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Athos Wearable Technology: A Comparison Study

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Abstract

Technological advances permit the assessment of new variables, and over time miniaturize and make portable equipment that once was restricted research or clinical settings. Validation of the new equipment is essential before it can be used. This study compared Athos Wearable Technology to a standard form of electromyography (EMG). We hypothesized that Athos would produce a similar percent of MVIC data when compared to a standard EMG during a series of movements. Participants performed five movements, once while wearing the Athos pants, and once while wearing Noraxon Wireless EMG Electrodes on their vastus lateralis, vastus medialis, and biceps femoris. The five movements were: bilateral hamstring curls, box step-ups leading with the left foot, box step-ups leading with the right foot, five steps of the Charleston dance, and then ten steps of the Grapevine. The order that the movements were performed was the same for both modes of measurement. The data were analyzed using Two-way repeated measures ANOVA and correlation analyses. The correlation results for the two forms of EMG ranged from r=-0.96 to r=0.96 indicating that relationship between the Athos suite and the Noraxon EMG were not consistent. Two-way Repeated measures ANOVA revealed that the EMG output from the Athos suite and the Noraxon were significantly different for all measurements regardless of the movement performed. In conclusion, the results of this study indicate that the Athos EMG suite does not provide data consistent with a traditional EMG system, and thus is not an acceptable alternative form of EMG to be used in clinical, research, or training setting.

Abbreviations

MVIC - maximum voluntary isometric contraction

EMG - electromyography **VMO-** vastus medialis

VLO - vastus lateralis **BF** - biceps femoris

Introduction

Skeletal muscle is responsible for all voluntary movements. During skeletal muscle contraction, several distinct cycles of alternating contraction/relaxation periods are present. Motor units are responsible for controlling the contraction/relaxation cycles of skeletal muscle. A motor unit is comprised of a motor neuron and all of the muscle fibers that it innervates (Drewes, 2000). Once a motor neuron receives enough stimulation, it transmits an electrical signal known as an action potential to the intended muscle. This action potential triggers a depolarization of the muscular membrane, which then leads to muscular contraction. Once the muscle relaxes, the membrane has no action potential. The number of motor units recruited determines the force that the skeletal muscle produces. Contractions that produce a large amount of force require a large number of motor units to be recruited (Drewes, 2000).

Electromyography, or EMG for short, can be used to assess the depolarization of the membrane (Drewes, 2000). EMG records the action potentials of motor units along muscle fibers from a neuromuscular junction and then shows these action potentials as visual data (Mañanas, Rojas-Martínez, & Alonso, 2016). Knowledge of motor unit activation is important in both clinical and athletic settings.

In the field of clinical neurophysiology, EMG can aid in the diagnosis of neuromuscular diseases (Mananas et al., 2016). Patients recovering from stroke are very likely to have neuromuscular issues. The use of an EMG to provide feedback on how the muscle is responding to therapy has important clinical implications. However, most EMG technology in clinical settings is used for diagnosis and post-therapy assessments. It is not often used throughout therapy. There are two basic types of EMG electrodes: 1) intramuscular, where needles are inserted into the muscle; and 2) surface EMG electrodes, which are placed directly onto the skin. The noninvasive surface EMG has been suggested for use in clinical practices (even though they could potentially be less sensitive than intramuscular EMG) because it is able to detect large muscle group activity and provide feedback to the care provider (Mananas et al., 2016). Traditional EMG systems have long wires that connect the electrodes and the signal processor, which makes it difficult for subjects/patients to move freely while wearing the electrodes as well as tethering the subject/patient to a confined space. While newer EMG systems (such as the Noraxon DTS Wireless Electromyography System) are wireless and allow greater freedom of movement than older EMG systems, the user is still limited by the range of the system, its access to external power sources, and cost.

A company named Athos has developed garments that claim to utilize EMG in order to provide information about muscle activity during exercise. Athos suits claim to record the percentage of "maximal exertion" during movement. "Maximal exertion" refers to a person's maximal voluntary isometric contraction (MVIC). Athos takes these maximal values and records the percentage of the MVIC that a person reaches throughout the workout. Athos is marketed for elite training because it claims to give reliable and instant feedback about muscle group activity as a person is training. It can provide feedback on whether a user is sided (using their right or left side more than the other). Unlike traditional EMG methods, the Athos wearable technology is self-contained and includes both the electrodes and data recorder, which allows the user virtually unlimited freedom. However, the data recorder does not store the raw EMG tracings, and proprietary algorithms convert the data to a single value (percent of MVIC).

