Injury Prevalence in Open Water Swimmers

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SUPERVISORY AND EXAMINING COMMITTEE

Dionne Tatlow, candidate for the degree of **Master of Science in Kinesiology and Health Studies,** has presented a thesis titled, ***Injury prevalence in open water swimmers,*** in an oral examination held on **December 19, 2022**. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

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Abstract

Open water swimming (OWS) is currently one of the fastest growing mass participation sports worldwide, and differs from pool swimming in that athletes swim in natural bodies of water such as lakes, oceans and rivers. Participation in this sport spans a wide range of individuals of all ages with a roughly equal sex distribution. No prior investigations have evaluated the musculoskeletal (MSK) injuries characteristic to the sport in a recreational capacity, and only one group has completed biannual surveillance in an elite population on three occasions. The purpose of the current study was to investigate the prevalence and explore possible risk factors associated with MSK injuries in non-elite OW swimmers during the COVID-19 pandemic (for circumstantial reasons). Participants were invited through a variety of social media channels and OWS community communications to complete a self-administered internet-based survey to evaluate the details of any injuries sustained within the previous 6-month period and various other demographic and training related details. 156 participants completed or partially completed the survey (95 female, 52 male, 9 did not disclose their sex; average age 47.7 (±12.4) years). The 6-month prevalence of MSK injury within this population was 30% (n=36), with the most commonly injured region being the shoulder (n = 25), and the second most common being the cervical spine (n = 6). A logistic regression was performed to assess the association between self-reports of injury (outcome variable) and various predictor variables. The final model yielded one significant predictor variable: participation in efforts to prevent injury (OR [95% CI] = 5.004 [1.356, 18.465], Wald = 5.843, p = 0.016). Two marginally-significant predictor variables were age (OR [95%

CI] = 1.039 [0.996, 1.084], Wald = 3.093, p = 0.079) and sex (female) (OR [95% CI] = 2.614 [0.852, 8.021], Wald = 2.821, p = 0.093). Results of this study will be dispersed among the OWS community via academic and open-access publications, and may be used to guide injury prevention and rehabilitation efforts in this growing population.

***Keywords*: epidemiology, athletic injuries, swimming, sports medicine, sports injury, open water swimming, long distance swimming**

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List of Abbreviations

Body mass index (BMI)

Channel swimming association (CSA)

Disc degeneration (DD)

External training load (ETL)

Fédération internationale de natation (FINA)

Global swimming series (GSS)

Internal training load (ITL)

Lake Ontario Swim Team (LOST)

Low back pain (LBP)

Magnetic resonance imaging (MRI)

Marathon swimmers federation (MSF)

Mechanism of Injury (MOI)

Musculoskeletal (MSK)

National Collegiate Athletic Association (NCAA)

Open water (OW)

Open water swimming (OWS)

Training load (TL)

Chapter 1: Introduction

The 2008 Beijing Olympics marked the introduction of the 10km open water (OW) swim into the Olympic program; this inclusion both reflected and further propelled open water swimming (OWS) events into one of the fastest growing mass participation sports world-wide (Tipton & Bradford, 2014). In contrast to traditional pool swimming events, OWS takes place in natural bodies of water (e.g., lakes, oceans, rivers, etc.) and events are based on water temperature (e.g., ice swimming occurs in water <5°C), distance (e.g., 10km is a marathon; >15km is deemed an ultramarathon), and/or event placement (i.e., either stand-alone, within a triathlon or ‘swim-run’) (International Ice Swimming Association, 2019; FINA, 2019: FINA, 2017). OW swimming requires athletes to perform repetitive sport-specific movements of the upper and lower limbs to propel the swimmer forward in the water, while both stabilizing the core and rotating various spinal segments. This has the potential to place the OW athlete at an increased risk of injury. Despite the popularity of the sport, there have been minimal investigations related to the risk of injury within this growing population. Therefore, investigation of injury type, prevalence and possible risk factors in adult recreational OW swimmers is required to guide the development of sport-specific prevention strategies.

The rules and regulations of marathon OWS are quite diverse; FINA, the International Swimming Federation, governs international competitive programming whereas local associations tied to a body of water typically govern geographically adjacent swims. For instance, the Channel Swimming Association (CSA) is a governing body regulating swimmers attempting to swim the English Channel. In countries where long-distance OWS is less popular, swimmers may opt to complete swims according to rules and regulations set out by the Marathon Swimmers Federation (MSF) and hire a third-party observer to ratify their swim (Marathon Swimmers Federation, 2020). The majority of OWS associations have rules congruent with those of the MSF and they also seem to share a large cohort of administrative members. Therefore, the MSF tends to act as an overarching regulatory body for those swimmers completing swims outside of FINA-regulated and mass-participation, community-based (unaffiliated) events.

FINA governs competitive OWS events, which include the world championships, the Olympic Games, and various international competitions. However, the number of athletes participating in community-based events and MSF-sanctioned swims outnumbers those competing in the FINA circuit. The Global Swimming Series (GSS), founded by Canadian Rob Kent in 2014 is an OWS series with the ultimate goal of developing the sport and connecting swimmers from around the world (Global Swim Series, n.d.). Prior to the COVID-19 pandemic, the GSS included over 100,000 swimmers in 156 races and 37 countries competing in distances from 1 to 25 kilometers (Global Swim Series, n.d.). These races are generally community-sanctioned with very few being formally regulated by either FINA or the MSF. Further, the GSS is not an exhaustive database of OW swims; there are many unaffiliated races and solo swims attempted outside of structured regulatory bodies. Thus, one may conclude that participation in OWS events is not limited to young competitive swimmers, but in fact may be dominated by swimmers participating outside of FINA-sanctioned events. Because of the diverse nature of these events, it is difficult to tabulate an accurate representation of the population; however, Baldassarre et al. (2017) reported that the average age of athletes who have successfully swam the Catalina or English Channel (20 and 21 miles, respectively) is roughly 40 years of age and a roughly equal split between male and female swimmers.

