH cyclists and not elite athletes. Despite significant fluctuations in power and cadence, Hurst and Atkins (2006) reported remarkably stable heart rates during downhill riding. They concluded that this, in part, may be due to the influence of isometric contractions of the upper body musculature. However, the recruitment activity of these muscles has yet to be quantified during downhill mountain biking in elite XCO and DH riders.

Several studies have used surface electromyography (sEMG) to investigate the activity of muscles in response to different road cycling conditions (Egaña et al. 2010; Matsuura et al. 2011; Blake et al. 2012), though these studies were generally laboratory based and focused primarily on the lower limb muscles. Duc et al. (2008) investigated the influence of hand grip position during uphill road cycling on upper body muscle activity. However, this was again laboratory based and the hand grip positions used in road cycling do not reflect those used in MTB. Therefore, the muscle activity observed in MTB are likely to differ from those observed in road cycling. To our knowledge, Hurst et al. (2011) is the only study to investigate upper body muscle activity during simulated MTB. However, the study was limited in that it was also performed within a laboratory setting, simulated a single drop of only 30 cm and recruited non cyclists as participants. As such, the results of their study may not compare, or be generalised, to the responses of elite level athletes in a field-based environment.

The quantification of upper body muscle activity during downhill off road cycling has practical implications for riders and coaches. Unlike road-based cycling disciplines, MTB involves more dynamic movements of the upper body to manoeuvre the bicycle over and around obstacles and to aid the dampening of trail shocks. Knowledge of this activity may help riders and coaches to set up bicycles more effectively for a given course. In addition, such knowledge may also lead to more effective training plans to aid MTB performance and potentially reduce the risks of injury through improved bicycle handling and reduced muscle fatigue.

The aims of this study were therefore to 1) quantify upper body muscle activity during off road downhill cycling in elite XCO and DH cyclists and 2) investigate the influence of course type on upper body muscle activity.

Materials and methods

Participants

Ethical approval for the study was granted by the University of Central Lancashire Ethics Committee and the Swedish Winter Sports Research Centre and the research proposal was in accordance with the Declaration of Helsinki. Participants were informed both verbally and in writing of the test procedures and written informed consent was obtained. Twelve male elite mountain bikers (n=6 XCO; age 23 ± 4 yrs; stature 180.5 ± 5.6 cm; body mass 70.0 ± 6.4 kg and n=6 DH; age 20 ± 2 yrs; stature 178.8 ± 3.1 cm; body mass 75.0 ± 3.0 kg) took part in this study. All riders represented the Swedish National Cycling team at their respective disciplines. No significant differences were found for anthropometric variables, with the exception of percentage body fat (11.2 ± 4.1 % and 5.6 ± 1.3 %; p=0.010, for DH and XCO respectively). Anthropometric measures were conducted following the guidelines of Lohman et al. (1989) and using the seven site prediction equation of Jackson and Pollock (1978).

Course Profile

Testing was conducted at the Åre Bike Park, Åre, Sweden. All participants were allowed to use their own race bicycles, with XCO riders using hard-tail XCO mountain bikes with between 100 ± 0 mm of front only suspension travel, whilst DH riders used full-suspension DH bikes with 202 ± 1.55 mm of suspension travel. Suspension systems were set up according to individual preferences with respect to compression rate and rebound dampening. Each group were tested on two different courses, technically relevant to their discipline. Courses were categorised as either NT XCO (length = 1358 m, vertical drop = 271 m, mean gradient = 19.7 %) and NT DH (length = 1363 m, vertical drop = 431 m, mean gradient = 29.2 %) or MM XCO (length = 1387 m, vertical drop = 273 m, mean gradient = 19.5 %) and MM DH (length = 2182 m, vertical drop = 473 m, mean gradient = 22.9 %). Courses were representative of the type of terrain encountered during downhill sections of XCO courses and DH specific tracks at a World Cup level. Riders were allowed two days to familiarise themselves with the courses prior to testing. Course length and profiles were recorded using a 5 Hz global positioning satellite system (GPS) (Minimax X3, Catapult, Australia) positioned in a harness at approximately the C7 vertebrae. The GPS system was also used to record mean and peak velocity.

