Obstacle Course Racing: Trends, Physiology, and Injuries. NSCA Manuscript final masters project

Research Proposal · April 2017

DOI: 10.13140/RG.2.2.16437.37609

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Obstacle Course Racing: Trends, Physiology and Injuries

--Manuscript Draft--

Manuscript Number:	
Full Title:	Obstacle Course Racing: Trends, Physiology and Injuries
Short Title:	Obstacle Course Racing: Trends, Physiology and Injuries
Article Type:	Article
Keywords:	Obstacle course racing; injury rates; military obstacle course; elite endurance athletes; anthropometric measurements; sports nutrition for endurance athletes
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Order of Authors Secondary Information:	
Manuscript Region of Origin:	UNITED STATES
Abstract:	As of 2016 over 40 countries and 4 million people have participated in obstacle course racing (OCR). Since the debut of OCR in the USA there has been scant research on training strategies, physiological determinants of top racers, demographics, and injury mechanisms. Injury rates range from 2% to 25% and there have been several documented deaths. Ankle injuries tend to be the most common injury and competing between 12:30 to 2:00pm leads to the highest rate of injuries. Elite OCR performers tend possess lean physiques, high relative strength, power, and VO2max.
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Obstacle Course Racing: Trends, Physiology and Injuries:

A manuscript for submission to the *NSCA Strength and Conditioning Journal*

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[Nonblinded title page]

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Introduction

Wake, eat, work, sleep, and repeat. This formula drives human beings in first world countries. Long over are the days of running away from lions, stalking prey and exposure to the elements. These stresses have been replaced by paying for student loans, improving the quality of relationships, and seeking job security. Myths and tales of family lore told around a tribal fire have been replaced by YouTube videos and Facebook postings that provide us with enjoyment and a vast ocean of information. But it seems that wide access to data has dulled our excitement and arousal. How can we reinvigorate ourselves? We live boring and mundane lives where all of our desires can be solved with a simple "buy with one click' button on Amazon.com.

However, all it not lost. Humans are creative and innovative beings, and determined to break the status quo. We have an innate desire to learn, master, and challenge our skills. A solution has recently emerged that challenges not only our aerobic, anaerobic, and muscular fitness, but also our mental toughness and resilience! The answer is obstacle course racing (OCR).

Obstacle course racing can range anywhere from 5 kilometers to 20 kilometers and involves challenges that the average gym goer rarely encounters. Personal experience with OCR obstacles include scaling a hill while carrying two 30lbs buckets of sand, climbing over 9-12 foot walls, swimming through mud, and crawling through a tunnel while being shocked by exposed electric cables. These unique events provide a challenging (and dangerous) environment for weekend warriors to compete against themselves, other athletes, and in teams.

In 1987, OCR made its international debut with the advent of the Tough Guy Race in the United Kingdom. It was the first time in modern history that the masses could simply register, without prerequisites, for a no holds barred adventure style race (Agar, Pickard, & Bhangu, 2009). Since the Tough Guy took off there have been many imitators. The Tough Mudder, Spartan Race, and Warrior Dash are the most popular and successful.

Obstacle course racing has seen unprecedented success and is estimated to be a burgeoning $360 million industry (Fischer, 2015). The most notable is the Tough Mudder Series. The founders of this series started with a personal investment of $20,000 in 2010. Within their first three events they had accumulated $2 million revenue and by 2012 a whopping $70 million (Keanelly, 2012). Participation has also exploded from an estimated 700,000 participants in 2010 to 4.5 million in 2014 in the USA alone (Fischer, 2015).

Obstacle course racing is a successful multimillion dollar industry that has added hundreds of jobs to the global economy, as well as providing an outlet for aspiring professional athletes. There have even been attempts to further legitimize OCR by making it an Olympic event. In 2014 Spartan Race Inc., created the International Obstacle Course Racing Association to boost acceptance for OCR into the 2024 Summer Games (Perez, 2015). It is unlikely that professional OCR racers consider OCR their sole profession but there are many sponsorships available from supplement and sports apparel companies and top race organizations. Prize winnings are also substantial. Table 1 compares elite athletic events to OCR.