Prior research into the health of OW swimmers has largely focused on medical concerns and physiological factors concerned with thermoregulation, body composition and environmental exposures (Baldassarre et al., 2017). Musculoskeletal (MSK) injury prevalence and injury-prevention strategies among the OW swimmer population have largely been either anecdotally generated or theoretically deduced from research conducted among pool-swimmers (Baldassarre et al., 2017; Khodaee et al., 2016). There has been a small emergence of data collected among elite OW swimmers competing at the biennial FINA world championships, however, there appears to be no published reports on MSK injury prevalence in a non-elite OW swimming population (Mountjoy et al., 2016). Given that the distances swam in OW events are considerably greater than pool swimming events (the farthest pool swimming event is 1500m) and the OW swimmers' dependence on capricious water conditions, an investigation into the MSK injuries characteristic to the sport is necessary to better guide injury prevention and rehabilitation efforts within this growing population of OW swimmers.

1.1 Purpose

The purpose of this survey study was to investigate the prevalence and explore possible risk factors associated with MSK injuries in non-elite OW swimmers during the COVID-19 pandemic. The reasoning for this timing was circumstantial given that this study was completed as part of a Master's degree with a timeline that coincided with the pandemic. Descriptive statistics were used to analyze injury prevalence, and regression analyses were used to assess the association between self-reports of injury and several self-reported training factors, event participation, and injury prevention efforts.

Chapter 2: Literature Review

There is currently no peer-reviewed published literature that has investigated MSK injuries in a non-elite OWS population. Thus, studies investigating injury prevalence and associated risk factors in similar populations were used as a guide. Most swimming research has been conducted in pool swimmers; however, smaller and less rigorous explorations of injury epidemiology and risk factor analysis have been conducted in masters' pool swimmers, triathletes, elite OW swimmers, as well as the broad category of 'aquatic athletes' (Wolf et al., 2009; Baker et al., 2019; Feijen et al., 2020; Johnston et al., 2019; Mountjoy et al., 2016; Zwingenberger et al., 2014). As such, these investigations will be used for comparison with the OW swimming population in this literature review.

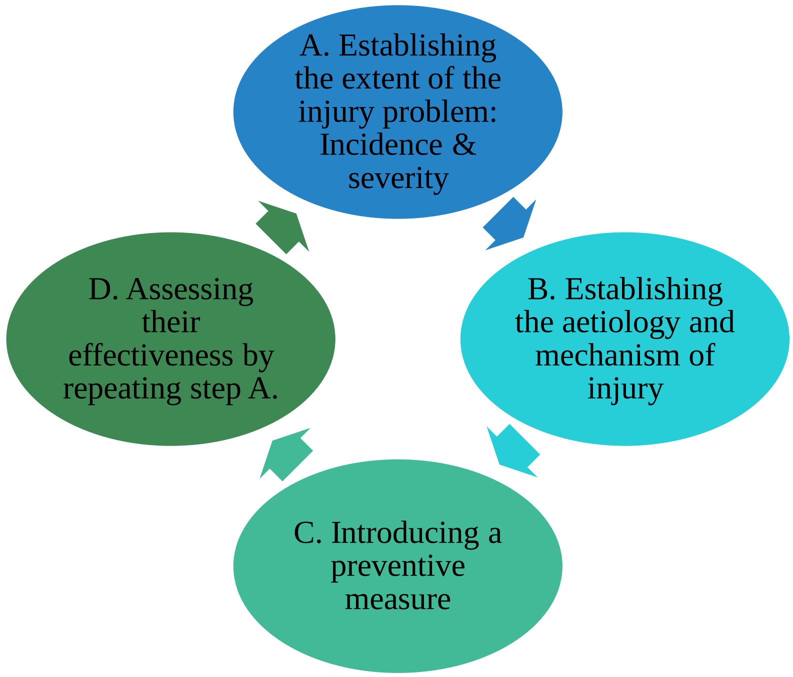
2.1 Sport Injury Prevention

Sport-related injuries are significant, not only because of various factors relating to one's physical and mental health (e.g., decreased participation and enjoyment in sport), but the total injury burden also contributes to components of population health such as the costs associated with absenteeism from school and work, as well as healthcare costs associated with obesity and chronic disease management (Emery & Pasanen, 2019).

2.1.1 Frameworks in Sport Injury Prevention

In 1992, van Mechelen proposed a four-step model for injury prevention that has since become the groundwork for many sport injury prevention programs (Emery & Pasanen, 2019). The model begins with determining the extent of injury within a population (step A), followed by establishing the etiology and mechanisms associated (step B) (Emery & Pasanen, 2019). Once the injury mechanisms are understood, preventative measures and strategies can be introduced (step C), and finally, their effectiveness can be evaluated by repeating the first step of the model (step D) (Figure 1) (van Mechelen et al., 1992; Emery & Pasanen, 2019). Given the paucity of research concerning injuries in recreational OW swimmers, this study focuses on the first two steps of the van Mechelen model. The primary aim was to establish the 6-month prevalence of MSK injuries within this population, followed by an exploration into potential causes, mechanisms and risk/preventative factors associated with such injuries.