As no direct comparisons between groups were planned at onset of the study, the use of different MM and NT courses for each group is justified considering that the primary aims of the study were to quantify upper body muscle activity in XCO and DH riders and investigate the influence of course type on muscle activity within groups. From a health and safety perspective, it was deemed unsafe to require XCO riders to complete the same MM and NT courses as the DH riders due to the differences in bicycle designs outlined above. In addition, the use of different courses was more ecologically valid as the technical demands experienced during racing differ between groups.

Surface EMG Processing and Analysis

Surface electromyography (sEMG) data were recorded using Biometrics Bipolar AG-AgCl differential sEMG sensors (model SX230, Biometrics Ltd., UK) at 1000 Hz from the left biceps brachii, triceps brachii, latissimus dorsi and brachioradialis muscles. The upper body movement patterns used to absorb trail shock in mountain biking are similar to those observed during push up exercises, and hence the above muscles were selected for investigation as they are the primary muscles involved during push ups (Freeman et al., 2006). The left side of the body was chosen due to this being the side of the dominant braking hand. Sensors were positioned longitudinally in parallel to the muscle fibres on the medial aspect of each muscle. Positioning of the sensors was in accordance with the Surface EMG for Non-Invasive Assessment of Muscles project (SENIAM) recommendations. Prior to placement of the sensors, the skin was prepared by shaving the area, lightly abrading and cleaning with alcohol wipes to minimise skin impedance and electrode-to-skin artefacts. A ground reference cable (R306) was placed on the styloid process of the right radius to reduce the likelihood of 50 Hz noise. In addition, a pre-calibrated (absolute zero) twin axis goniometer (model SG110, Biometrics Ltd., UK) was used to record elbow joint angle in the sagittal plane. This was placed across the left elbow joint ensuring that the goniometer crossed the joint centre. Elbow joint angle was defined as a relative angle, with 0° indicating full extension and 180° indicating full flexion. All sensors were secured in place using medical tape and cables were routed underneath the riders' clothing to a small backpack that would house the Biometrics data logger.

In the absence of a ground contact matt to synchronise the sEMG data for identifying the start of each run, run times were used and the raw sEMG data were cropped from the first change in elbow joint angle from the 0° position to indicate the start of each run. The change in elbow joint angle was indicative of riders pulling on the handlebars during acceleration off the start line. Run times were recorded using a Freelap TX Junior wireless radio transmitter system (Freelap, Switzerland). During post processing data were full-wave rectified then filtered at 20 Hz using a first order low pass zero-lag Butterworth filter in accordance with Li and Caldwell (1998 and 1999) to create a linear envelope. Mean and peak sEMG amplitudes were determined for each muscle and run using DataLink Version 5.06 (Biometrics Ltd., UK).

A maximal voluntary isometric contractions (MVIC) was performed for each muscle prior to data collection on course. Due to the field-based nature of testing and in the absence of fixed immovable objects against which to perform MVIC's, participants performed them against the resistance of an examiner following the clinical recommendations of Kendall et al. (2005) for manual muscle testing. In order to minimise variability the same examiner performed all assessments of MVIC. Biceps brachii, triceps brachii and brachioradialis MVIC's were performed in a seated position with the left elbow in a 90° position. Participants were instructed to keep the elbow in contact with the side of the torso during the MVIC's, to reduce extraneous movements, whilst the examiner provided a manual resistance to oppose the prime movement of the muscle under investigation. The MVIC's for latissimus dorsi were performed with the participants' lying prone with the shoulder blades retracted and the arm in adduction, extension, and internal rotation whilst attempting to raise the left arm posteriorly against the manual resistance of the examiner.

Due to the use of manual resistance for the determination of MVIC's, angular joint displacement of the elbow and shoulder was a possibility. Though this was not formally assessed during the performance of MVICs, it was not observed. Nonetheless, to account for the possible influence of joint displacement and in accordance to standard MVIC data collection procedures for sEMG normalization, three trials for each muscle were performed. Maximal voluntary isometric contraction values for each muscle represented 100 % and with the highest value determined from the three trials used for normalization, where sEMG amplitude was averaged over a 5 s steady state isometric contraction for each trial. Subsequent on course data for mean and peak sEMG are therefore presented as a percentage of MVIC values (% MVIC).