Table 1. Comparison of prizes for OCR vs Non OCR races

Conventional endurance racing	1st Prize $USD
2015 Boston Marathon	$150,000
2015 IAAF World Championships, Beijing (individual events)	$60,000
2015 IAAF World Cross Country Championships, Guiyang	$30,000
Obstacle course racing	
2015 Warrior Dash World Championships Pulaski, Tennessee	$30,000
2016 Spartan Race World Championships Olympic Valley, California	$15,000
2016 World's Toughest Mudder Las Vegas, Nevada	$10,000

(Spartan.com, Toughmudder.com, Warriordash.com, IAAF.com, 2016)

Winning an adventure race does look appealing financially, but first place winnings don't come close to first place winnings in most other elite level running events. First place in the World's Toughest Mudder is financially equivalent to sixth place in the 2015 Boston Marathon (2016 prize structure).

The "Tough Mudder" has become part of the vernacular. But despite the financial backing and popularity there is minimal research on OCR. Searching on Montclair State University's online library, PubMed, and SportDiscus, (including exercise physiology journals with keywords "obstacle + course + racing"), yielded only 12 relevant articles. These studies reported demographics and injury rates. But none of these studies examined non-military OCR racers' physiological characteristics such as maximal oxygen consumption (VO_{2max}) and body fat. There is a wide gap in researching the psychological and physiological demands of the sport. Understanding this information is important for the millions of people participating in these events, medical personal employed at each event, and wellness professionals who train race participants. Therefore, the goal for this project is to compare available evidence of OCR to the

physiological demands of similar sports, injury rates, ideal biometric characteristics, and trends of the sport; and create a manuscript for NSCA's Strength and Conditioning Journal.

Introduction

Obstacle course racing (i.e. Tough Mudder, Spartan Race, and Warrior Dash) has exploded in popularity since it's USA debut about 10 years ago. These events are can be held on mountainous areas (often ski resorts in the ski off season), range from a 5k to half marathon distance, and offer a string of body weight and non-bodyweight obstacles. OCR obstacles may require the participant to lift a heavy object from the ground (deadlifting), require a high volume of upper body pulling (pull ups, rock and rope climbing), and gripping odd objects for a lengthy amount of time (carrying sand bags, gravel buckets, logs). Squat variations, deadlifts, pull ups, overhead presses, rows, and various forms of loaded carries may improve OCR performance as these movements mimic OCR obstacles. However, unloaded trail, uphill, and downhill running make up the most of any OCR challenge. Table 1 below highlights a few obstacles that are frequently seen on Spartan races that are biomechanically similar.

Table 2 Examples of Spartan Obstacles (41)

Name of Obstacle	Description
Atlas Carry	Pick up heavy round concrete stone, carry specified distance on flat terrain, complete 5 burpees, repeat

Wall Jump	Negotiate moving up and over 7' wall, typically landing on uneven ground
Bucket Brigade	Fill bucket with gravel and carry along prescribed route (often uphill)
Running uphill/downhill unloaded	Distance can range from 50m to over 1600m
Hercules Hoist	Pull rope to raise weight until the set knot of weight reaches the top and lower under eccentric control
Traverse Wall	In a fatigued state traverse a manmade wall using only handhold and footholds

As of 2014 4.2 million people worldwide participated in OCR events. Despite this popularity little research has been conducted on OCR. Therefore, it is important to disseminate available literature on injury rates, physiological demands of OCR and sports similar to OCR, and physiological attributes of elite and recreational OCR racers. This article will be beneficial for individuals involved in OCR such as fitness enthusiasts, wellness professionals, race organizers, and on site medical personnel.