Figure 1: The model for sport injury prevention as described by van Mechelen



2.1.2 Key Terminology in Sport Injury Prevention

Measuring injury in a population may be done several different ways, with incidence and prevalence being the most commonly used. Incidence is defined as the number of new injuries within a particular timeframe in a defined population, while point-prevalence is the total number of injuries at a given point in time; this may include old injuries that began prior to the assigned time period (Kuhn et al., 1997). The timeframe for the current study is further discussed in Section 2.6.1, with a 6-month prevalence being selected to remain consistent with recreational running related injuries (Yamato et al., 2019).

In the second step of the model proposed by van Mechelen and colleagues, researchers aim to identify risk factors and etiology associated with each injury. Risk factors are the descriptors that relate to the reasons an athlete may be at risk for injury in a given situation, and injury mechanisms are how the injury happens (Bahr & Holme, 2003). There are two broad groups of risk factors: intrinsic and extrinsic (Bahr & Holme, 2003). Intrinsic (internal) risk factors relate to the athlete while extrinsic (external) risk factors relate to the environmental (Bahr & Holme, 2003). Each factor can also be further described as modifiable or non-modifiable, depending on whether it can be changed (Bahr & Holme, 2003). For example, age is non-modifiable whereas training mileage is modifiable. It is important to note that risk factors may be related to injury but are not necessarily related to causation (Meeuwisse, 1994). Risk factors, mechanisms, and the complex interaction between them must be explored in order to establish a complete understanding of the injury (Bahr & Holme, 2003).

2.2 Prevalence & Risk Factors by Anatomic Location in Swimmers

2.2.1 Shoulder Injuries

2.2.1.1 Prevalence

In the 1970s, Hawkins and Kennedy coined the term “swimmers’ shoulder” due to the high prevalence of shoulder injury reported among the swim team at the 1972 Olympic games (Kennedy et al., 1978). This term was initially defined as anterior shoulder pain created by “impingement of the rotator cuff under the coracoacromial arch”; however, it has since been generalized to indicate any pain localized to the shoulder region without regard for the mechanism or anatomical structures involved (Struyf et al., 2017 p. 775). Shoulder injury has since been investigated in numerous pool swimming populations with reported prevalence ranging from 20.8 to 91% (Sein et al., 2010; Wanivenhaus et al., 2012; Tate et al., 2012). Prien et al., (2017) conducted a review of the injuries reported at the FINA aquatic world championships in 2009, 2013, and 2015 and reported that shoulder injuries are the most common complaint cited by other aquatic sporting populations as well (e.g., elite water polo, high-diving, diving, synchronized swimming, OW and pool swimmers). They postulated that the upper limbs are responsible for generating the majority of the propulsive force to travel through water across aquatic disciplines and attributed this to the increased risk of injury to the shoulder complex (Prien et al., 2017).

2.2.1.2 Risk Factors

Risk factors associated with developing shoulder pain in pool swimmers are not universally agreed upon; however, a systematic review of various studies which utilized both self-administered surveys and clinical assessments, by Hill et al. (2015) concluded with a 'moderate' degree of certainty that clinical joint laxity, glenohumeral rotation range of motion, previous history of pain and injury as well as the competitive level of the swimmer were associated with an increased risk of injury (no risk factors were listed with a 'high' degree of certainty of association with shoulder injury). It must be noted that a self-administered survey cannot provide a valid measurement of glenohumeral laxity and range of motion, and therefore was not addressed in the questionnaire used in the current study. However, there has been association reported between a history of traumatic shoulder injury and glenohumeral laxity, which suggests that future studies should distinguish the nature of any prior injury reported to yield more descriptive results (i.e. traumatic vs overuse) (Hill et al., 2015). The majority of investigations into the development and diagnosis of shoulder pain in swimmers has been done clinically, without the use of imaging; however, Sein et al. (2010) examined 52 competitive swimmers' shoulders via magnetic resonance imaging (MRI). They found a positive association between training volume (weekly meterage and duration) and pain attributed to either internal or external rotation-inducted shoulder impingement (Sein et al., 2010). They also reported that thickening of the supraspinatus tendon as evaluated by MRI was correlated with increased training time, training distance and cumulative shoulder use (Sein et al., 2010). The MRI study by Sein et al. was one of twelve included in a 2020 systematic review by Feijen, et al., in which they concluded a level II level of evidence between the association of swim-training volume and shoulder pain in an adolescent population (15-17yoa) and a level III level of evidence in young (<15yoa), adult (18-23yoa) and masters (23-77yoa) populations.