This technology is marketed for optimizing athletic performance. However, no data is available that demonstrates the validity of this equipment compared to traditional EMG technology. Therefore, the purpose of this study was to compare the Athos wearable EMG suit to a traditional EMG model (the Noraxon DTS Wireless Electromyography System).

The Athos “men’s shorts” and “women’s leggings” record data for the “hamstrings,” “inner quad,” and “outer quad.” Three muscles were targeted specifically for the Noraxon system to compare to these three muscle groups: the vastus medialis, vastus lateralis, and the biceps femoris. The biceps femoris is also known as the hamstring (The Muscles, 1989). The biceps femoris has two origins: the long head originates in the ischial tuberosity and the sacrotuberous ligament, and the short head originates in the lateral lip of linea aspera and lateral supracondylar line of femur as well as in the lateral intermuscular septum (The Muscles, 1989). The biceps femoris inserts into the lateral side of the head of the fibula, lateral condyle of the tibia and the deep fascia on the lateral side of the leg (The Muscles, 1989). The biceps femoris allows for flexion and lateral rotation of the leg at the knee, extends, adducts and laterally rotates the thigh at the hip (The Muscles, 1989).

The vastus lateralis and vastus medialis are both part of the muscle group known as the quadriceps (The Muscles, 1989). The vastus medialis originates at the lower half of the intertrochanteric line, medial lip of linea aspera, upper part of medial supracondylar line, medial intermuscular septum, and the tendons of adductor magnus and adductor longus (The Muscles, 1989). The vastus medialis inserts at the medial border of the patella and through the ligamentum patella into the tibial tuberosity (The Muscles, 1989). The vastus medialis extends the leg at the knee and draws the patella medially (The Muscles, 1989). The vastus lateralis originates at the upper part of the interochanteric line, anterior and lower borders of the greater trochanter, the lateral lip of the gluteal tuberosity, upper half of the linea aspera, lateral intermuscular septum, and the tendon of the gluteus maximus (The Muscles, 1989). The vastus lateralis inserts into the lateral border of the patella and through the patellar ligament into the tibial tuberosity. The vastus lateralis extends the leg at the knee and draws the patella laterally (The Muscles, 1989).

This study asked participants to perform hamstring curls, box step-ups, the Charleston, and the Grapevine. The hamstring curls and box steps require extension and flexion of the knee, requiring involvement from vastus lateralis, vastus medialis, and biceps femoris. The dance movements (the Charleston and the Grapevine) also require extension and flexion, but were expected to require greater utilization of the hamstrings due to more adduction and lateral rotation at the hip (The Muscles, 1989).

The null hypothesis for this experiment is that the Athos Wearable Technology will provide similar percent of MVIC as the Noraxon EMG, meaning that these percentages will not be statistically significant from the Noraxon EMG results and will not correlate to the Noraxon values.

Methods

Six dancers were recruited to participate in the study: three females and three males. However, the data for the first two participants (one male and one female) could not be used because of a user error made on the Noraxon program during the Noraxon EMG portion of testing.

Subject Demographics					
Participant Number:	**Gender:**	**Age (years):**	**Height (feet):**	**Weight (pounds):**	**Dominant Leg:**
1	Female	22	5’5”	120	Left
2	Female	21	5’9”	140	Left
3	Male	21	5’4”	145	Right
4	Female	21	5’8”	135	Right
5	Male	23	5’7”	150	Right
6	Male	22	5’11”	150	Right

Subjects were asked to perform a total of three sets of ten repetitions of the five movements per EMG collecting device. All participants signed an informed consent form before beginning the study. The inclusion/exclusion criteria for this study is attached. No subjects were required to be excluded from this study.

Study Design:

Participants were assigned to either order A or B before beginning the study. Three were assigned order A, and three were assigned order B. Participants assigned to order A wore the Athos EMG Shorts for the first round of exercises and exercise shorts with EMG electrodes on their skin for the second round of the same exercises. Participants assigned to order B wore the Noraxon EMG electrodes first and the Athos suit second. After their order was assigned to them, subjects' suit size was ascertained based on verbal communication regarding typical pants size. Then, they were asked to present their dominant leg. All data, both Athos and Noraxon, was collected for only the participant's dominant leg because that leg should provide the most consistent results.