Injury Trends and Rate of Injury in Obstacle Course Competitions

Rate of injury. At a first glace it would seem that OCR has a high rate of injury. There have been unique and serious injuries that received media coverage ranging from rhabdomyolysis, norovirus infections, myocarditis (from electric shock), heat stroke, and even drowning (16). To date there have been four deaths. Two race participants died in 2011, allegedly from hot humid conditions, and two more from accidental drowning in 2012 and 2013 (3). Jagim, Repshas, and Oliver (2014) surveyed 122 recreational OCR athletes and 25% reported suffering an injury during a race. Despite this high risk of injury and high cost of race entry ($100-$250) OCR continues to be popular with double digit participation growth until just recently (14).

Recent research (1,10,16,17,25,26,36) highlights injury rates on active participants from 2006-2015 (Table 2 below). Data summarized across these seven studies includes seven different OCR races, over 24 separate events, and over 220,000 people. Average overall injury rate of participants receiving medical attention across studies was 1.62% with the percentage of injured participants requiring EMS transport to a hospital (ambulatory percent) at 1-4%. For most OCR events the ambulatory rate (number of race participants requiring EMS transport to a hospital) was between 0.13-0.25 per 1000 people, although one event, the 2013 Tough Mudder in Pennsylvania (22,000 people) (16), saw an abnormally high ambulatory rate at 1.73 per 1000 participants. There does seem to be clear evidence that more robust medical services on site, especially the ability to suture lacerations, will decrease the ambulatory rate, reduce healthcare costs, and mitigate utilization of local medical resources (1,25,26). Other sport venues such as the winter and summer Olympic Games and marathons have an ambulatory rate of under 5% (1). Compared to other large USA sporting events injury rates of OCR are not unusual and suggest a stable pattern despite different types of events, environments, and fitness levels. Considering this finding concerns about comparative high rates of injury of OCR maybe unfounded.

Table 3. Injury rates for individual races from 2006-2015

Author	Event	Date	N	% Needing medical attention	Ambulatory percent / ambulatory rate
Coleby (2016)	Canadian Spartan race	2014	40123	0.40%	4.2% (0.17/1000)
Luke (2014)	Australian Tough Mudder	2012	22000	2%	.6% (0.13/1000)
Greenberg et al.(2014)	USA Tough Mudder	2013	22000		38/22000 (1.73/1000)
Agar et al. (2009)	UK Tough Guy	2006-07	20000	1-2%	4% (0.25/1000)

Pearkes et al. (2016)	Wolf Run UK 10k	2015	43000	1% 411 clinical encounters/43,000	1.7% (0.16/1000)
Hawley (2016)	Various UK OCR races	2015	45285	2%	1.97% (0.24/1000)
Lund et al (2015)	UK Tough Mudder & Warrior Dash	2011-13	45325	3%	0.6%-1.1% (.18/1000)

Injury trends and techniques to reduce injury. It is important to note that there is no medical screening prior to entry for any OCR, although participants are advised to train for the rigors of the event (31). Several authors (9, 26, 36, 18) reported that acute muscular/skeletal injuries are the most common form of injury with ankle/achilles injuries, knee injuries, and lacerations that required sutures being the most common injuries requiring transport to the hospital. Obstacles commonly include balancing across uneven surfaces, downhill running, and jumping off high barriers. Given the high prominence of ankle and knee injuries it is recommended that OCR participants focus on a longer training phase to enhance their balance and strengthen their lower extremities. More specifically exercises involving strengthening of hip lateral rotation, ankle multi-planar strengthening, proprioceptive stability, resisted ankle eversion, as well as taping and orthotics may reduce risk of ankle and knee injury (4, 45).