Protocols

Following determination of MVIC's, riders performed a 10 min self-paced warm up on a SRM indoor cycle trainer, which included a series of short maximal effort sprints. This was followed by self-selected dynamic stretching. Immediately prior to starting each run, the riders were instructed to remain static and to relax the upper body as much as possible to allow the setting of base line and zeroing the sEMG signals. Riders were then given the verbal command "3,2,1 GO" to start each run. Each rider performed one run of the MM and NT courses relevant to their respective discipline, preceded each time with the above warm up protocol and zeroing process. Chair-lifts were used to transport riders to the respective start points. The order of runs was randomised for all participants. Upon completion of each run data were transferred from the data logger for later analyses.

Statistical analyses

A Shapiro-Wilk test determined that the data for each group were normally distributed. Differences between MM and NT courses were then analysed within groups using paired students t-tests. To determine whether differences existed between muscles by course, within groups one-way repeated measures ANOVA's were used. To control for type I error the alpha levels were adjusted using a Bonferroni correction during post hoc analyses. If the homogeneity assumption was violated then the degrees of freedom were adjusted using the Greenhouse Geisser correction. Effect sizes were calculated using a partial Eta2 ($\eta 2$). Significance was accepted at the $p \leq .05$ level and data are presented as mean ± standard deviation values. All statistical procedures were conducted using SPSS 19.0 (SPSS Inc., Chicago, IL, USA).

Results

Descriptive data for mean and peak velocity and run times are presented in table 1.

Analysis of sEMG data revealed no significant differences ($p>.05$) in mean or peak values when expressed as a % MVIC, for any of the muscles when comparing activity between MM and NT courses for the DH riders. Mean sEMG data for each muscle, by course, are presented in figure 1, whilst figure 2 shows the peak sEMG data by course. When muscles were compared against each other within the MM runs, a significant difference was revealed in mean sEMG activity ($F_{3,20}$ = 5.23, p=.008, $\eta 2$ =.440). Post hoc analysis found mean differences between biceps brachii and triceps brachii (14.7 ± 7.1 and 46.4 ± 29.1 % MVIC, respectively; p=.016) and triceps brachii and latissimus dorsi (19.0 ± 6.3 % MVIC; p=.046). Significant differences were also found for sEMG between muscles within the NT runs ($F_{3,20}$ = 6.20, p=.004, $\eta 2$ =.480), with post hoc analysis showing the differences occurred again between biceps brachii and triceps brachii (16.9 ± 6.4 and 49.1 ± 25.9 % MVIC, respectively; p=.008) and triceps brachii and latissimus dorsi (22.0 ± 6.4 % MVIC; p=.031). No significant differences were found for peak sEMG between muscles within either MM or NT runs for DH

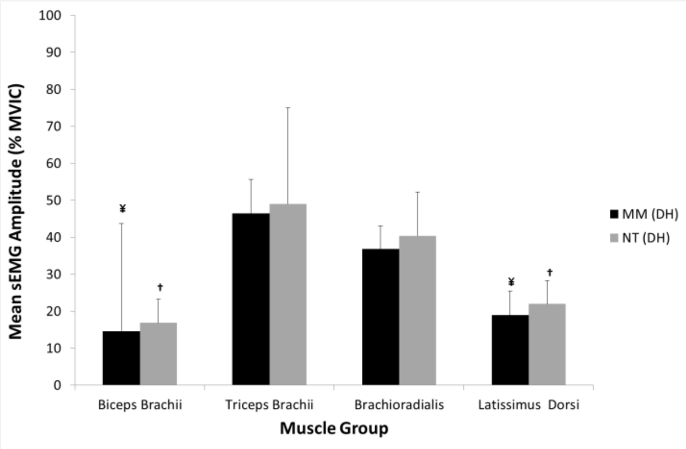

Figure 1. Mean ± standard deviation of mean sEMG signal amplitudes as a percentage of maximal voluntary isometric contraction for DH riders during NT and MM downhill runs.¥ Significantly different to Triceps Brachii (MM); † Significantly different to Triceps Brachii (NT).