Athos EMG Suit:

When it was time for the participants to be tested with the Athos shorts, an Athos profile was created for each of them. The Athos program requested each participant's age, height, and weight. The Athos sensors require direct contact to the skin, so the subjects left the room to undress and put on the Athos shorts. After they returned, the Athos program then asked the subjects to calibrate the suits by performing light activity for five minutes. However, due to time constraints and the space of the testing location, this type of calibration was not completed. Instead, subjects calibrated the suits via two MVIC's. First, the subjects performed the MVIC for vastus lateralis and vastus medialis. During this calibration, the subjects were asked to sit on a treatment table and extend their knee as hard as they could against the static opposing force of the principal investigator's hand. The second MVIC was for biceps femoris. During this calibration, subjects lay prone on a treatment table, with the portion of their leg that contained the Athos sensors hanging off of the table so as not to interfere with data collection. Then, the subjects were asked to flex the knee of their dominant leg as hard as they could against the static opposing force of the principal investigator's hand.

Noraxon EMG System:

When it was time for the participants to be tested with the Noraxon EMG, three electrodes were placed on the vastus lateralis ("outer quad" according to Athos), the vastus medialis (the "inner quad" according to Athos), and the lateral aspect of the biceps femoris (hamstring). The sensors were placed in the middle of the muscle belly. Two sensors were placed on the skin, parallel with the muscle fibers, and then connected to the wireless transmitter, which conveyed the EMG information to a nearby laptop. Participants performed the same two MVIC's exactly as described in the Athos calibration.

Movement Patterns:

After the respective calibrations, the subjects began the movements. Each of the five movement was repeated three times before moving on to the next movement. First, subjects performed bilateral hamstring curls. Subjects lay prone on a treatment table, with the portion of their leg that contained the Athos sensors or the Noraxon EMG electrodes hanging off of the table so as not to interfere with data collection. They then performed ten bilateral hamstring curls. This was repeated two more times for a total of three sets. Next, the left leg box step-up was performed. Subjects stepped up onto a twelve inch box leading with their left leg. The left foot remained on the box for all ten repetitions while the right foot touched the floor in between repetitions. This was also repeated for a total three sets. For the next movement, the subjects switched leading legs so that the right leg was leading the movement and performed box step-ups for the same number of repetitions and sets. The Charleston dance move was performed next. The Charleston dance move consists of five repetitions of the “kick” portion of the dance which involves moving the right leg forward first then behind the left leg, then the left leg back behind the right and forward again. This was also done for three sets. Lastly, the Grapevine Dance movement was performed. The Grapevine consists of five steps side to side from beginning to end. The right leg comes out as the left comes behind it, right leg out again and left leg comes in front while moving laterally to the left. The number of steps was increased from the initial five steps to ten steps after the first subject, because it was discovered that five steps did not yield enough data. This was also done for three sets.

Data Analysis:

The same five movements were done in the same order using the same set and repetition scheme while using the alternative mode of EMG. A rest period was present during the change of the type of EMG while the subject changed into or out of the Athos pants. The subjects performed the same movements while wearing this form of EMG sensor. The data for Athos was stored in an Excel document, while the data from the Noraxon system was saved to the MyoMuscle EMG Analysis Software so that it could be condensed later for analysis. Data were analyzed by two-way analysis of variance with repeated measures on both factors to determine differences between Athos and Noraxon results. Pearson correlation were used to analyze the degree of association and direction of association between Athos and Noraxon results. Data were considered significant if $\alpha \leq 0.01$.

Results

The Noraxon data had to be condensed in order to be compared to the Athos data. The Noraxon data was originally shown in millivolts. The mean of the three sets of muscle activation (in millivolts) during each activity was divided by the peak of the MVIC in order to determine the percentage of activity. This normative data is what Athos produces. The values are the percent of MVIC. Since the sample size was 4, the power was low and alpha was set to a p-value<0.1. Utilizing two-way ANOVA analysis of the data with repeated measures for both factors it was found that the Noraxon EMG produced statistically significant data throughout each exercise and participant. The p-value was consistently below 0.1. The Athos data was never below 0.1. There was no correlation between the two forms of EMG either. Between Athos and Noraxon no interactions were found. Then, trends between the data were examined to see if Athos showed the same muscle groups activating on average higher or lower during an exercise compared to the same muscle groups with EMG. Only one exercise showed trend data that was comparable. The hamstring curl followed the same trend for both Athos and Noraxon; however, Athos produced markedly lower values. The other exercises showed no consistent trends within the data. There were data points that were very high for the Noraxon EMG. One exercise produced EMG data that was 785% of that participant’s MVIC. Athos also had several data points that were over 100% of the participant’s MVIC. This can be seen visually in the bar graphs below.