Other factors that influence injuries rates during OCR events are time of day and season. With regard to time of day, competition heats that start between 12:30 to 2:00 pm often see the most athlete density which leads to the highest rate of injuries (1,34). Pearkes et al. (2016) theorized that high risk scenarios occur when an obstacle combines high speed followed by idling. For example, sliding down an obstacle into a small muddy

pool can lead to higher injury rates due to participants falling on top of each other. This injury rate can be compounded as participant density increases. Therefore, it is recommended that prospective OCR athletes enter heats outside this time slot as there will probably be less clustering of athletes at any given obstacle. In addition, there is lower risk for injury competing in the fall, spring, and summer months compared to the winter (1). Agar et al. (2009) reported that hypothermia accounted for many of the injuries in the winter, where soft tissue injuries (abrasions, lacerations, and blisters) were most common in the summer.

Future research on OCR should focus on the causation of specific skeletal muscular injuries. There is only minimal documentation on how the most serious injuries occur (3). Do more injuries occur running uphill versus running downhill, when carrying odd objects, or deaccelerating after jumping off an obstacle? Clarification of causation of injury will assist fitness professionals to develop more robust programs for OCR participants.

Physiological Demands of Obstacle Course Races

OCR is a new competitive sport. Due to this there have not been any peer review studies on the ideal physiological characteristics of OCR participants. Therefore, examining characteristics of military members who are high performers of military obstacle courses would represent a credible method to investigate this new competitive sport.

Obstacle course physiological characteristics of high performing military personnel. Virtually all who enter any military service in the USA and Canada must

show their mettle by completing some sort of obstacle course. These obstacle courses are not as long as a traditional Spartan race, but still offer variable obstacles that are physically taxing and mentally challenging.

Research (7, 13, 19, 20, 23, 27) seems to support that high relative strength, power, lean physique, and VO_{2max} are correlated to high-intensity military style obstacle courses in males and females. In fact, several sources (7, 19, 27) showed significant correlations between performance times and muscular strength. Lower body fat and higher VO_{2max} are also important characteristics in moving more efficiently through obstacles and maintaining speed for long runs. Mullins (2012) mentions that as body size increases, body volume increases disproportionately to muscle cross-sectional area and therefore strength. Thus, larger and fatter people are at a disadvantage in activities requiring rapid movement over long distances (14). In most sports learner athletes have an advantage over less lean athletes in the ability to produce power, strength, and maintain endurance (4). Research from several authors (6, 13, 32) highlights that obstacle courses require speediness, a high VO_{2max}, and a high degree of coordination to negotiate obstacles. The ideal somatotype is one with a high strength to low body weight ratio. Interestingly, as the external weight (battle gear load) increases there is more reliance on aerobic energy systems (13, 40). Also, it seems that during short anaerobic dominant events hosting a lean physique is less of a physiological determinant for success (6, 13, 23). Due to the short and intense nature of these events it is recommended that military members training for top placement predominately focus on speed, agility, strength, and rate of force development.

It is important to note that there are relatively few studies investigating major indicators for physical performance in military obstacle courses. Military obstacle courses reviewed were typically under 600 meters in length with the US military academy indoor obstacle course test (IOCT) being the longest and most time-consuming event. The table and figures below showcase several obstacle courses and describe the major factors for top performance.

Table 4 Review of performance characteristics for top performers in military obstacle courses.

Author	Date	N	Course	Major indicators for top performance (p=<0.05)
Bishop et al.	1999	47 males	US Military Academy indoor obstacle course test	Light mass, lean, high 1 RM lat pull down and leg press, high relative arm peak power and relative arm and leg mean power (wingate test), high lower/upper extremity VO_{2peak}
Jette et al.	1990	43 males	Indoor obstacle course test with full gear	High maximal aerobic power, high strength index (grip strength, 1 RM shoulder press, and 1 RM leg press), high muscular endurance (bench press until failure with 36.3kg). Time to completion of obstacle course was negatively correlated with higher skinfold measurements
Mala et al.	2015	18 males	Timed battle simulated course that included carrying an 18-kg load (or unloaded), 30-meter run, and a 27 m zigzag run, 10 m casualty drag	Significant correlations between performance times and muscular strength (1 RM back squat and bench press) and lower body power (countermovement jump).
Frykman et al.	2001	11 females	6-station obstacle course obstacle course carrying either a 14kg or 27kg heavy backpack.	Higher pushups and sit ups correlated to faster time with 14 kg load. Higher Army Physical Fitness Test score best correlated to faster time with 27 kg load
Kusano et al.	1997	38 females	US Military Academy indoor obstacle course test	Soldiers who had higher body fat performed slower on the obstacle course