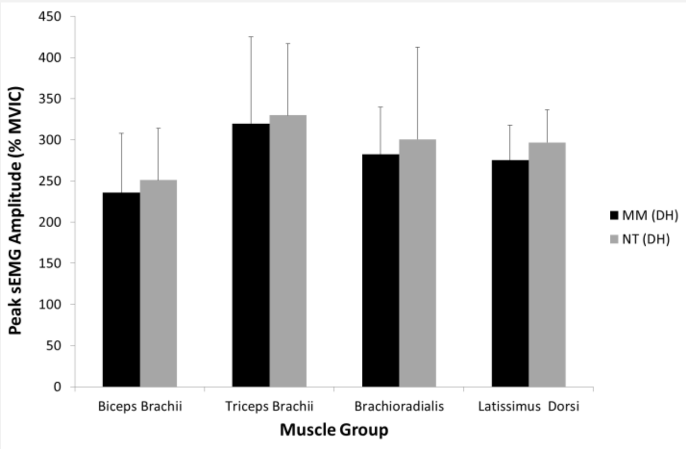

Figure 2. Mean ± standard deviation of peak sEMG amplitudes as a percentage of maximal voluntary isometric contraction for DH riders during NT and MM downhill runs.

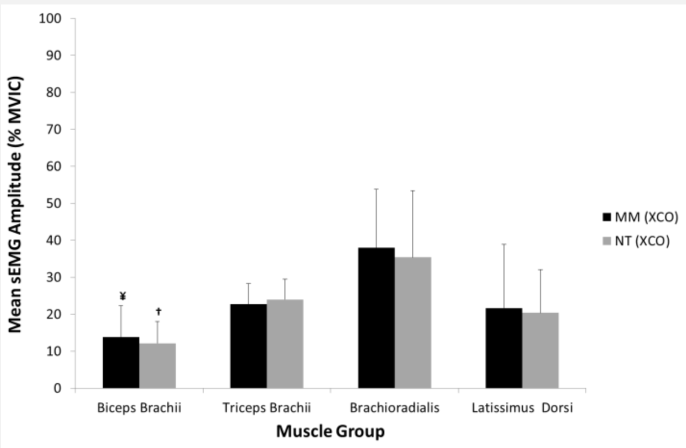

Figure 3. Mean ± standard deviation of mean sEMG amplitude as a percentage of maximal voluntary isometric contraction for XCO riders during NT and MM downhill runs. ¥ Significantly different to Brachioradialis (MM); † Significantly different to Brachioradialis (NT).

riders.

Analysis of XCO riders' sEMG data also revealed no significant differences in mean or peak sEMG between MM and NT courses (p>.05). Mean and peak sEMG values by course are presented in figures 3 and 4 respectively. When muscles were again compared against each other within courses, there was a significant difference in mean sEMG activity within MM runs ($F_{3,20}$ = 3.77, p=.027, $\eta 2$ =.361). Post hoc analysis revealed differences between biceps brachii and brachioradialis (13.8 ± 8.6 and 37.9 ± 15.8 % MVIC, respectively; p=.022). A significant difference was also found in mean sEMG amplitudes between muscles within the NT runs for the XCO riders ($F_{3,20}$ = 4.25, p=.018, $\eta 2$ =.389). Post hoc testing again found the differences to be between biceps brachii and brachioradialis (12.1 ± 5.9 and 35.4 ± 18.0 % MVIC, respectively; p=.013). No significant differences were found for peak sEMG amplitudes between muscles within either MM or NT runs for the XCO riders.

No significant differences were found for mean elbow flexion angles within groups between NT and MM courses. Mean elbow flexion angles for each group are presented in figure 5.