The association between shoulder injury and biological sex has been investigated with varying results. Hill et al. (2015) cited five studies that investigated this association with only one retrospective study reporting a significant increase in shoulder pain among female swimmers. This lead Hill et al. to refute an association between sex and shoulder pain. However, when one examines the other four studies cited by Hill et al., it appears that at least one of these studies suggested an association between sex and shoulder pain prevalence. Kruger et al. (2012) investigated shoulder pain among a group of 282 master's swimmers and found a slightly elevated odds ratio of 1.34 (95% CI, 0.829-2.179) for shoulder pain among female swimmers. Additionally, in a retrospective survey of 194 Italian teenage swimmers, the authors reported that female swimmers were more likely to experience shoulder pain (Tessaro et al., 2017). Bak & Fauno (1997) proposed the increased risk of shoulder injuries in female swimmers may be associated with an average elevated number of strokes per lap (presumably due to shorter arms on average) as compared to their male counterparts. They proposed that biomechanically, this may predispose female swimmers to overuse injury because of an increased average of strokes per lap (Bak & Fauno, 1997). In conclusion, the possibility that female swimmers report an elevated number of shoulder injuries is inconclusive; however, Bak & Faunn (1997) presented a plausible theoretical basis and the literature does not present a unified conclusion. Therefore, it is worthwhile to study the relationship between sex and injury in OW swimmers, especially due to the presumed discrepancies in stroke count over the large distances covered in OWS events.

2.2.2 Spine Injuries in Swimmers

2.2.2.1 Prevalence

Axial injuries are not uniformly tabulated across the literature. Two studies using data generated from prospective injury and illness reporting software in NCAA swimmers reported that neck injuries accounted for 3.2% of total reported injuries, and the vague terms of ‘back’ or ‘trunk’ injuries comprised 16.2% of the total reported injuries (Chase et al., 2013; Kerr et al., 2015). Another prospective study of NCAA swimmer’s reported that 21.5% of the total reported injuries were attributed to the neck and back, with no distinction between the axial skeleton segments (cervical, thoracic, lumbar or sacral) (Wolf et al., 2009). Furthermore, a systematic review by Hill et al.

(2022) grouped neck and back together, but noted it was the third most commonly reported anatomical site for injury (behind the shoulder and knee) and cited incidences (point-prevalence to 12 months) varying from 18.4% to 47%. Nevertheless, given that reports of cervical pain are quite low, it appears that neck pain composes less of the injury burden than that of other areas of the axial spine. Yet it appears more of an effort should be made in future research to specify the precise anatomic region of any injuries reported.

There have been a handful of studies, most of which appear to come from the same research group, that specifically investigated low back pain (LBP) within a pool swimming population and reported lifetime prevalence ranging from 23.5%-76% (Hangai et al., 2009; Kaneoka et al., 2007; Matsuura et al., 2019a). Matsuura et al. (2019a) investigated MSK injuries reported by Japan national swimmers from 2002-2008 and found that lumbar spine injuries were more prevalent than any other injury site, including the shoulder. Although this is limited to a single national team and may be due to several confounding factors (e.g., coaching style, lifestyle factors, education regarding injury prevention, dryland workouts, etc.), it is notable that LBP has been documented as being relatively problematic within a population of elite swimmers.

Hangai et al. (2009) investigated the prevalence of LBP among various athletic populations, including swimmers, in comparison to a non-athletic control group. The authors collected demographic information and asked clinical questions regarding the lifetime and past four-week incidence of LBP and its severity; a midsagittal MRI of the lumbar spine (L1-2 to L5-S1) was also reviewed for each subject (Hangai et al., 2009). The authors defined disc degeneration (DD) as either multi-level degeneration of grade I or higher, or a singular level of grade III, IV or V degeneration, according to a Phirrmann classification (Hangai et al., 2009). They reported an odds ratio of 2.76 (95% CI: 1.24-6.49) for LBP in a sample of 47 university-level swimmers as compared to a non-athletic control population (Hangai et al., 2009). Notably, swimmers and baseball players exhibited the highest prevalence of multi-level DD findings (other sports included were basketball, kendo, soccer and running); however, the authors did not comment on the severity of the DD, but they did note an association between reported LBP and the presence of DD (Hangai et al., 2009). Comparatively, Kaneoka et al. (2007) investigated the prevalence of LBP and lumbar DD in two distinct groups of swimmers: a 'high-load' group consisted of 56 university level swimmers and a 'low-load' group consisted of 28 swimmers who belonged to a recreational swim club. They found the prevalence and severity of LBP to be similar between the two groups; however, the 'high-load' group exhibited significantly more DD when evaluated by MRI, although the authors reported no association between LBP and DD within this sample (Kaneoka et al., 2007). Although this study appears to be from a similar group of authors, their definition of DD was the presence of grade III, IV, or V degeneration evaluated segmentally, and they did not discuss multi-level findings (Kaneoka et al., 2007).

These conflicting findings appear to be congruent with investigations associating DD and LBP in the general population (Brinjikji et al., 2015; Endean et al., 2011). In a systematic review, Brinjikji et al. (2015) concluded that imaging evidence of DD increases with age and is not highly correlated with the presence of LBP. Conversely, another systematic review estimating the association of DD and LBP, as evaluated by MRI, reported a metaestimate of an odds ratio of 2.5 (95% CI, 2.0-7.4) (Endean et al., 2011). Regardless of the association between DD and LBP, complaints of LBP among swimmers appear to be relatively common within the pool-swimming population and the suggested mechanism, as reviewed below, is shared with their OW counterparts (Hangai et al., 2009; Kaneoka et al., 2007).

2.1.2.2 Risk Factors and Mechanisms (Cervical Spine)

In their recent systematic review, Hill et al. (2022) noted with a low level of certainty that sex (female) and training volume may be associated with the development of neck pain and LBP. In a retrospective survey study of 87 triathletes, Villavicencio et al. (2006) found an association between the development of neck pain and the number of previous sports-related injuries, although most athletes attributed their neck pain to cycling instead of swimming.

