MISSION-DIRECT RESEARCH

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MOUNTAIN TACTICAL INSTITUTE
MTI WHITE PAPER - CASE STUDY:

The Physiological Demands of Snowmobile Hill Climbing

The Physiological Demands of Snowmobile Hill Climbing

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1. STUDY SUMMARY

1-1. Purpose

To date, not a single study could be found which assessed the physical and physiological demands of Snowmobile Hill Climbing. The purpose of this study was to quantify the demands faced by our snowmobile athletes so that we can better prepare them for their competitions.

1-2. Subjects & Event

Both case study subjects were experienced hill climb racers. The male athlete (35 years old) had just over two years of competitive experience and the female (32 years old), a professional, had four years of racing experience.

All races were completed between 26-28 FEB, 2016 in Afton, WY. The competition was part of the 2016 Rocky Mountain States Hill Climb Association race series. Race Link

1-3. Design

This case study was conducted in two parts. The first looked specifically at race and physiological data. The second assessed muscle activation.

Part I: Race and athlete data was collected over the course of four hill climb trials - two for each athlete. During all four trials the athletes wore a Medtronic Zephyr Bioharness 3.0 (Model BH3) which collected physiological and GPS data.

Part II: During a single trial MTI collected a snapshot of muscle activation data using Athos Surface Electromyography (sEMG) garments.

1-4. Results & Discussion

Part I: Found that Hill Climb race data varied greatly depending on the course and the athlete. However, our four trial produced the following averages: Hill Grade Incline = 44.5%; Time = 33.0 sec; Horizontal Distance = .14 miles; Elevation covered: 338.1 ft; Max Speed = 23.7 mph; Average Speed = 13.8 mph.

Physiologically, our data showed that both our male and female athletes were competing at over 80% of their max HR (84.4% and 84.2% respectively). Subjects also experienced a 42.5% and 55.3% increase in their breathing rate and a 41.4% and 44.6% decrease in their HRV, respectively. This decrease in HRV is indicative of increased sympathetic nervous system activation, often characterized by “fight or flight” decision making in times of high stress.[1]

Part II: Found about twice as much muscle activation in our athlete’s upper body as in their lower body. This is likely a combination of “muscling” the sled through difficult terrain and also a reaction to both Whole Body Vibration (WBV) and Hand Arm Vibration (HAV) discussed in previous research.[2],[3]

[1] (12) Nunan, D; Gavin, R; Sandercock, H and Brodie, D. A quantitative systematic review of normal values for short-term heart rate variability in health adults. *Pacing Clin Electrophysiol.* 33(11):1407-1417, 2010.

[2] (3) Antonnen,H. and Virokannas, H. Hand-arm vibration in snowmobile drivers. *Arctic Medical Research*, 53(3), 19-23, 1994b.

[3] (4) Kjellberg, A., Wikstrom, B. Whole-body vibration: exposure time and acute effects – a review. *Ergonomics*, 28(3), 535-544, 1985.

Our study also found that, although the posterior muscle groups were slightly more active (4-5%), our rider's muscle activity was fairly even between anterior and posterior muscle groups in both the upper and lower body.

1-5. Conclusion and Recommendations

Based on the data collected during this case study MTI makes the following conclusions and recommendations for applying the information.

1. **Snowmobile Hill Climb racing should be classified a high-intensity anaerobic activity.**
   Recommendation: To train this attribute, MTI recommends the inclusion of maximal effort high intensity interval training of between 60 and 180 seconds.

2. **Balanced (pushing and pulling) upper body muscular endurance is a major component of Snowmobile Hill Climb race performance.**
   Recommendation: Based on this MTI would recommend strength training which utilized higher rep ranges and focused on loads of between 50-60% 1RM. Strength training should also balance pushing and pulling movements. Finally, based on previous research, vibration-based training could also serve as a valuable tool.

