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Graduate Studies

THE RELATIVE EXERCISE INTENSITY AND SELECTED PHYSIOLOGICAL CHARACTERISTICS OF ELITE LOG ROLLING ATHLETES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the requirements for the Degree of Master of Science in Clinical Exercise Physiology

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THE RELATIVE EXERCISE INTENSITY AND SELECTED PHYSIOLOGICAL CHARACTERISTICS OF ELITE LOG ROLLING ATHLETES

By Jacob R. Hawes

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Masters of Science in Clinical Exercise Physiology.

The candidate has completed the oral defense of the thesis.

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ABSTRACT

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The purpose of this study was to determine heart rate responses during competitive log rolling matches and to measure select physiological characteristics of elite log rollers. Subjects included 7 male and 11 female elite log rolling athletes between the ages of 18 and 44 years of age that competed in a log rolling competition. HR recordings were collected for each subject during a competitive match. The results indicated that the male and female athletes averaged 88% and 91% of predicted HRmax, respectively. Peak HR values ranged from 90% to 109% of predicted HRmax. Three subjects who participated in the first phase of the study also had height, weight, flexibility, percent body fat, grip strength, and maximal oxygen consumption measured during laboratory testing. Body composition values were within the optimal health range for each subject. Recorded VO_{2max} values were categorized as excellent to superior and flexibility ranged from average to well above average. All subjects were below average for age-predicted grip strength.

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With sincere gratitude and appreciation, I would like to thank my family who has been so extremely supportive of me throughout my entire undergraduate and graduate career. You saw things in me that I would have never seen in myself if it was not for your continued encouragement. Thank you for all that you have done.

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Last but not least, I want to extend a huge thank you to Dr. John Porcari for his time and effort throughout this thesis. It was an absolute pleasure working with you. I am extremely grateful for the patience you have had with me during the process of completing this thesis. I could not have done it without your help.

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INTRODUCTION

Log rolling has been around since as far back as the early 1900's and was actually recognized as an occupation in the logging industry. Lumberjacks, also known as log drivers, would walk on and guide timber as it floated down river to the sawmill. Being a log driver required good balance and quick reflexes. At times, these log drivers would have friendly competitions to see who the best "log roller" was. The competitiveness of the sport officially began in 1960, with the start of the Lumberjack World Championship in Hayward, WI. Since that time, the athletes, both male and female, have become stronger, the competition has become fiercer, and the training has tried to become more specialized.

A problem arises, however, when trying to design training programs for log rollers. There is no research to guide training programs for these athletes or to describe the attributes that may be beneficial for success in the sport. To date, there is no research related to the effectiveness of training methods for athletes in the sport of log rolling. Further, there is very little information about the physiological demands of the sport and the level of fitness required to be successful.

METHODS

Therefore, the purpose of this study was twofold: 1) to determine heart rate responses during an actual competitive match and 2) to assess select physiological characteristics of elite log rollers. This study was conducted in two phases. The first phase involved collecting heart rates of log rollers at the Lumberjack World Championship in Hayward, WI and at the Three Rivers Roleo Log Rolling Tournament in Onalaska, WI. The second phase involved collecting select physiological characteristics at the Human Performance Laboratory on the University of Wisconsin-La Crosse campus.

Subjects

All subjects were between 18 and 45 years of age and were classified as an elite log roller. Each subject provided written informed consent prior to undergoing any procedures. This study was approved by the Institutional Review Board for the Protection of Human Subjects.

Procedures

Phase 1

The first phase of the study was conducted at the Lumberjack World Championship in Hayward, WI and at the Three Rivers Roleo Log Rolling Tournament in Onalaska, WI. Competitors who volunteered to participate in the study had a Polar Team^2 Transmitter (Polar Electro Inc., Lake Success, NY) strapped to their upper torso prior to a competitive match. Once it was verified that the monitor was recording, a stopwatch was started to track the time the athlete had the monitor on. The monitor began recording prior to the match to allow for the athlete to become comfortable with wearing it as well as to collect resting and warm-up heart rate data. When the athlete began his or her match, the time the match started on the stopwatch, as well as the times that the athletes were on and off the log were recorded. Thus, heart rate data could be correlated to what was happening during the match. All matches were the best of five. At the conclusion of the match, heart rate data was downloaded onto a personal computer using Polar Team^2 Pro Software (Polar Electro Inc., Lake Success, NY).