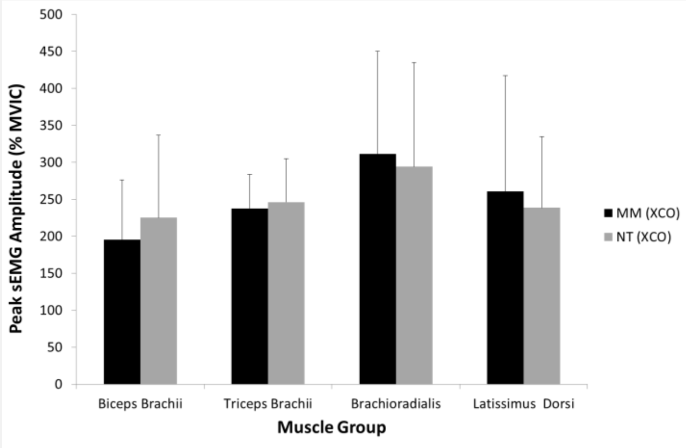

Figure 4. Mean ± standard deviation of peak sEMG amplitude as a percentage of maximal voluntary isometric contraction for XCO riders during NT and MM downhill runs.

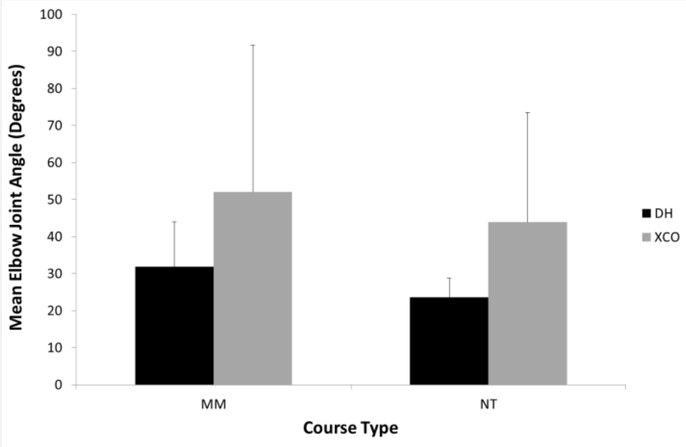

Figure 5. Mean ± standard deviation of mean elbow joint angle for XCO and DH cyclists during man-made (MM) and natural terrain (NT) downhill mountain biking.

Discussion

To the best of our knowledge, this study represents the first to investigate the contribution of upper body musculature during field-based downhill MTB in elite athletes. A secondary aim was to determine the influence of course type on muscle activity in this population of elite XCO and DH cyclists. As data in this field of research is scare it is difficult to make direct comparisons to previous research. Furthermore, considering the differing length and nature of the courses used in the present study, it is challenging to compare upper body muscle activity between XCO and DH cyclists using statistical analysis, though the discussion attempts to provide some reasons for the apparent lack of differences in upper body muscle activity. The key observations from this investigation were: 1) when muscular activity were compared within groups, no differences were revealed between MM and NT courses for either XCO or DH riders, 2) significant differences in mean sEMG amplitudes were evident between muscles within both MM and NT courses for both XCO and DH groups and 3) no significant differences in elbow joint angle between courses within either group were revealed.

Though not directly tested for statistical comparisons between groups due to the use of different course, sEMG amplitude would appear similar for both groups. The reduction in velocity seen in the XCO group and the technical differences in DH bicycle design and set up may result in similar isolation of riders from trail shock, leading to comparable muscle activation between groups, with the exception of the triceps brachii muscles. This supports the previous findings of Hurst at el. (2011) in that suspension reduces the forces transmitted to the upper body muscles during a simulated drop off. The ability of the bicycles to effectively absorb trail shock, likely also explains the non-significant differences in sEMG within both groups between MM and NT courses.

The riding dynamics of DH cyclists are different to those of XCO cyclists during descents. This may in part be due to DH bicycles having approximately 100 mm more suspension travel than XCO bicycles and slacker bicycle frame head tube angles, thus influencing riding dynamics. Such differences would potentially result in greater tyres contact with the ground, affording DH cyclists the ability to accelerate more frequently over rougher ground throughout the descents. This may have led to the greater activity of the triceps brachii observed in the present study in DH compared to XCO cyclists as a result of increased lateral sways during acceleration. This theory is supported by Duc et al. (2008) who also found that increases in lateral sways when cycling uphill resulted in increased triceps brachii activity. Further research is therefore warranted to determine the contribution of these lateral sways on triceps brachii activity during downhill riding.