Pollard and Fernandez (2004) reviewed the possible mechanisms for cervical spine injuries in swimmers and noted that older swimmers may be more likely to develop neck pain due to an increased likelihood of degenerative changes such as disc dysfunction and spondylosis throughout the cervical spine. They noted that any deviation of the spine from the longitudinal axis could cause extension and rotation through the neck, which would create excess stress through the elements of the cervical spinal column and musculature (Pollard & Fernandez, 2004). This extension would occur if a swimmer was breathing or looking forward, which is rather disadvantageous when swimming freestyle in a pool because neck extension while swimming forces the hips to fall in the water and creates more drag (Pollard & Fernandez, 2004). Notably, there is no guiding line to follow while OWS and the swimmer must instead ‘sight’, which is when the athlete looks forward above the water to orientate themselves. Depending on the swimmer's technique and ability, as well as water and environmental conditions, swimmers may sight as often as every 6 to 20 strokes with varying degrees of cervical extension, which would create a possible mechanism for injury (Pollard & Fernandez, 2004). It appears that this has not been investigated within the available literature.

2.2.2.3 Risk Factors and Mechanisms (Lumbar Spine)

Seemingly there has recently been an effort to describe low back injuries, their mechanisms, and possible risk factors more specifically within swimming-related literature. Reviewing the proposed mechanism for the development of lumbar pain, Nyska et al. (2000) suggested that repeated lumbar flexion/extension during the butterfly and breaststroke may act as a mechanism for spondylolysis in adolescent swimmers, although subsequent studies have failed to find a clear association between stroke specialty and reports of LBP (Capaci et al., 2002; Kaneoka et al., 2007; Nyska et al., 2002). Another proposed mechanism associated with lumbar pain in swimmers is prolonged lumbar hyperextension, which places excess stress on the posterior structures of the lumbar spinal column including the pars interarticularis and facet joints (Wanivenhaus et al., 2012). Matsuura et al. (2019b) investigated the immediate effect of deep trunk stabilization exercises on lumbar lordosis angles while swimming in 13 university-aged swimmers. They reported a decrease in the lumbar lordotic angle when swimming (i.e. less extension through the lumbar segments) immediately after the exercises were performed (Matsuura et al., 2019b). It is important to note that this research was done in a healthy, pain-free, population of 13 university-aged swimmers, and would therefore provide only a theoretical basis for the prevention or treatment of LBP in swimmers using an exercise-based approach. However, the exercises utilized in this study were the same used in the ‘lumbar injury prevention project’, which was initiated in 2009 with the Japanese national swim team (Matsuura et al., 2019a). The lumbar injury prevention project consisted of an initial period of education and instruction on prevention strategies for lumbar injury (i.e. trunk stabilization and core muscle activation) followed by guidance for daily implementation within the athlete’s subsequent training (Matsuura et al., 2019a). The authors reported a significant decrease in the prevalence of lumbar injury from 23.5% to 14.8% ($p<0.05$) after the program was implemented in 2009 and lasting until data collection commenced in 2016 (Matsuura et al., 2019a). Perhaps with more research, the findings between both Matsuura papers could be extended and a link between deep muscle activation and LBP could be established (Matsuura et al., 2019a).

A 2006 study by Villavicencio investigated neck and spine pain in 87 triathletes via a retrospective survey study. Through regression analysis, they reported two predictive factors for the development of LBP: the number of prior incidents of sporting-related injuries, as well as the number of triathlons the respondents participated in (Villavicencio et al., 2006). They did not elaborate on these previous injuries, and although triathletes train in OWS, a higher proportion of their training time was reported to be spent on the bicycle (Villavicencio et al., 2006). Nevertheless, prior reports of injury were also included in the questionnaire used in the current study.

Notably, a major difference between swimming in a pool compared to OWS is the presence of a turn at the wall after the swimmer completes a length of the pool; this movement inevitably involves a period of lumbar flexion, which theoretically would briefly unload the posterior elements of the lumbar spine. Thus, OW swimmers may be more predisposed to prolonged hyperextension than pool swimmers due to the distance of the swimming events and the absence of an embedded moment of lumbar flexion while the swimmer turns at the wall of a pool.

2.2.3 Hip, groin and thigh injuries in swimmers

Hip, groin and thigh complaints are not uniformly tabulated within the existing literature. Wolf et al. (2009) reported hip/thigh complaints in 7/94 (4.3%) NCAA swimmers over the course of five years within one swim team, and Kerr et al. (2015) reported a 4.8% prevalence of hip/groin pain over four years in a separate study of NCAA swimmers and divers (these populations were not separated for the statistical analysis). Anteromedial hip and thigh pain is typically attributed to adductor strain associated with the whip-kick motion of breaststroke (Gaunt & Maffulli, 2011). Further, an investigation of 296 NCAA swimmers reported a 6.92% point-prevalence of hip pain in breaststroke swimmers as compared to 0% in non-breaststroke swimmers (Grote et al., 2004). The authors also found that 42.7% of breaststroke swimmers compared to 5.8% of non-breaststroke swimmers had experienced an episode of hip pain that limited their ability to swim or kick breaststroke within the previous year (Grote et al., 2004). Given that OW swimmers typically rely on freestyle stroke (and therefore using flutter kick), the prevalence of hip pain in an OW population was postulated to differ from that reported in pool swimmers.