Phase 2

The second phase of the study was conducted in the Human Performance Laboratory on the University of Wisconsin-La Crosse campus. Three subjects who participated in phase one completed a number of tests to get a general picture of their overall fitness. Measurements included height, weight, flexibility, percent body fat, grip strength, and maximal oxygen consumption. The tests were administered in the same order for each subject and the measurements were made by the same research assistant throughout the testing period.

Height and weight were measured without shoes. Hamstring and lower back flexibility were assessed using the sit and reach test (YMCA of the USA, Chicago, IL). A yardstick was placed on the floor and a tape line at the 15 inch mark indicated where the subject's heels needed to be. Slowly reaching forward with both hands, subjects were asked to reach as far as possible. This was repeated three times. The most distant measurement was then recorded.

Percent body fat was measured using a Lang Skin Fold Caliper (Cambridge Scientific Industries, Inc., Cambridge, MD). The sites used for women were at the triceps, abdomen, and suprailium. The sites used for men were at the triceps, chest, and subscapula. Three measurements on the right side of the body were collected for each site and averaged. The sum of the three sites averages were then calculated to estimate each subjects percent body fat using the Jackson and Pollock equation (Jackson & Pollock, 1985).

A Jamar Adjustable Dynamometer (Marsh Industries Company, Skokie, IL) was used to assess grip strength. Subjects were instructed to place their arm at a 90 degree angle. Once in this position, they were asked to squeeze the device as hard as they could. The achieved number was then recorded by the research assistant. Subjects measurements were recorded on both the left and right arm three times and were averaged.

Each subject also completed a maximal treadmill test using the Bruce protocol. Throughout the test, oxygen consumption (VO_2) was measured with the AEI Technologies metabolic cart (Moxus System, Naperville, IL) and heart rates were monitored using a Polar heart rate monitor (Polar Electro Inc., Lake Success, NY). At the end of the stage and at maximal exertion, subjects were asked to rate their perceived effort using the 6-20 Borg Scale.

RESULTS

Descriptive characteristics of the subjects are summarized in Table 1. There was a significant difference ($p<.05$) in age, height, and weight in males compared to females.

Table 1. Descriptive characteristics of the subjects.

	Males (n=7)	Females (n=11)
Age (yrs)	26.4±9.0* (18-44)	21.8±4.1 (18-30)
Height (in)	69.4±1.1* (68-71)	65.2±3.3 (62-71)
Weight (lbs)	166.4±16.3* (150-200)	132.1±16.7 (110-160)

Values represent mean ± standard deviation.
Values in parentheses represent the range.
*Significantly different than females ($p<.05$).

Maximal HR was predicted using the equation of Gelish et al. (2007). The equation is represented as HRmax = 206.9 - (0.67 x Age). Heart rate responses during an actual log rolling competition are presented in Table 2. Males had significantly ($p<.05$) lower peak and average HR responses than females. When represented as a percentage of predicted HRmax, there was no significant difference, however.

Table 2. Heart rate responses during a log rolling competition.

	Males (n=7)	Females (n=11)
Predicted HRmax	189±6.2 (177-194)	192±2.6 (187-195)
Peak HR	178±9.6* (164-193)	190±10.3 (172-205)
Peak % HRmax	94±3.3 (90-100)	99±6.0 (89-109)
Average HR	167±12.4* (150-191)	174±10.1 (158-192)
Average % of HRmax	88±4.8 (85-99)	91±5.1 (84-100)

Values represent mean ± standard deviation.
Values in parentheses indicate the range.
*Significantly different than females ($p<.05$).

The heart rate response of a representative subject during a log rolling competition is shown in Figure 1. Each peak represents a single bout running on the log during the competitive match. Her peak HR was 172 bpm and average HR was 158 bpm.