3. **Finding the right balance of psychophysiological stress, as measured by HRV, should have a positive effect on hill climb performance.**
   We found that both athletes had their worst performances during their lowest HRV measures. This seems to hint at a "sweet shot" between too much stress and too little - which is fairly common in extreme activities.[4]

[4] (12) Nunan, D; Gavin, R; Sandercock, H and Brodie, D. A quantitative systematic review of normal values for short-term heart rate variability in health adults. *Pacing Clin Electrophysiol.* 33(11):1407-1417, 2010.

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3. INTRODUCTION

3-1. Previous Research

Not a single study could be found which examined the sport of competitive snowmobiling. To date, research pertaining to snowmobiling has been almost wholly focused on injuries in occupational and recreational riders.[5] Although not specific to the sport of hill climbing, the occupational and recreational injury research does offer a few key points of interest.

3-1.1 Whole Body Vibration (WBV)

The first such item is whole body vibration (WBV). WBV is the reverberation from the machine's engine which is transferred to the rider through the seat and floorboard.[6] From an epidemiological stand-point WBV is important because it increases the driver's risk for developing injuries and functional disorders of the skeleton and of the joints.[7] From a competitive standpoint, WBV undoubtedly has a physiological impact on a rider's performance.

Exposure to WBV has been shown to immediately increase muscle activation. Electromyogram (EMG) recording have shown that WBV causes muscles to become vigorously active in order to control motion, stabilize movements and through a phenomenon called "tonic reflexes".[8]

3-1.2 Hand Arm Vibration (HAV) and Steering

Much like the snowmobile seat and floorboard, according to a 2006 study by Astrrom et al., snowmobile steering devices also transmit a possibly hazardous level of vibration-acceleration to the upper limbs.[9] From a competitive stand-point this upper body vibration drastically increases upper body muscle activation as the rider attempts to pilot the sled while fighting to stabilize the vibrating yoke.

Furthermore, driving in a standing or kneeling position (as is done in a snow mobile hill climb) has been shown to cause the driver to shift their body mass away from its supporting points which increases the physical force needed to hold and steer the yoke.[10]

3-1.3 Overall Demands

The task of manipulating a 400+ pound, unstable machine under difficult environmental conditions is both inherently risky and demanding. Epidemiological studies have shown that even occupational and recreational operators are at an increased risk of musculoskeletal injuries in the back, neck, shoulder, arm and knee.[11]

It stands to reason that the increased intensity of competition only furthers these physical demands and risks. Although no research to-date has looked specifically at competitive snowmobile racing, a 2002 study from Rehn et al. definitely found this to be true. In their study, Rehn et al. concluded that competitive all-terrain vehicle (ATV) racers experienced 2-3 times as many injuries as a control group of occupational riders like park rangers.[12]

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[5] (1) Pierz, J. Snowmobile injuries in North America. *Clinical Orthopaedics and Related Research*, 409, 29-36, 2003.

[6] (2) Anttonen, H. and Niskanen, J. Whole body vibration and the snowmobile. *Arctic Medical Research*, 53(3), 24-28, 1994a.

[7] (4) Kjellberg, A., Wikstrom, B. Whole-body vibration: exposure time and acute effects – a review. *Ergonomics*, 28(3), 535-544, 1985.

[8] (5) Torvinen, S; Kannus, P; Sievanen, H; Jarvinen, T; Pasanen, M; Kontulainen, S; Jarvinen, T; Jarvinen, M; Oja, P and Vuori, I. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology and Functional Imaging*, 22(2), 145-152, 2002.

[9] (6) Astom, C; Rehn, B; Lundstrom, R; Nilsson, T; Burstrom, L and Sundelin, G. Hand-arm vibration syndrome (HAVS) and musculoskeletal symptoms in the neck and the upper limbs in professional driver of terrain vehicles – A cross sectional study. *Applied Ergonomics* 37, 793-799, 2006.

[10] (7) Nayha, S; Antonnen, H and Hassi, J. Snowmobile driving and symptoms of the locomotive organs. *Arctic Medical Research*, 53(3), 41-44, 1994.