Prior to the current study commencing, the author participated in personal anecdotal conversations with various groups of long-distance OW swimmers. It appeared that there was perhaps an undocumented phenomenon of anterior hip discomfort and tightness (loosely referred to as “tight hip flexors”) that may be common within this population. A blog post from an Australian physical therapy group reported tightness and dysfunction in the rectus femoris, iliopsoas and tensor fascia latae to be common in swimmers and attributed this to sustained, powerful activation of these muscles over a small range of motion of the hip joint (Physiohealth, 2020). Kitamura et al. (2020) investigated the elastic moduli of the iliacus and psoas muscles (separately) in 33 male college-level swimmers, 11 of which reported LBP and 21 healthy controls. They reported that a higher elastic modulus of the psoas (i.e., stiffer) was correlated with the presence of LBP. Their study was of cross-sectional design; however, they suggested two possible mechanisms for this: the first being that a stiffer psoas major would exert a force on the lumbar spine favoring extension (particularly from L1-L3) and the second being that increased tension through the psoas major would cause a shearing force through the lower levels of the lumbar spine (Kitamura et al., 2020). Both prolonged, exaggerated extension, as well as a shearing force could be responsible for the generation of pain within the lumbar region (Kitamura et al., 2020). This mechanism of LBP has also been investigated in other sports as well; Evans et al. (2005) found an association between tight hip flexors, as measured by a modified Thomas test, and LBP in a group of elite golfers. The Evans study was included in a review article by Moradi et al. (2015) that reported a ‘moderate’ level of evidence that hip flexor tightness is positively associated with LBP.

2.2.4 Knee injuries in swimmers

Knee pain represented only 6% of the total injury burden within a sample of 499 masters pool swimmers (Baker et al., 2019). The prevalence of knee injuries among competitive swimmers may be as high as 76%. However, like hip pain, knee pain appears to disproportionally affect competitive swimmers who specialize in breaststroke (Chase et al., 2013; Gaunt & Maffulli, 2011). The biomechanics of the kicking motion for the breaststroke differs greatly from that of dolphin kick or flutter kick used in butterfly and freestyle swimming, respectively, by including a rotary movement at the hip that results in a valgus force at the tibiofemoral joint (Khodaee et al., 2016). As above, because OW swimmers typically rely on a freestyle stroke, the prevalence of knee pain in this population is likely to differ from that in pool swimmers.

2.3 Global injury risk & associated factors in swimmers

2.3.1 Sex

The association between swimming-related injuries and biological sex has been reported with no clear consensus reached; Martins et al. (2014) surveyed 47 elite swimmers at the 2009 FINA World Championships and reported an 18% prevalence of injury in male athlete’s vs 75% in their female counterparts without explanation. However, it must be noted that when Prien et al. (2017) compiled the injury surveillance data from three FINA world championships (2009, 2013, 2015) this discrepancy was not maintained, and in fact, was insignificantly reversed with males reporting slightly more pre-competition injuries than female athletes in the four weeks leading up to the 2015 competition. An increased prevalence of injury in female swimmers has also been reported in two separate samples of NCAA swimmers and a group of Japanese national swim team members, with two of these long-term studies reporting a statistically significant difference in injury rates between the sexes (Chase et al., 2013; Wanivenhaus et al., 2012; Matsuura et al., 2019a). There is currently no explanation widely offered to explain why female swimmers may be more predisposed to MSK injuries and a definitive conclusion has not been reached within the literature. Perhaps it is due to smaller average body size, which would alter biomechanical factors as previously discussed. However, this may also involve numerous other differences related to sex and gender such as anatomical characteristics, hormonal or neuromuscular control and/or societal or environmental variances (Lin et al., 2018).

2.3.2 Previous history of injury

There appears to be a global increased risk of injury when the athlete has any previous history of injury. In a prospective study of NCAA swimmers, Chase et al. (2013) found an increased risk of injury, not only if the athlete reported previous pain at the same anatomic site, but also if the athlete reported any prior incidence of injury at all. Additionally, Gosling et al. (2008) cited two studies that reported an increased incidence of injury in triathletes who have reported any prior history of injury or pain. Korkia et al. (1994) conducted an eight-week prospective study of 155 British triathletes and reported an increased incidence of injury in those who reported they sustained an injury in the year prior to the beginning of the study onset.

2.3.3 Training Load

Training load (TL) is a risk factor that has received recent attention due to its modifiable nature (Eckard et al., 2018). It can be defined as "the cumulative amount of stress placed on an individual from single or multiple training sessions over a period of time" (Eckard et al., 2018, p. 1930) and can be measured in a variety of ways. The quantification of training load is multifactorial and a number of metrics have been identified to best quantify this in relation to each individual athlete (Eckard et al., 2018). These include external or internal training load (ETL/ITL); ITL involves the quantification of an athlete's response to loading and can be measured objectively (e.g., blood lactate, heart rate) or subjectively (e.g., self-reported measures), while ETL is a purely objective measurement (e.g., distance, duration). Further, load quantification can also be classified as absolute or relative (Eckard et al., 2018). Relative loads consider a number of external and internal metrics and tend to express variance in load across time periods, while absolute loads are simply the sum of loading metrics over a given period of time (Eckard et al., 2018). In a systematic review of 57 studies examining various measurements of training load and risk of injury, Eckard et al. (2018) found that studies that monitored relative TL demonstrated that small to moderate changes in TL compared to previous loading was "associated with a reduced risk of injury compared with larger or smaller changes" (p.1957). This finding may explain the findings in a study by Chase et al. (2013) who found that first-year NCAA swimmers were at an increased risk of injury as compared to 2nd through 4th year athletes, as well as the systematic review by Feijen et al. (2020) that reported a stronger association between training volume and shoulder pain in adolescents (15-18 years of age) vs. adults (18-23 years of age). Both authors postulated that this phenomenon may be due to the abrupt changes in TL that occur when the athlete enters competitive training as an adolescent, or moves from high school-level to university-level swim programs (Chase et al., 2013; Feijen et al., 2020). Further, an earlier investigation by Wolf et al. (2009) also noted an increased prevalence of injury in college freshman as they adapted to the new demands of collegiate-level training.