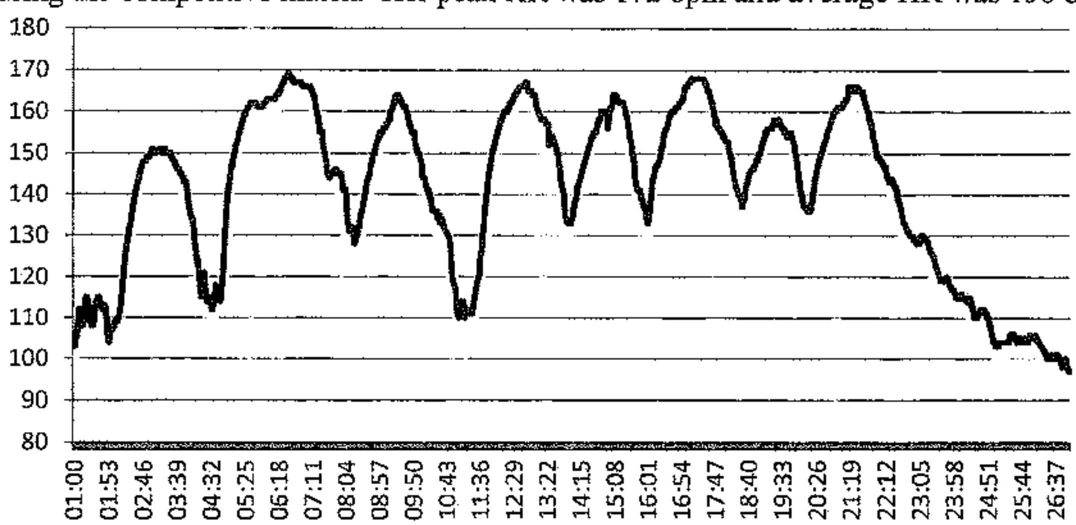

Figure 1. Heart rate response of a representative subject during the Hayward, WI log rolling competition.

Select physical characteristics of three elite log rollers are presented in Table 3.

Table 3. Select physical characteristics of three elite log rollers.

	Roller 1 (F)	Roller 2 (F)	Roller 3 (M)
Age (yrs)	19	27	29
Height (in)	63.5	63	68
Weight (kg)	53	61	74
% Body Fat	25.7	31	11
VO_{2max} (ml/kg/min)	43	43.6	63.9
Sit and Reach (in.)	21	37	35.5
Grip Strength (lbs) Right	54	56.7	100.7
Grip Strength (lbs) Left	41	40	94

DISCUSSION

This study examined heart rate responses of men and women during a competitive log rolling match and also determined select physiological characteristics of three elite log rolling athletes. The results indicate that the male and female athletes averaged 88% and 91% of predicted HRmax, respectively, throughout their competitive bout. This is at the upper range of ACSM's guidelines, which recommended an exercise intensity ranging from 64% to 94% of maximum HR (ACSM, 2005). This indicates that they were performing vigorous exercise. The athletes also attained peak HR values ranging from 90% to 109% of predicted HRmax. One plausible explanation for these findings may simply be from the weight of the log. The cedar logs used during competition weigh approximately 500 pounds. A tremendous amount of force and muscular effort is needed to "roll" the log. In addition to the weight of the log, an opponent on the opposite end of the log is trying to make them lose their balance, which creates additional challenges. These factors alone will cause an increase in heart rate. Additionally, the competitive nature of being in a match could also contribute to the high heart rates.

The physical characteristics of each of the log rolling athletes show a general picture of their overall level of fitness. All data was compared to norms published in *ACSM's Guidelines for Exercise Testing and Prescription* (ACSM, 2013). Body composition values for each athlete were within the optimal health range of 10% to 22% and 20% to 32% for males and females, respectively. Roller 1 (F) and 2 (F) were towards the upper end of the recommended range for females and roller 3 (M) was towards the lower end of the recommended range for males. Recorded maximal VO_2 values for roller 1 (F) and 2 (F) were categorized as excellent and roller 3 (M) as superior according to ACSM's fitness categories for maximal VO_2. Flexibility values for roller 1 (F) and 2 (F) were above average and well above average, respectively, and roller 3 (M) was well above average. All subjects were below average for age-predicted grip strength in both their right and left arms.

One of the limitations of the study was that maximal HR was predicted instead of being measured. Due to logistic issues, only three subjects performed a maximal treadmill test that had maximal HR determined experimentally. Because of the high muscular demands and competitive nature of the log rolling competition, it was felt that HR could not be used to predict the energy cost of log rolling. Thus, future research may want to measure the caloric expenditure of log rolling directly.

REFERENCES

American College of Sports Medicine (2013). *Guidelines for Exercise Testing and Prescription* (9th ed.) Baltimore: Williams & Wilkins.

American College of Sports Medicine (2005). *Guidelines for Exercise Testing and Prescription* (7th ed.) Baltimore: Williams & Wilkins.