[11] (8) Heisler, E. The Relationship of snowmobile year, track length, and riding terrain to the occurrence of musculosketetal symptoms in recreational snowmobile drivers. *UNLV Theses/Dissertations/Professional Papers/Capstones.* Paper 766, 2010.

[12] (9) Rehn, B; Bergdahl, C; Ahlegran, C; From, C; Jarvholm, B; Lundstrom, R; Nilsson, T and Sundelin, G. Musculoskeletal Symptoms among Drivers of All-Terrain Vehicles. *Journal of Sound and Vibration* 253(1), 21-29, 2002.

3-2. MTI's Mission Direct Approach

As can been seen above there is very little which is know about the specific physiological demands of a snowmobile hill climb competition. As the sport continues to grow and athletes become more and committed to maximizing their performance this lack of physiological understanding is sure to hold-back athlete's progress.

Our driving purpose at the Mountain Tactical Institute is:

To improve mountain and tactical athletes' mission performance, and keep them safe.

Central to this purpose is the focused intention of being "Mission Direct" in everything that we do – daily training sessions, training plans, articles, research, etc.

For this particular study being "Mission Direct" means simply trying to understand the physical demands faced by our athletes so that we can better prepare them for their performance.

4. STUDY DESIGN

4-1. Subjects

This case study used two subjects, both experienced hill climb racers. The subject's demographic information can be found in TABLE 1.

TABLE 1: Subject Data

		Subject 1	Subject 2
	Gender	Male	Female
Age	years	35	32
Height	inches	72	65
Weight	pounds	195	125
Pre-Race HR	Beats/min	102.0	104.0
Pre-Race BR	Br/min	20.0	19.0
Pre-Race HRV	rMSSD (ms)	59.1	50.8
Racing Experience	years	2	4

4-2. Event

Races were completed between 26-28 FEB, 2016 in Afton, WY. The competition was part of the 2016 Rocky Mountain States Hill Climb Association race series. Race Link . Athlete placing was as follows:

TABLE 2: Event Performances (2016 Afton Hill Climb)

Male Events	Afton Placing
Semi-Pro Stock	11th
Semi-Pro Improved	14th
Semi-Pro Mod	N/A

Female Events	Afton Placing
Pro Women's Stock	7th
Pro Women's Improved	6th
Pro Women's Mod	5th

4-3. Data Collection

This case study was conducted in two parts. The first looked specifically at race and physiological data. The second assessed muscle activation.

PART I: Race and athlete data was collected over the course of four hill climb trials - two for each athlete. During all four trials the athletes wore a Medtronic Zephyr Bioharness 3.0 (Model BH3) which collected physiological and GPS data.

PART II: During a single trial MTI collected a snapshot of muscle activation data using Athos Surface Electromyography (sEMG) garments.

4-3.1 PART I: Physiological and GPS data

Physiological data was collected using the Medtronic Zephyr Bioharness 3.0 (Model BH3). The two athletes wore the bioharness during their entire day of competition. Data was collected throughout the entire 8-12 hour period. Then using OmniSense 4.0 software the researchers were able to chunk the data into trial runs, competitive trials and rest periods.

The physiological data included: Heart Rate (HR), Heart Rate Variability (HRV), Breathing Rate (BR), and accelerometer measures. Using the GPS data, MTI was able to assess: Time, Distance, Elevation, Speed and Acceleration.

4-3.2 PART II: Muscle Activation

To assess muscle activation our female athlete donned Athos upper body and lower body Electromyography (EMG) garments. This clothing system uses Surface Electromyography (sEMG) via embedded electrodes to detect electrical activity generated by the wearer's muscles.

The clothing reports unilateral muscle activation in six upper body muscle groups and four lower body muscle groups. The Athos system reports "percent muscle effort [PME] on a scale of 0 to 100% where 100% is [an individual's] highest potential." According to the company, a muscle effort score is based on the sEMG upper signal bound (the highest signal or output an individual's muscle can produce).