The measurement of smaller cycles of TL is difficult within a retrospective survey study, as is a gross measurement of various internal or relative TL metrics; however, it is worthwhile to investigate aspects of swimmers' TL such as meterage and duration across TL cycles (i.e., seasons) to obtain more information regarding progressive loading and training habits.

2.3.4 Age

Tate et al. (2012) examined 236 swimmers aged 8-77 and found that masters swimmers aged 23 and over (n=67) were not at an increased risk of shoulder pain in comparison to younger age groups (8-11 years, 12-14 years, 15-22 years); however, they did not examine variances within this group to investigate if injury rates change as masters athletes age from their early twenties onwards. Conversely, Baker et al. (2019) did investigate global injury rates within a sample of 499 masters pool swimmers aged 20-86 years and reported an increased risk of injury of 1.6% with every year of increasing age. The authors negated the importance of this value; however, if one considers a 16% increase over a 10-year span, it may warrant further attention. Further, if this increase was not linear it would be interesting to note the trends the authors may have found. Therefore, investigating the relationship between age and injury incidence should be prioritized.

2.4 Injury Prevention

2.4.1 Dryland warmups

Dryland warmups prior to athletes entering the pool for a training session appear to be a common practice in the pool swimming population (Mcgowan et al.,2016); however, there appears to be only one study investigating the relationship between dryland warmups and the incidence of injury. Tessaro et al. (2017) focused their investigation on the prevention of injuries to the shoulder complex and conducted a retrospective observational study of eight groups of Italian teenage competitive swimmers (n=197). They found that a pre-swim dryland warm-up lasting 5-10 minutes was associated with a reduction in injury whereas a warmup lasting over 10 minutes was associated with increased shoulder injury (Tessaro et al., 2017). Given that OW swimmers may engage in the practice, and it has previously been shown to affect the incidence of injury, it is worthwhile to investigate this within an OW swimming population.

2.4.2 Cross-training

Cross-training or participating in athletic activities outside of one's primary sport, is a common method employed to maintain or improve sport performance components such as aerobic fitness or muscular strength while off-loading the tissues exposed to the "repetitive stress of sport-specific training" (Baker et al., 2019, p. 52). Baker et al. Conducted a survey study of 499 masters pool swimmers and investigated the association between injury prevalence and participation in a cross-training activity. They reported that swimmers who opted to participate in cycling, running or 'dryland training' activities reported significantly less injuries than those who did not. Conversely, Tate et al. (2012) found that participation in water-polo was associated with an increased risk of shoulder pain, disability or dissatisfaction in a study of 236 female pool swimmers aged 8-77 years of age. It must be noted that the shoulder injury rate in water-polo is also elevated due to the reliance on the upper limb for propulsion, and the movement patterns used in water-polo would be similar to swimming, which in turn would fail to properly off-load the sport-specific musculature that is subject to overuse injuries in the pool swimming population (Prien et al., 2017).

A survey study of 500 aquatic athletes competing at the 2017 FINA world championships reported that although injury rates remained stable across all countries regardless of success, the athletes competing for countries with higher rates of success reported higher participation in dryland injury prevention exercises (Mountjoy et al., 2021). The authors went on to note that this was an unexpected finding and may be explained by the failure of their survey to capture the severity of the reported injuries (Mountjoy et al., 2021). Further, a recent review investigated the value of exercise therapy interventions on reducing shoulder pain and concluded that a 6-to-8 week program that includes strengthening and stretching exercises can decrease the incidence of shoulder pain in swimmers (Yoma, et al., 2022), although it must be noted that the swimmers had already sustained a shoulder and the program was being used as a treatment. It appears that there is a gap in the literature surrounding the effectiveness of targeted dryland exercises at preventing the onset of MSK injury.

2.4.3 Preventative sports health care

Currently there are no published studies investigating the role of preventative visits to health care professionals such as registered massage therapists, physical therapists, osteopaths, or chiropractors in the prevention of MSK injuries in swimmers. As aforementioned, Mountjoy, et al. (2021) surveyed 500 elite aquatic athletes competing in the 2017 FINA world championships and found that countries ranking higher in the world standings had better access to support staff, including massage therapy and physical therapy. Further, personal communication with OW swimmers suggests that many visit health care professionals in a preventative capacity. Thus, descriptive statistics would be beneficial to understand the utilization of such services in this population.

2.5 Population comparison

As described above, the majority of research on swimming has been conducted in a population of elite pool swimmers. However, research conducted in other populations may be used to aid the formulation of a hypothesis on injury rates in a recreational OWS population. Two populations of interest, triathletes and elite OW swimmers, will be highlighted below.