Fig 1. **West Point's IOCT Nowels, R. (2015) permission granted**

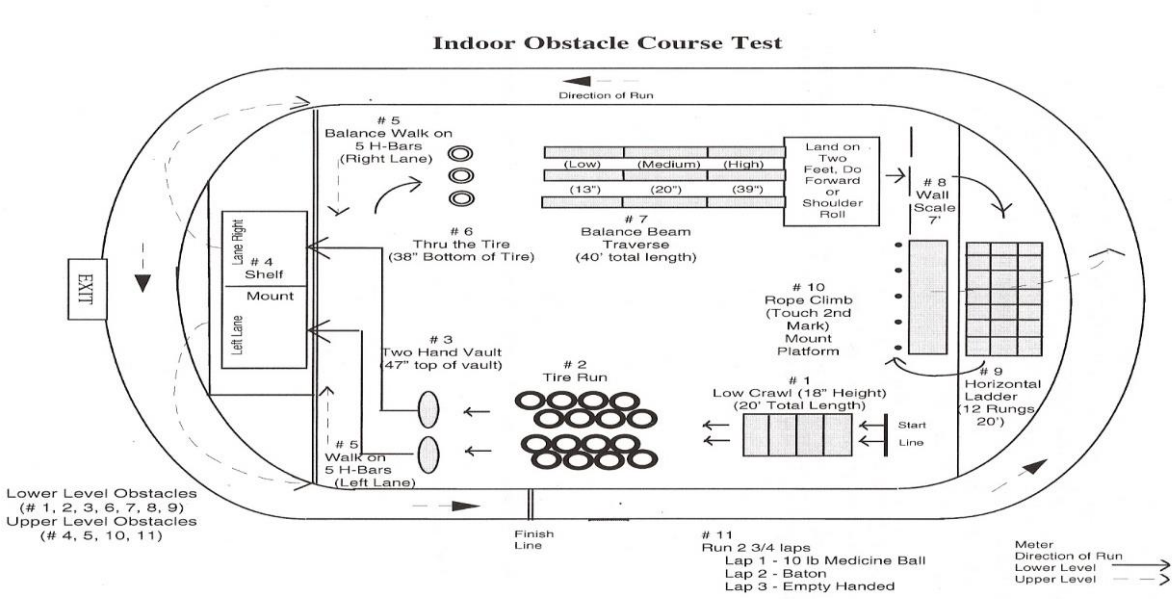
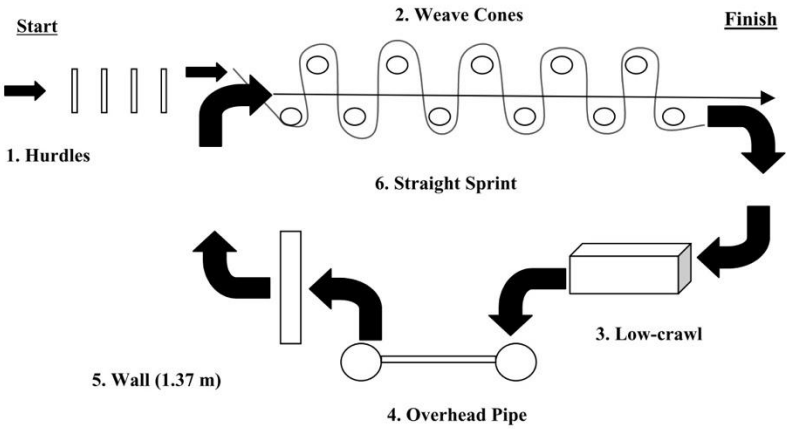