Gellish, R. L., Goslin, B. R., Olson, R. E., McDonald, A., Russi, G. D., & Moudgil, V. K. (2007, May). Longitudinal modeling of the relationship between age and maximal heart rate. *Medicine & Science in Sports & Exercise, 39*(5), 822-829.

Jackson A. S., Pollock, M. (1985) Practical assessment of body composition. Physician Sport Med. 13: 76-90

APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

The Relative Exercise Intensity and Select Physiological Characteristics of Elite Log Rolling Athletes

I, ____________________, volunteer to participate in a research study being conducted by the University of Wisconsin-La Crosse.

Purpose and Procedures

- The purpose of this study is to determine heart rate responses during log rolling and determine how many calories are expended during an actual competitive event.
- My participation will require me to wear a chest strap to monitor my heart rate during a competitive log rolling event.
- A second session will require me to complete a maximal exercise test on a motorized treadmill. This test will be conducted on the University of Wisconsin-La Crosse campus. The test will start at a low level and progressively increase until I can no longer continue. During the test I will wear a chest strap to measure my heart rate and a scuba-like mouthpiece to collect my expired air.
- Research assistants will be conducting the research under the direction of Dr. John P. Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

- I may experience muscle fatigue, muscle soreness, and possible musculoskeletal injuries from participating in the log rolling competition. Additionally, shortness of breath, irregularities in heart rhythm, heart attack, stroke, and even death are possibilities of vigorous exercise. However, the risk of serious or life-threatening complications is very low (<1/10,000 tests) in apparently healthy adults.
- All testing will be stopped immediately if there are any complications.
- Individuals trained in CPR and Advanced Cardiac life Support (ACLS) will be available during all testing sessions. Additionally, an Automatic External Defibrillator (AED) will be available during all testing.

Benefits

- As a participant in this study, I will learn my individual aerobic fitness level as well as my heart rate response during a log rolling competition.

Rights and Confidentiality

- My participation in this study is entirely voluntary.
- I may choose to discontinue my involvement in the study at any time, for any reason, without penalty.
- The results of this study have the potential of being published or presented at scientific meetings, but my personal information will be kept confidential and only group data will be presented.

I have read the information provided on this consent form. I have been informed of the purpose of this study, the procedures, the expectations of myself and the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

If I have any other questions that arise I may feel free to contact Dr. John P. Porcari, the principal investigator, at (608) 785-8684 (office) or (608) 386-5416 (cell). Questions in regards to the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

Subject:______________________________ Date:___________

Investigator:__________________________ Date:___________

APPENDIX B

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

Log rolling has been around since as far back as the early 1900's with the logging industry. However, the competitiveness of the sport really became known in 1960 with the start of the Lumberjack World Championship in Hayward, WI. Since that time, the athletes, both male and female, have become stronger, the competition has become fiercer, and the training has attempted to become more specialized. Additionally, with a growing interest in the sport and recreation of log rolling, due to the recent invention of the Key Log, the question of "how hard am I working?" has become a frequent discussion among athletes.

A problem arises, however, when trying to design training programs for these athletes. To my knowledge, there has been no research done on the sport of log rolling which makes it difficult to structure a training program.

Because research is non-existent in this sport, supporting literature for the study becomes challenging. Taking the task of finding relevant material, we began looking for research on activities that may resemble the mechanics of log rolling. Backward running and walking, forward running and walking, stride length, stride frequency and anticipatory heart rate response are the areas of interest that resembles the sport. However, it is important to recognize that each of these studies are not sport specific to log rolling. This will be able to show us a picture of what may happen in our findings, but because of the highly specific training and physiological adaptations involved in log rolling, there may not be any relation at all.

Key Log

With traditional ways of log rolling, a 500-pound, 12 foot western red cedar log has been used to practice and compete. This makes it difficult for the sport and recreation of log rolling to gain momentum. The Key Log, according to founder Judy Scheer-Hoeschler, is changing this traditional sport into a true aquatic one making log rolling accessible to everyone. This has become an entertaining and innovative way to log roll and has potential to become the catalyst to a gaining popularity in the sport. The Key Log is a lightweight synthetic log that only weighs 64 pounds when empty and 480 pounds filled, which makes transportation from ground to swimming pool, lake or ocean easy to accomplish. Because the Key Log has made log rolling a much more convenient way to enjoy the sport, more and more people will begin to turn to log rolling as a form of exercise (Hanson, 2013).