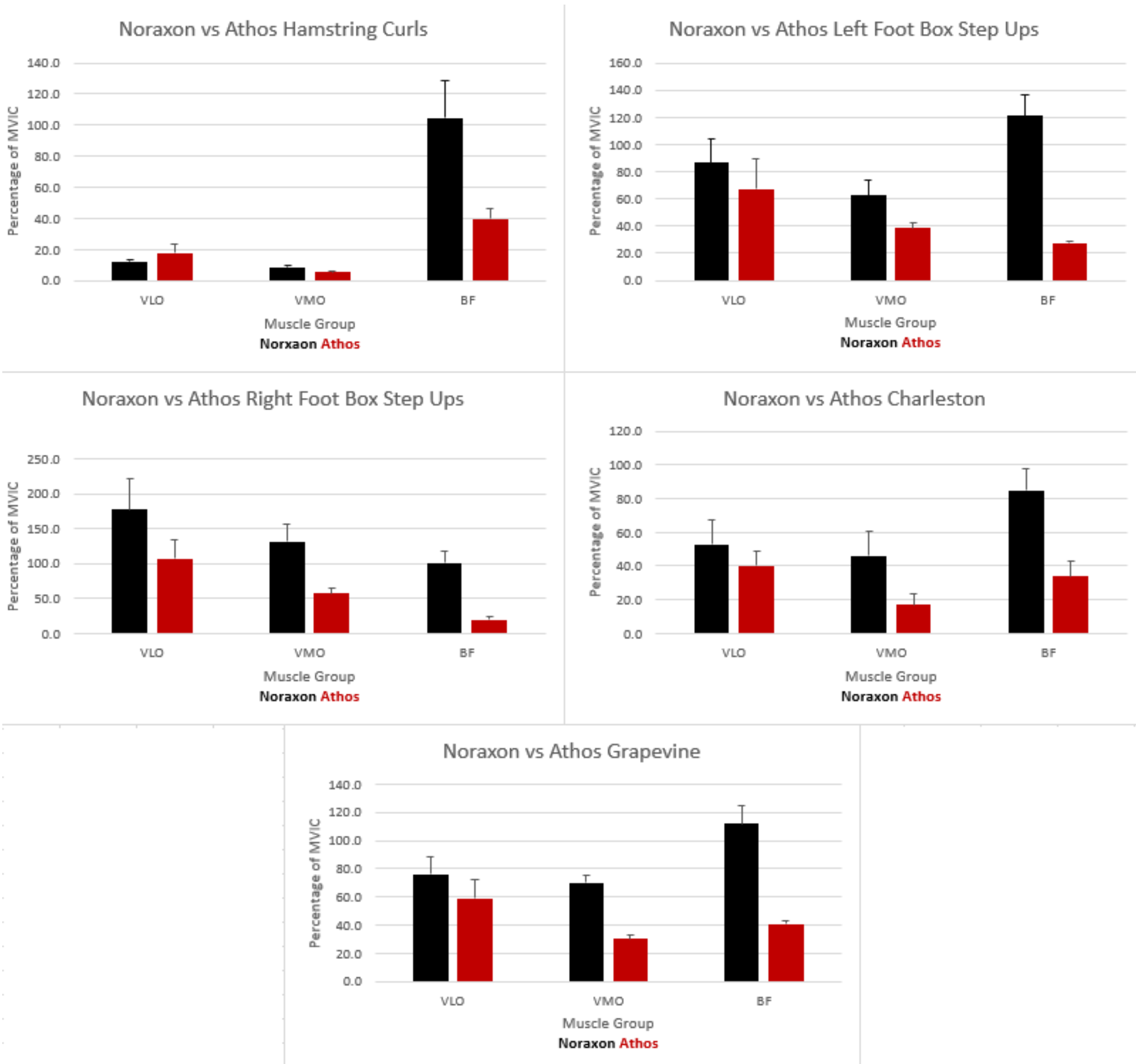

Figure 1-Noraxon vs Athos average percent of MVIC values for each exercise. VLO stands for vastus lateralis (outer quad for Athos), VMO stands for vastus medialis (inner quad), and BF stands for biceps femoris (hamstrings).