Cross-country riders produced mean and peak velocities approximately 5 $km.h^{-1}$ and 10 $km.h^{-1}$ slower than DH riders on MM and NT courses, respectively. These slower velocities may be imposed due to the reduced suspension travel of XCO bicycles compared to DH bicycles used in the present study (100 ± 0 mm and 202 ± 1.55 mm, respectively). This difference may result in XCO riders reducing speed to maintain bike control, consequently reducing the number of accelerations and activity of the triceps brachii muscles. Conversely, the longer travel DH bikes are capable of absorbing much higher trail forces. In addition to longer suspension travel, DH bicycles also have larger volume tyres run at lower pressures than those used for XCO, therefore further increasing ground contact enabling higher velocities whilst still maintaining control of the bike.

The higher speeds achieved by the DH riders are also likely in part to be the result of steeper DH courses, as evidenced by the greater vertical drop and descent gradient outlined in the methods, and also the more powerful brakes on DH bicycles, which allow riders to brake later and therefore maintain speed more effectively. As the brakes are more powerful, DH riders may also brake less frequently leading to the lower brachioradialis recruitment relative to triceps brachii muscles observed in the DH group, unlike that observed in the XCO group.

Mountain bike suspension systems are set up largely based on rider body mass, with the compression and rebound rate of the shocks being adjusted to suit the type of course and terrain. As such, when these systems are set up for individual riders and courses this may result in an upper limit to force transmission to the muscles and for subsequent muscular activation, again leading to the seemingly comparable sEMG amplitudes observed in each group. However, further investigation is warranted to identify the specific role suspension set up has on muscle activity. For this type of comparison to be statistically valid, riders should perform over the same course. However, this brings into question the ecological validity of such a study design and inherent risk to riders.

Results also showed significant differences in mean sEMG amplitudes within groups over both courses between muscles. Differences were observed in DH riders during both MM and NT runs between biceps brachii and triceps brachii and triceps brachii and latissimus dorsi, with the triceps brachii producing the greatest % MVIC followed by the brachioradialis. In contrast, the XCO riders produced significant differences in mean sEMG amplitude between biceps brachii and brachioradialis, with the latter being activated to the greatest extent, relative to the other upper body muscles investigated. These differences in muscle activity between groups most likely reflect differences in riding styles and body position. Due to the shorter travel bikes used in XCO racing, the XCO riders in this study showed a trend for greater elbow flexion, approximately 20º, over both courses than the DH riders, presumably to aid the absorption of trail shocks due to the reduced suspension travel available to them. The straighter elbow angle observed in DH riders could also be due to the steeper courses, result in the greater engagement of the triceps brachii muscles in these DH riders, relative to the other tested muscles, as riders move body mass further towards the rear of the bicycle to maintain stability and control on steeper ground. Though not to a level of significance, the muscle activity in the DH group was slightly lower during MM runs than NT runs for all muscles investigated. This possibly indicates a difference in body position due to the less steep gradient of the MM course, therefore reducing muscle activity and supporting the previous discussion point. In contrast, the XCO group did not show any particular trend, as the activity of individual muscles different dependent upon which course was being ridden. This may be reflective of differences in skill levels and competence in descending between riders in this group. However, both groups demonstrated high standard deviations for all sEMG data extracted, which may be indicative of the wide variation in riding styles even within the groups of elite riders tested in the current study.

Brachioradialis activity in both groups may be indicative of hand grip force on the handlebars and/or braking. As stated previously, sensor placement on the left side of the body was chosen as this was the side of the front brake for all riders and the brake most used in cycling and as such would have potentially influenced muscular activation. Though the magnitude of activation was similar for both groups, the predominant recruitment of the brachioradialis relative to other upper body muscles in the XCO group may reflect these riders braking for longer during their descents than the DH riders. This may be due to the less powerful brakes fitted to XCO bicycles resulting in earlier and more prolonged braking. As discussed previously, the brakes on DH bicycles are more powerful due to larger disc rotors and brake callipers. This would potentially reduce the frequency and duration of braking required for decelerating the bicycle. The use of accelerometers and brake levers instrumented with strain gauges may help determine the extent of the differences in braking frequency, braking force, and muscle activity between XCO and DH riders.