4-3.3 Statistical Analysis

Descriptive statistics were calculated and reported using Microsoft Excel for Mac, version 15.19.1 (2016).

5. RESULTS & DISCUSSION

Note: *According to the International Snowmobile Racing Inc. Rules (2014) "[Course] format may vary according to the region, hill conditions and promoter preference…" Therefore all data should be assumed to be specific to the event in-which it was collected.*

5-1. PART I: Physiological and GPS Results

5-1.1 Race Data

Data was collected over two trials for each of athlete. Trial data varied considerably between the trials and the athletes. However the following averages were calculated in order to provide a "snapshot" estimate of a single race. TABLE 3 contains the race data averages by subject.

TABLE 3: Average Race Data by Subject

		Subject 1	Subject 2
Gender		Male	Female
Time	sec	39.5	26.5
Distance	miles	0.16	0.11
Elevation	ft	392.4	229.5
Average Grade	%	46.2	41.4
Speed max	mph	25.2	20.7
Speed avg	mph	14.1	13.4
Peak Acceleration	g	1.9	2.2

Below in FIGURE 1 is an example of the GPS race data which was collected during an athlete's trial. FIGURE 2 is the same trial, but zoomed out and overplayed with terrain and physiological data (%HR max). The trial displayed in both figures was completed by Subject 2 and lasted roughly 32 seconds. This trial covered about 1/3 of the hill climb course.

FIGURE 1: GPS Race Data

FIGURE 2: Physiological Race Data

5-1.2 Physiological Data

Despite the differences found between the athlete's trials, the physiological data was fairly consistent. TABLE 4 contains each subject's average physiological data as collected during their two trials.

TABLE 4: Race Physiological Data by Subject

		Subject 1	Subject 2
	Race Class	M	F
HR max	BPM	168.0	164.5
HR avg	BPM	152.0	160.0
BR max	Br/min	30.0	35.5
BR avg	Br/min	28.5	29.5
HRV min	rMSSD (ms)	28.0	21.5
HRV avg	rMSSD (ms)	34.6	27.8

As can be seen in TABLE 4, during their races both athletes were competing at over 80% of their max HR (84.4% and 84.2% respectively). Subjects also experienced a 42.5% and 55.3% increase in their breathing rate and a 41.4% and 44.6% decrease in their HRV.

This decrease in HRV is indicative of increased sympathetic nervous system activation, often characterized by "fight or flight" decision making in times of high stress. This response allows our athletes to narrow their focus and be reactive to the task-at-hand. However, research has shown that too tight of focus can have a negative effect on performance.[13] This was definitely the case for both of our athletes. Our data showed that between the two measured trials, the event with the lower HRV score was the worst performance.

5-2. PART II: Muscle Activation

Note: *Due to the limitations of Electromyography (EMG) garments, muscle activation was only assessed for a 15 second period during the race. Thus, muscle activation data represents a "snapshot" of the entire race.*