The above figures show the mean for the percent of MVIC for each muscle group. The black bars show the data from the Noraxon system and the red bars show the data from Athos. The standard error is on top of each bar.

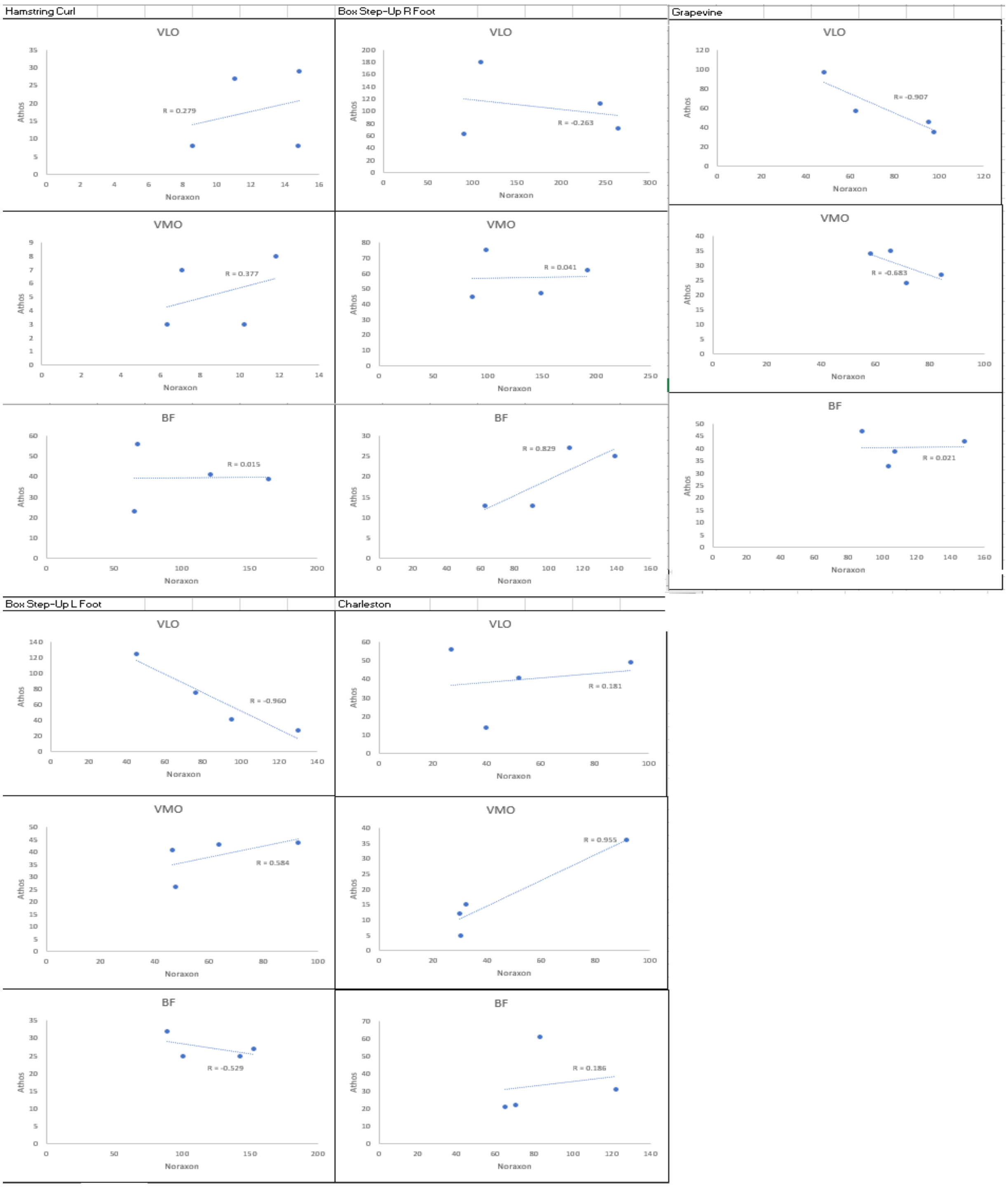

Figure 2- The correlations per muscle per exercise for with Athos compared to Norazon with R values listed for each. All four participants average data are represented in the graph with a trendline demonstrating the correlation of the data.