The finding that brachioradialis activity was the highest for the upper body muscles investigated for the XCO group in contrast the DH group may again reflect differences in body position on the bike. Modern XCO bicycles have a head tube angle of approximately 70-72º, compared to around 64-66º for DH bikes. This steeper angle would subsequently place XCO riders into a more forward position and thus potentially resulting in more force being exerted on the brachioradialis.

Peak sEMG values for both groups on both MM and NT courses were greater than 100 % MVIC. This could be the result of several factors. Firstly, as a manual resistance was used for the MVIC determination, it could be argued that true MVIC was not attained for each muscle. However, due to the field-based nature of the present study and according to the recommendations of Kendall et al (2005), the methods used are justified. Alternatively, the peak sEMG values observed during MTB descents may be due to the high eccentric loads encountered by riders when landing from large drops and jumps. Though suspension systems are effective in reducing these eccentric trail shocks, there is a limit to their capabilities and therefore the riders themselves must also absorb some of the trail shock with the upper body and leg muscles. Future research may seek to use accelerometers to quantify the eccentric loading imposed on riders in these specific instances.

Limitations

One of the limitations of the current study was the use of only one run per rider on each course. This was due to access constraints imposed by the ski resort operators. As such rider only had time to complete one run on each course. Future research should endeavour to perform multiple runs on different course to allow means to be determined to account for the variability often observed in sEMG measure.

Another potential limitation to the present study may be the determination of mean and peak values over the whole runs. As riders completed their runs in different times, muscular fatigue could potentially influence the mean and peak values determined. However, it should be noted that at the time of testing, the ability to synchronise the sEMG and GPS data were not possible, making the use of techniques such as frequency analyses to quantify the contribution of fatigue challenging. However, newer equipment now allows this synchronisation and would therefore enable the evaluation of the impact of muscular fatigue on the current study results. Additionally, these systems would also allow researcher to accurately pinpoint muscle activity at any given point on a course for all rider. Therefore, any future investigations should seek to employ these newer systems.

Conclusions

In conclusion, this study revealed differences between upper body muscles in mean and peak activity in elite XCO and DH mountain bike riders, though the magnitude of activation differed little between groups irrespective of riding conditions. This may be due to differences in riding dynamics and bicycle set-up. Future research could aim to quantify the impact of suspension set-up on muscle activity and investigate hand grip and braking forces and their influence on muscular fatigue during downhill MTB. The use of a standardised course would help evaluate the impact of these systems on the physiological and biomechanical demands of off road descending and allow direct comparisons to be made between XCO and DH riders, though such a study design would lack the ecological validity of the current study alluded to previously. Despite the limitations, the present study still presents the first investigation to attempt to evaluate the upper body muscle contribution to performance in off road downhill MTB and to determine the influence of course type on muscle activity. Future research should seek to employ novel equipment that permits synchronisation of GPS and sEMG data to extend upon the current study results.

Practical applications

The findings of the current study appear to indicate that course terrain has little influence on the mean and peak amplitudes of muscle activity during descent for both XCO and DH riders. However, there are significant differences in activity between muscles of the upper body within courses in each group. The only true means of accurately comparing XCO and DH riders would be to have them ride the same course. However, doing so would compromise the ecological validity of the study, as it is not realistic or safe to expect cyclists from different sub-disciplines of MTB to perform on courses they would not normally encounter during racing. As such the findings of the current study provide a more realistic representation into the demands of downhill MTB descent in both elite XCO and DH bikers over courses relative to their disciplines.

The current findings also indicate that differences in bicycle set ups and components may influence the physiological and biomechanical demands imposed upon MTB riders during off road descending. Athletes and coaches should therefore bear this in mind when training and preparing for different races. Most elite cyclists participate in some form of muscular conditioning programme as part of their training. Given the current findings, XCO riders would potentially benefit from focusing on forearm strength as part of a general upper body conditioning programme. In contrast, the present study would suggest that DH riders should prioritise the triceps brachii within their conditioning programmes due to the increased recruitment of this muscle group during downhill riding that was observed. Increases in strength, particularly in these areas may result in lower sEMG activity for a given force, therefore potentially reducing muscle fatigue and the risk of injury and improving overall performance.

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