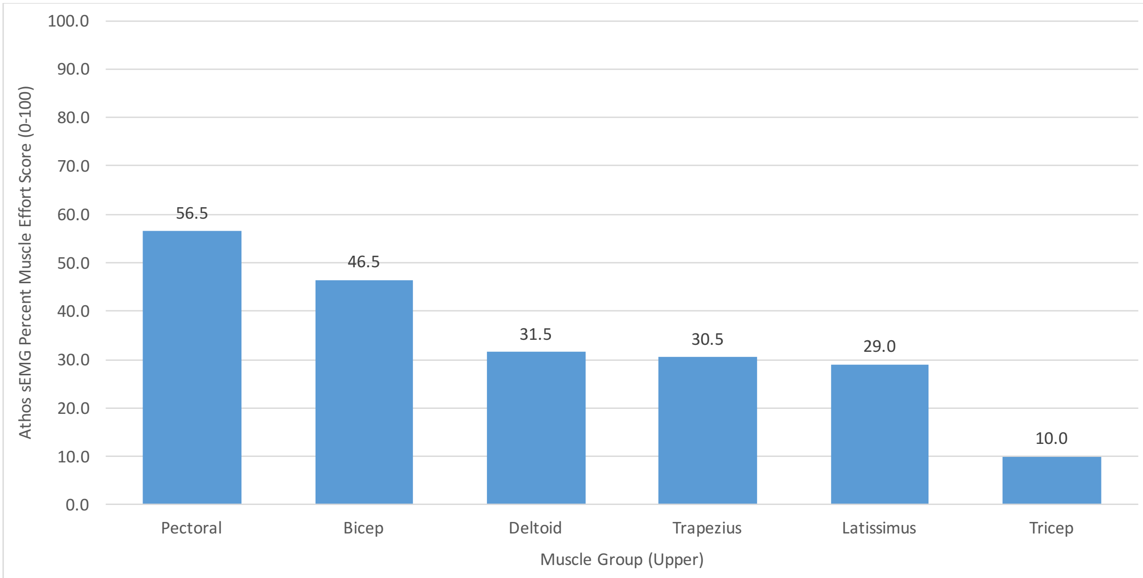
The system used in the study reports "percent muscle effort [PME] on a scale of 0 to 100% where 100% is [an individual's] highest potential." Thus, muscle activation scores will fall between 0 and 100.

5-2.1 Upper Body

Upper body muscle activation was recorded in six major muscle groups. GRAPH 1 shows the PME score recorded during the trail.

[13] (12) Nunan, D; Gavin, R; Sandercock, H and Brodie, D. A quantitative systematic review of normal values for short-term heart rate variability in health adults. *Pacing Clin Electrophysiol.* 33(11):1407-1417, 2010.

GRAPH 1: Upper Body PME Muscle Activation (0-100)

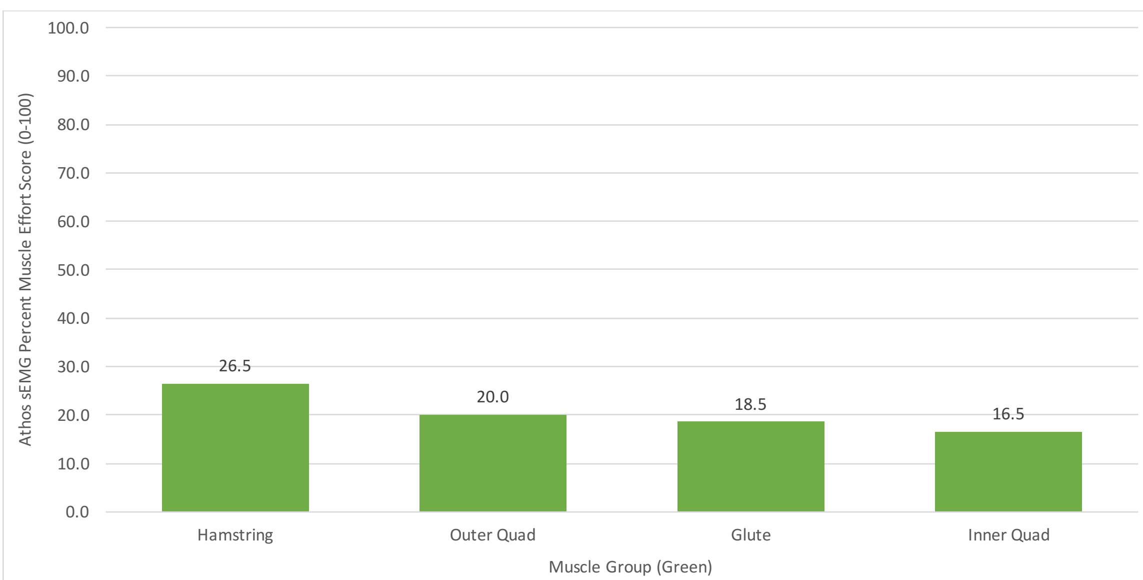


Clearly the graph shows that the pectoral muscles were the most active. What is possibly more interesting is the similarity we see in muscle activation between pushing (pectorals and triceps, PME = 66.5) and pulling (bicep and latissimus, PME = 75.5) groups.