Fig 2. **Six station obstacle course Frykman et al. (2001) permission granted**



Physiological determinants in sports similar to obstacle course racing. To perform at a high level of competition endurance sports require a strong cardiovascular

engine. Hosting a high VO_2 max and lean body composition will enhance the body's ability to deliver oxygen to working muscles and buffer CO_2, thus delaying acidic conditions that are detrimental to performance (29). Higher $\dot{V}O_2$max scores are correlated with high performing aerobic endurance events and obstacle course performance when courses involve carrying heavy loads for an extended distance (40). Endurance athletes who also possess more lean mass can achieve higher maximum speeds and have also been found to perform better at obstacle courses when carrying heavy loads (7, 13, 40). Determination of ideal VO_2 max, body fat, other anthropomorphic characteristics, demographics, and training history is important in understanding the physiological make up of elite endurance runners.

Many authors (11, 15, 28, 30, 37, 39, 43) have looked at elite male American and European middle (800m-1500m) and long distance (3000m-marathon) athletes. It seems that these athletes are usually under the age of 27 years old, have a height around 180cm, weigh less than 70kg, have a BMI of under 22 kg/m^2, body fat of 7-14%, and a VO_2 max of over 68 ml/kg/min. Several studies (11, 15, 24, 28, 37, 42) have also reported that female distance runners are usually under the age of 27 years, have a height around 166 cm, a body mass close to 53kg, a BMI around 19 kg/m^2, a body fat of 12-15%, and a VO_{2max} over 63 mg/kg/min. It is also common for both men and women elite endurance runners to have a resting heart rate under 50 beats per minute (8, 29).

Another sport that mimics the demands of OCR is mountain racing. This form of running is similar to OCR as athletes in both ventures must often negotiate very steep slopes that are over 20% in grade for distances in excess of 21 kilometers in some cases (5). Spartan races are notoriously known for being held on ski resorts where elevation is

also extreme. Balducci et al. (2016) surveyed 10 high-level male endurance mountain runners who were considered the best runners of the French National Trail Tour. These athletes averaged an age of 38.5 ± 6.4 years, height of 177 ± 0.08 cm, mass of 69.8 ± 8.6 kg, body mass index of 22.3 ± 1.9 kg/m², and a VO_{2max} of 63.5 ml/kg/min.

Tables 4-5 below highlight anthropometric data from several studies of men and women previously discussed. These values no doubt indicate that elite endurance runners are lean, and house superior aerobic engines compared to the lay person. Elite endurance athletes likely spend much of their time focusing on muscular endurance and running outside on stable surfaces (i.e. paved street, inclined ground, gradual turns). In comparison, elite OCR athletes train on uneven ground (trail or mountainous terrain) with intermittent low/high impact obstacles. It is a prudent recommendation that OCR athletes focus on contrast training with more emphasis on uphill/downhill running, longer distance interval running, plyometerics, unilateral stability, and speed. Additionally, many of the obstacles commonly seen in OCR events require muscular strength to enhance ability to pull body weight and carry heavy objects for a period of time.

Table 4. Characteristics of the elite male middle-distance (MD) and long- distance (LD) runners (mean±s)

Mooses, M et al. (2013)	MD (n=20)	LD (n=20)
Age (year)	21.1 ± 3.4	25.4 ± 3.8
Height (m)	1.80 ± 0.04	1.81 ± 0.05
Body mass (kg)	70.5 ± 6.3	69.0 ± 4.5
BMI (kg m-2)	21.6 ± 1.5	21.1 ± 1.2
Body fat (%)	8.1 ± 2.0	7.6 ± 1.9
V02max(ml/kg/min)	64.2 ± 5.8	67.4 ± 5.9
Manuel et al (2011)	MD (n=40)	LD (n=32)
Age (year)	23 ± 4	25 ± 4
Height (m)	1.80 ± 0.05	1.73 ± 0.06