Forward and Backward Walking

When thinking about the mechanics of log rolling, we see movements that resemble both forward and backward walking and running. A study looking at the cardiorespiratory and metabolic responses during forward and backward walking looked to see if there was a difference in the metabolic cost of walking forward and backward. This was achieved by having 11 male and 6 female subjects who were healthy and free from any orthopedic injury and were not involved in any competitive sport. Each subject was asked to complete a treadmill maximal oxygen uptake (VO_2max) test and walk under 4 constant velocity trials. Each trial included walking forward and backward at 2 speeds at 0% and 5%. A familiarization trial was given prior to the VO_2max test and experimental trials to accustom the subjects to backward walking. This was done for the safety of the subjects because most people are unfamiliar with walking backwards. Once subjects were familiarized to the backward walking, they were put through various different experimental trials, where oxygen uptake (VO_2), expired ventilation, heart rate (HR), and rating of perceived exertion (RPE) were assessed during the last 3 minutes of each trial (Chaloupka, Kang, Mastrangelo, & Donnelly, 1997).

It was found that under all conditions, backward walking resulted in higher VO_2, ventilation, and HR values compared to forward walking. According to Chaloupka et al. (1997), the likely cause of the increase in metabolic cost during backward walking compared to forward walking was because of the difference in peripheral muscle requirements for backward walking. During backward walking, the quadriceps muscles group is working isometrically as a knee stabilizer and concentrically as an accelerator. This is the exact opposite of what forward walking contributes, where the quadriceps muscle group in forward walking functions normally as a decelerator, contracting in a mostly eccentric motion (Chaloupka et al., 1997).

Another study looked at the effects of graded forward and backward walking on HR and VO_2 and found very similar results to those of Chaloupka et al. (1997) study. In this study, Hooper et al. (2004) found 17 female and 12 male volunteers who were free of cardiac, metabolic, systemic, or orthopedic conditions in the past 10 years. Subjects performed three sessions of exercise. Each was separated by 2 days or more. Subjects were given a familiarization pre-test to forward and backward walking, were given a VO_2

max test using Bruce protocol, and had electrocardiogram electrodes placed in a 4-lead arrangement to monitor HR for each session (Hooper et al., 2004).

What was found in the study was that the level of fitness of each subject being tested was collectively "good" to "excellent" based on their VO_2max values. It was also found that there was a 17% to 20% increase in the cost of oxygen for each treadmill grades for backward walking compared to forward walking. This is consistent with the previously mentioned study which found that backward walking had an increased metabolic demand compared to forward walking (Chaloupka et al., 1997; Hooper et al., 2004).

Forward and Backward Running and Walking

Flynn, Connery, Smutok, Zeballos, & Weisman (1994) compared the cardiopulmonary response differences of forward and backward walking to running. In this study, 10 healthy, physically active men volunteered to participate. Subjects were classified as being able to maintain a good level of physical fitness and were able to run two miles in under 15 minutes. Similar to previous studies, subjects were given a familiarization treadmill session to be able to allow for each participant to adapt to backward walking and running. Following the familiarization session, subjects performed trials of forward and backward walking and running on a treadmill on two separate days with at least 24 hours between testing periods. During each session, cardiopulmonary measurements and blood sampling were recorded.

It was found that minute ventilation, VO_2, respiratory exchange ratio (RER), and HR were significantly higher during both backward walking and running. Interestingly, the subjects reported muscular quadriceps fatigue and an increased difficulty in maintaining backward walking as the limiting factor, rather than breathlessness or overall fatigue. For backward running, there was not a similar response in the metabolic cost but was higher compared to forward running. Several subjects were also not able to complete the backward trials. They seemed to experience thigh fatigue which caused a sudden "loss of coordination" in the last 3 minutes on the running test (Flynn et al., 1994).

Forward and Backward Walking and Running in Log Rolling

As previously stated, it may be difficult to apply these findings to the sport of log rolling. As an athlete in log rolling, their training involves both forward and backward movements. Because these are highly trained athletes in this sport, there will be physiological adaptations to both the quadriceps and hamstring muscles. There may not be any physiological differences between forward and backward movements that would hinder their competition performance. What can be useful to this study is that there is indeed metabolic differences to forward and backward locomotion and that athletes need to adjust training regimes to accommodate for those differences.