5-2.2 Lower Body

Lower body muscle activation was recorded in four major muscle groups. GRAPH 2 shows the PME score recorded during the trail.

GRAPH 2: Lower Body PME Muscle Activation (0-100)

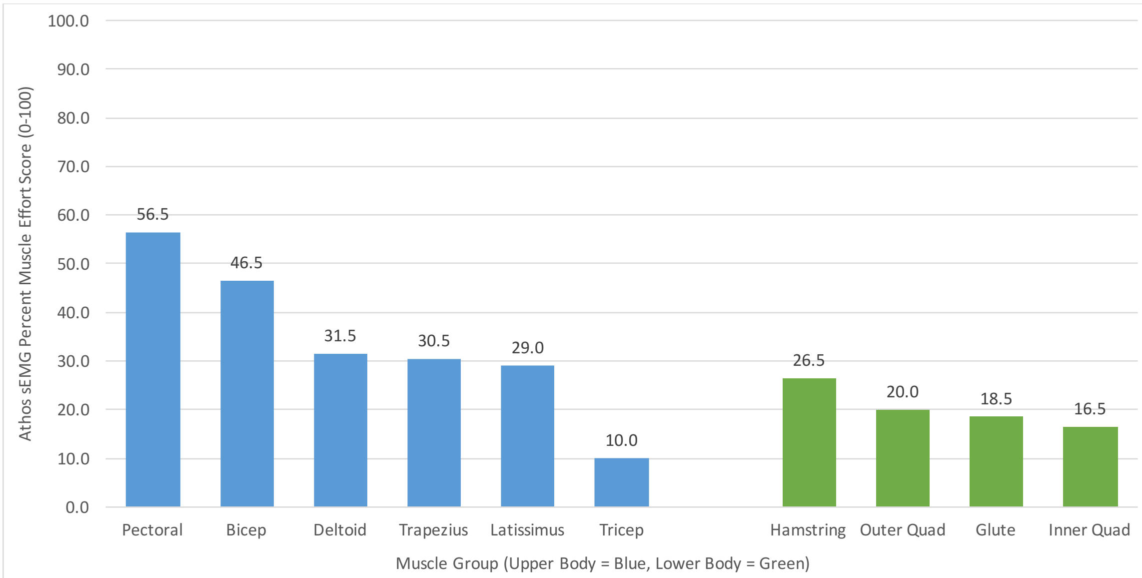


Lower body muscle activation was fairly evenly spilt between the four groups (PME range 26.5 - 16.5). Just like was found in the upper body measurements, we see a reasonable balance between anterior (outer and inner quad) and posterior (hamstring and glute) lower body groups.

5-2.3 Overall Discussion

Our data shows that, during a snowmobile hill climb, the rider's upper body is significantly more active than their lower body. This difference is compelling given the fact that a snowmobile racer is not only standing during the race, but is also traversing across the seat multiple times in order to steer the sled. GRAPH 3 shows a side-by-side comparison of upper- and lower-body muscle activation.

GRAPH 3: Upper and Lower Body PME Muscle Activation (0-100)



The significant load placed on the upper body is likely a combination of "muscling" the sled through difficult terrain and also a reaction to both WBV and HAV.[14,15] Previous research has shown the intense effect vibration can have on muscle activation and thus, WBV likely also plays a significant role in the lower body muscle activation.[16]

Lastly, of note, although the posterior muscle groups were slightly more active, it seems that piloting a snowmobile during a hill climb is actually fairly evenly split between anterior and posterior muscle groups. For the upper body, anterior muscles produced a cumulative PME score of 98.0 while the posterior muscles were slightly higher, with a PME score of 106.0. For the lower body, anterior muscles produced a cumulative PME score of 36.5 while the posterior muscles were, again, slightly higher at 45.0.