Body mass (kg)	67.2 ± 5.9	59.8 ± 5.1 kg
BMI (kg m-2)	20.7	20
Body fat (%)	n/a	n/a
V02max(ml/kg/min)	65.9 ± 4.5	71.6 ± 5.0
Daniels (1992)	MD (n=13)	LD (n=32)
Age (year)	26.6	27
Height (m)	1.82	1.8
Body mass (kg)	69	64
BMI (kg m-2)	20.8	19.8
Body fat (%)	n/a	
V02max(ml/kg/min)	72.5	75
Table 5 Characteristics of the Elite female middle-distance (MD) and long- distance (LD) runners (mean±s)		
Daniels (1992)	MD (N=8)	LD (n=12)
Age (year)	25.5	27
Height (m)	1.66	1.66
Body mass (kg)	51.8	52
BMI (kg m-2)	18.8	18.9
Body fat (%)	n/a	n/a
V02max(ml/kg/min)	63.1	68.2
Martin, Benardot (2005)	MD (24=8)	LD (n=23)
Age (year)	24.6 ± 0.80	27.0 ± 0.87
Height (m)	1.675 ± 0.66	1.657 ± 1.15
Body mass (kg)	53.3 ± 0.78 kg	53.3 ± 0.88
BMI (kg m-2)	n/a	n/a
Body fat (%)	12.3 ± 0.59	13.2 ± 0.57
V02max(ml/kg/min)		
Graves, Pollock, Sparling (1987)	(n=15)	
Age (year)	27.6±5.4 161	
Height (m)	1.61±4	
Body mass (kg)	47.2±4.6	
BMI (kg m-2)	n/a	
Body fat (%)	14.3±3.3	
V02max(ml/kg/min)	n/a	

Pichard et al. (1997)	(n=17)	
Age (year)	26.5±1.4	
Height (m)	168.4 ± 1.4	
Body mass (kg)	53.7 ± 0.9	
BMI (kg m-2)	n/a	
Body fat (%)	14.8 ± 0.9	
V02max(ml/kg/min)	n/a	

Obstacle Course Racing Demographics

The world's most popular obstacle race, the Tough Mudder, offers some insight into participant demographics. Toughmudder.com/press-room mentions that their races have a completion rate of 78%, participants are 65% male versus 35% female, and have an average age of 29-35 years old. Thorough researching of other press releases and results from athlinks.com, crossfit.com, outside.com, toughmudder.com, and Spartan.com, this author gathered data on basic anthropometric measures of elite OCR racers. Average age, height, weight, and body mass index (BMI), were identified for 24 elite participants (men, n=12; women, n=12) of a major OCR championship series from 2012 -2015 Spartan World Racing Championships. Analysis showed that on average the top 3 ranked male champions were 31.2±5 years old, 178± 4.9 centimeters tall, 70.85±7.7 kg, and had a BMI of 22.4±1.3 kg/m². Top ranked females on the other hand were on average 30.1±7.5 years old, 168± 6.1 cm, 60.0±4.4 kg, and had a BMI of 21.4 kg/m². Jagim et al. (2014) published similar data on 122 recreational obstacle course athletes (men, n=75; females, n=47). On average men were 32.3±10 years old, 179.3 ± 6.8 cm, 82.4 ± 11.1 kg, and had a BMI of 25.6±3.1 kg/m². Recreational females on the other hand were on average 28.4±7.4 years old, 164.8±7.9 cm, 66.8±12.4 kg, and had a BMI of

24.6±4.6 kg/m². Interestingly, it was also reported that 82% of recreational OCR racers had participated in high school sports, while 25% reported competing at the collegiate level. Obstacle course enthusiasts' main training modality was long slow distance running (LDSR) with 6.0±11.9 hours weekly, followed by resistance training at 4.8±3.6 hours weekly, and finally some form of high intensity interval training (HIIT) for 2.5±2.6 hours weekly (18).