Stride Length and Frequency

When viewing an athlete who is competing in log rolling, stride rate and stride frequency plays a huge part in their ability to maintain their position on the log. If they are not able to keep up with the spinning log, they are bound to fall. With rapid changes in direction, we want to see if there are any differences in stride length or frequency in backward and forward walking and running and if there is a difference in metabolic needs with these variations as well. Looking back at our previous study, Flynn et al. (1994) questioned if length and frequency varies in forward and backward walking and running.

What was found was that backward walking and running resulted in significantly shorter stride length and significantly greater stride frequency than forward walking and running. In the walking group, the stride frequency for forward walking was 126 steps per minute, compared to 145 per minute for backward walking. Results for running were similar. Stride frequency for forward running was 158 steps per minute and backward frequency was 190. This indicates that oxygen demand may be different with an alteration in stride frequency.

Physiological Response during Competition

Because we are looking at elite log rollers during competition, it is important to anticipate what may happen physiologically compared to a non-competitive match. Specifically, we want to look at the anticipatory heart rate response to determine if it will affect the results we are aiming to find in competition.

Bridge, Jones, & Drust (2009) looked at the physiological responses and perceived exertion during international Taekwondo competition. They studied eight male Taekwondo black belts who were competing in a World Taekwondo Federation-sanctioned senior-level international competition and collected HR, blood lactate, and RPE data across three rounds of combat. What they found was that each subject obtained near-maximal cardiovascular responses, high blood lactate concentrations, and increases in RPE across the match. These results suggested that a Taekwondo conditioning session should include both aerobic and anaerobic conditioning in order to achieve optimal performance during competition (Bridge et al., 2009).

A similar study looked at the physiological responses during competition in elite synchronized swimmers (Rodriguez-Zamora et al., 2012). This study is particularly interesting to our study because of the rank of the athletes, the technicality of the sport, and the physical demands that are placed on the athlete during the performance. The study included 34 female synchronized swimmers who had competed in a national and/or international level competition in the previous two years. Each subject had their HR, post exercise blood lactate concentration, and RPE monitored. What they found was a very intense anticipatory HR pre-activation and a HR that approached maximal levels in all of the swimmers. This was seen to be even more prominent in the junior swimmers, who were less experienced. According to Rodriguez-Zamora et al. (2012), the variability in each athlete's performance is likely due to this anticipatory HR response. Training programs that recognize and combat the anticipatory HR response that may hinder the athlete's performance would be useful.

Summary

In conclusion, in highly specialized sport such as log rolling, it becomes challenging to find research that supports our study. The research presented shows only a glimpse of what may be seen. Until further research has been conducted, the physiological responses seen in log rolling are relatively unknown. The hopes of this study are to bring attention to the sport of log rolling and to be a catalyst to further additional research to improve performance among the athletes.

REFERENCES

Bridge, C., Jones, M., & Drust, B. (2009). Physiological responses and perceived exertion during international taekwondo competition. *International Journal of Sports Physiology and Performance* , (4), 485-493.

Chaloupka, E. C., Kang, J., Mastrangelo, A. M., & Donnelly, S. M. (1997, May). Cardiorespiratory and Metabolic Responses During Forward and Backward Walking. *Journal of Orthopaedic & Sports Physical Therapy*, *25*(5), 302-306.

Flynn, T. W., Connery, S. M., Smutok, M. A., Zeballos, J. R., & Weisman, I. M. (1993, July). Comparison of cardiopulmonary responses to forward and backward walking and running. *American College of Sports Medicine*.

Hanson, K. (2013, 08 21). *Former logrolling world champ reinvents the sport.* Retrieved from http://www.upnorthexplorer.com/tag/judy-scheer-hoeschler/

Hooper, T. L., Dunn, D. M., Props, E. J., Bruce, B. A., Sawyer, S. F., & Daniel, J. A. (2004, February). The Effects of Graded Forward and Backward Walking on Heart Rate and Oxygen Consumption. *Journal of Orthopaedic & Sports Physical Therapy*, *34*(2), 65-70.

Rodriguez-Zamora, L., Iglessias, Z., Barrero, A., Chaverri, D., Erola, P., & Rodriguez. (2012, November). Physiological Responses in Relation to Performance during Competition in Elite Synchronized Swimmers. *PLOS ONE*, *7*(11).