[14] (3) Antonnen,H. and Virokannas, H. Hand-arm vibration in snowmobile drivers. *Arctic Medical Research*, 53(3), 19-23, 1994b.

[15] (4) Kjellberg, A., Wikstrom, B. Whole-body vibration: exposure time and acute effects – a review. *Ergonomics*, 28(3), 535-544, 1985.

[16] (4) Kjellberg, A., Wikstrom, B. Whole-body vibration: exposure time and acute effects – a review. *Ergonomics*, 28(3), 535-544, 1985.

6. CONCLUSIONS & RECOMMENDATIONS

Based on the data collected during this case study MTI makes the following conclusions and recommendations for applying the information.

1. **Snowmobile Hill Climb racing should be classified a high-intensity anaerobic activity.**
   With a maximum duration of between 60-120 seconds, a Snowmobile Hill Climb performance easily fails under the anaerobic energy system. Based on the finding that athletes are competing at between 80-90% of max HR, MTI classifies the event as high-intensity.

   Recommendation: To train this attribute, MTI recommends the inclusion of maximal effort high intensity interval training of between 60 and 180 seconds.

   Examples of Snowmobile Hill Climb Training circuits:

   5 Rounds
   - 15sec Shuttle Sprints
   - 15sec Battle Ropes
   - 15sec Burpees
   - 15sec Push-Ups
   - 90sec Rest

   5 Rounds
   - 90sec Repeat: Lateral Burpee Box Jump + 10 Push-Ups
   - 90sec Rest

2. **Balanced (pushing and pulling) upper body muscular endurance is a major component of Snowmobile Hill Climb race performance.**
   Our case study showed about twice as much activity in the upper body as it did in the lower body. We believe that most of this is easily attributable to "muscling" the sled through difficult terrain and WBV and HAV.[17],[18] This would also account for the fairly even balance we found between anterior and posterior activation (pushing and pulling).

   Furthermore, with upper body muscle activation between 10% and 56% of maximum effort, MTI would classify the strength demand as "strength endurance" rather than "maximum strength" (i.e. 90-100% maximum effort).

   Recommendation: Based on this MTI would recommend strength training which utilized higher rep ranges and focused on loads of between 50-60% 1RM. Strength training should also balance pushing and pulling movements. Finally, based on previous research, vibration-based training could also serve as a valuable tool.

3. **Finding the right balance of psychophysiological stress, as measured by HRV, should have a positive effect on hill climb performance.**
   Both of our athletes displayed a better than "average" HRV between trials (i.e. at rest).[19] As expected, immediately prior to competition both athletes saw significant decrease in their HRV. This psychophysiological response experienced by our athletes has a beneficial effect on performance, but only to a point. We found that both athletes had their worst performances during their lowest HRV measures. This seems to hint at a "sweet shot" between too much stress and too little - which is fairly common in extreme activities.[20]

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[17] (3) Antonnen,H. and Virokannas, H. Hand-arm vibration in snowmobile drivers. *Arctic Medical Research*, 53(3), 19-23, 1994b.

[18] (4) Kjellberg, A., Wikstrom, B. Whole-body vibration: exposure time and acute effects – a review. *Ergonomics*, 28(3), 535-544, 1985.

[19] (12) Nunan, D; Gavin, R; Sandercock, H and Brodie, D. A quantitative systematic review of normal values for short-term heart rate variability in health adults. *Pacing Clin Electrophysiol.* 33(11):1407-1417, 2010.

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(11) 14-15 International Snowmobile Racing Inc. Rules - Copyright 2014 GENERAL RULES AND REGULATIONS.

(12) Nunan, D; Gavin, R; Sandercock, H and Brodie, D. A quantitative systematic review of normal values for short-term heart rate variability in health adults. *Pacing Clin Electrophysiol.* 33(11):1407-1417, 2010.