To date the Jagim et al. (2014) work is the only peer reviewed published article that highlights OCR participant anthropometric measurements. However, initial evidence seems to show that elite level OCR racers are lighter and have a lower BMI than their recreational counterparts. In addition, it seems that elite conventional endurance athletes are younger, lighter, and have a lower BMI than their OCR counterparts. This difference in age might be associated with the high cost of entry for OCR competition ($75-$200), which is a deterrent for younger people. Also, Tønnessen et al. (2015) reported that elite endurance athletes spend less time focusing on building muscle mass (around 5-15% of total training volume). In addition to being a very popular recreational activity, over 4 million consumers in more than 40 countries participate of OCR racing (12, 34). As noted by Mullins (2012) achievement goal theory and self-determination theory may explain the reasons that people participate in these challenging races. Self-determination theory is a theory of motivation where individuals strive to fulfill three major needs; competence, relatedness, and autonomy. The large number of individuals and team registrations seems to indicate that OCR satisfies these needs. Achievement goal theory is the desire to demonstrate competence where the individual is either mastery oriented or ego-performance oriented. Mastery oriented individuals find success in honing their skills

based on their previous performances and future expectations. Ego-performance driven individuals generally see success as performing better than others and/or with less effort.

Obstacle course race participation is growing with men and women 29-35 years old and individuals who have special needs and disabilities (38,41). It is surprising that there is minimal research on this lucrative and popular sport. More robust research is needed on elite and non-elite athlete physiology, motivation, and training practices.

Nutritional strategies

An OCR course length can range from 3 to 13 miles (1.5-4+hours) over unforgiving terrain (40). Therefore, pre-workout, intra-workout, and post workout refueling strategies are important to delay fatigue. Pre-exercise or pre-competition feedings should occur approximately 3–4 hours before the workout and should contain 1–2 g/kg body mass of carbohydrate or 200–300 g of carbohydrate (42). Due to mud obstacles carrying a water bottle belt may weigh the athlete down, break, and become too unsanitary to utilize. Therefore, an excellent way to refuel intra-workout is to utilize edible gels/jelly beans or other nutrient packs at a rate of 30-45 grams of carbohydrates per hour. They can be easily stored in compression garments; some even offer compression stitched pockets. During post-race recovery, the athlete should recover with 16-24 oz. of fluid and consume 0.5-0.7 grams of carbohydrates per pound of bodyweight lost during the event. Due to the difficultly of weighing before and after an event athletes can assume that at least one pound will be lost (42).

Conclusion

One can conclude that high-level OCR athletes tend to possess lean physiques, high relative strength, power, and VO_{2max}. Competitive females should strive to obtain a VO_{2max} >50 ml/kg/min and a BMI around 19 kg/m^2. Competitive males should aim to attain a VO_{2max} >60 ml/kg/min and a BMI of under 22 kg/m^2. Both men and women should also seek lean body compositions. Finally, OCR requires high relative strength. Evidence from Bishop et al. (1999) highlights that top male performers in military themed indoor obstacle courses are capable of a 1RM leg press of 2.8±0.5 times their body weight and latissimus pull down 1.1±0.1 times their body weight.

There seems to be fewer OCR events scheduled in the winter versus the fall, spring, and summer. One training strategy that may be helpful to OCR competitors is to focus on building strength during the winter months while maintaining a strong aerobic base. During early spring athletes can increase running volume and focus on maintaining strength in various cycles. This periodization will allow for adequate recovery, decrease stagnation and risk for injury, and would be more comfortable to exercise outside than in winter. Additional research is recommended on participant demographics, physiological determinants and training habits of competitive OCR racers, as well as mechanisms of injury.

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