Figure 2 shows the correlation between Athos and Noraxon for the individual data of the participants. The R-values are represented in the graph along with a trend line. The R-values vary from positive values to negative values with some correlations being -0.960 and others being as high 0.955 and values in the middle such as -0.263, 0.041, and 0.377. There were no consistent correlations across the different exercise or different muscles.

Discussion

This is the first study to compare the results of the Athos EMG suit to a traditional EMG. The data do not support the validity of the Athos suit and therefore reject the null hypothesis.

The data analysis shows that Athos does not provide statistically significant data. The trends for the suits do not match the same muscle trend patterns as the Noraxon EMG, demonstrating that the suits do not accurately show the magnitude of muscle firing. This indicates that the suits do not accurately represent how much each muscle group is working, since they provide much lower numbers for percent of MVIC than what actually occurred. It was anticipated that the Athos program would provide higher data than the Noraxon EMG because Athos incorporates two muscles in its "outer quad," the rectus femoris and the vastus lateralis, while the Noraxon EMG just had the vastus lateralis as "outer quad." In other words, Athos recorded the effort of two muscles for "outer quad" while the Noraxon EMG only recorded the effort for one muscle for the "outer quad." However, Athos had consistently lower measures for the "outer quad" in comparison to the Noraxon EMG. Future studies should also place a sensor on the rectus femoris so that all of the same muscles are compared. There is no consistent correlation between Noraxon and Athos. As shown by Figure 2, the data is randomly distributed. There are no consistent correlations, meaning that Athos is not reliable. It does not show consistent differences, nor consistent similarities. The two way ANOVA analysis with repeated measures showed that Athos did not provide reliable data when compared to itself while Noraxon provided consistently reliable data, always have a p-value of less than 0.1. Athos never provided a p-value below 0.1 for any of the trials. This indicates that it does not accurately provide data between sessions.

Limitations of the Athos Shorts:

The sensors in the Athos suits require close skin contact in order to collect EMG information. Future studies should consider enhancing the connection between skin and Athos sensors via water or some kind of electrical transmitting gel, similar to the kind used for EMG electrodes. Participants also need to wear the suit multiple times to ensure proper calibration. Participants should go through a proper calibration phase and wear the suit again later as Athos re-calibrates after multiple training sessions.

While our study found that Athos suits are not a suitable substitute for a standard EMG in a research or clinical setting, they could still be used as a tool in an athletic setting. This study did not evaluate sidedness, so Athos suits could still potentially be valuable in that sense.

Conclusion

There were many issues with the suits throughout this experiment. However, if properly calibrated, Athos suits may be suitable for people who are training recreationally in order to determine if they are activating the muscles that they wish to activate. The Athos suits do show "sidedness," meaning that the suit tells you if you are activating one half of your body more than the other as well as showing if you are off balance. This could have clinical implications, allowing physicians or therapists to see if patients are performing movements correctly and not using one side more than another. The effectiveness of these suits should be further analyzed in future studies to see if it provides more reliable data under different conditions including multiple wears and use of a conductive substance such as gel or water.

Limitations

The Athos suits did not provide the anticipated data. On the website there are pictures of EMG readouts (refer to Figure 3), which gave the impression that the suits were going to provide typical neural EMG data in addition to the percent of MVIC data. This was not the case. The only data that the Athos suits yielded was regarding the percent of MVIC. Therefore, the research question as well as the data analysis had to be restructured around this new information. There were no prior indications that the suits would need calibration, meaning that until a participant wore the suit we did not realize there would need to be a five minute long calibration period. No user manual was included with the suits, although it appears one could be possibly have been requested.

Figure 3- Image from the Athos company regarding EMG activity and showing an image that relates to the images from the app making it appear as though this would be the way EMG would be shown in the Athos app.

Another issue relating to the low subject sample size was due not only to limited recruitment time but also due to the fact that the data from two subjects could not be used. The rectus femoris was selected instead of the vastus lateralis for the Noraxon EMG system. The system requires care selection of the muscles that have the sensors placed on them. This caused the data to be inverted. The wrong muscle was selected for the entire data collection of two participants making the data unusable. This made the small sample size of 6 subjects even smaller. As previously stated, a larger sample size should be used in the future to increase the power of the data.

Finally, Athos does not specify the actual muscles being looked at. They use terms like "inner quad" and "outer quad" but do not state which muscles they mean, such as the vastus lateralis and rectus femoris for "outer quad." This is done more for marketing purposes but is a limitation of the suit and the muscles should be listed rather than using generic terms.

Citations

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