2.5.1 Triathlon

Like recreational OW swimmers, the demographics of those competing in triathlon appear to involve a wide array of ages and abilities, with the average participant in their mid-thirties (Wicker et al., 2012). Since the swim portion of a triathlon is typically held in an OW setting, there may be similarities between triathletes and OW swimmers. However, the triathlon population typically trains swimming differently than the monosport population by decreasing the duration, frequency, and meterage of swim training (Schorn et al., 2018). In a study of 268 triathletes, 19% reported shoulder injuries attributed to overuse whereas 6% reported acute shoulder injuries (most of which were sustained while cycling) (Schorn et al., 2018). The authors noted a significant relationship between acute shoulder injury and weekly training time in all three disciplines; however, the athletes that reported a shoulder injury due to overuse spent significantly more time swim-training (Schorn et al., 2018). The authors also reported an association between shoulder overuse injury and hand-paddle use (a training aid), as well as event participation (Schorn et al., 2018). Other studies investigating injury prevalence in triathletes differed greatly due to the varied nature of the sport (e.g., distances ranging from one to 18-hour long competitions). Andersen et al. (2013) reported 87% of ironman distance triathletes reported an overuse injury during a prospective 26-week study, with the majority occurring in the lumbar spine or lower extremity. The authors did not speculate on a mechanism for this, but other studies have suggested that running may contribute to a majority of lower extremity injuries in triathletes (Korkia et al., 1994; Zwingenberger et al., 2014). Another study investigating injuries in amateur triathletes found that the main risk factor for injury was participation in a formal triathlon event, they found trends suggesting those with higher performance levels and those who train over ten hours per week may have a higher injury rate (Zwingenberger et al., 2014). The authors did not find an association with age, visits to physical therapy or coaching status (Zwingenberger et al., 2014).

2.5.2 Elite Open Water Swimmers

Due to the surge in the population of aquatic-sport athletes, FINA has initiated an injury and illness surveillance program at their biennial World Championships and further recommended a program for out-of-competition injury and illness recording and surveillance (Mountjoy et al., 2016). Results have been published concerning data collected for the duration of the 2009, 2013 and 2015 world championships as well as a retrospective survey of injuries and illness in the four weeks leading up to the 2013 and 2015 competitions (Prien et al., 2017). Noteworthy findings include a high in-competition injury rate for OW swimmers (52.5 injuries/1000 starts) as compared to pool swimmers (2.02 injuries/1000 starts) in 2009 and a relatively low rate of pre-competition injury in the four weeks leading up to the 2013 event (17.4%) (Mountjoy et al., 2010; Mountjoy et al., 2015). Unfortunately, the authors did not report any specific data on the anatomic location of injury or the possible associated risk factors (Mountjoy et al., 2016).

2.6 Survey Design

Studies utilizing survey-based methods provide information by systematically asking questions to study participants (Guppy & Gray, 2008). One must first establish the purpose of the survey, and from there questions are designed and administered accordingly (Fowler, 2013). Survey-based research is a useful tool for statistical exploration of trends within a population; however, the quality of a survey-based study is dependent upon the sampling, the question design, and the administration of the survey itself (Creswell & Creswell, 2018; Fowler, 2013). The current study employed a 176-question, self-administered internet-based survey that asked swimmers about their swimming-related MSK injuries, as well as various demographic data, training parameters, event participation, injury prevention strategies and COVID-related training changes that are further explained below.

2.6.1 Cross-sectional study design & recall bias

Cross-sectional survey research is characterized by participant responses given at a single point in time (rather than multiple responses administered at various times) (Field, 2009). Given that a cross-sectional study is not a true experimental design (groups may be formed based on existing differences only), the data collected can only be used for epidemiological and correlational statistics, as opposed to inferring causation (Field, 2009).

Since the data collection is limited to a single point in time and participants were asked to retrospectively identify any swimming-related injuries they sustained within their most recent 6-month period of training, the study is inherently subject to a level of recall bias. Historically, sports injury studies have utilized a 12-month timeframe for the recollection of injury incidence to cover an entire season; however, this has been challenged by a number of studies that have reported values ranging from 39% to 54% of athletes forgetting injuries within this period (Gabbe & Finch, 2003; Junge & Dvorak, 2000). This led to current guidelines of injury surveillance in various sports recommending a prospective design with a seven-day recall (Mountjoy et al., 2016; Fuller et al., 2007). Organized sporting regulatory bodies for elite athletes with on-site medical staff may have the resources to collect this data; however, this may be unrealistic for their recreational counterparts. A similar problem was identified in the recreational running population and a recent consensus statement was released to provide uniformity to injury surveillance studies (Yamato et al., 2015). The authors recommended that a 6-month timeframe be used in an effort to minimize participants' forgetting not only the occurrence of an injury but also the details, such as location, duration, mechanism, diagnosis and treatment (Yamato et al., 2015).

On March 11, 2020, the World Health Organization declared a global pandemic due to the COVID-19 virus outbreak (World Health Organization, 2020). In an effort to reduce transmission of the disease, a large number of jurisdictions across the globe restricted access to public pools and beaches and the majority of mass participation OW events were cancelled (Kent, 2020; Griffiths, 2020). This had implications for the current project because since March 2020, athletes have had to significantly alter their training regimes as compared to the pre-COVID time-period. It was not ideal to conduct the survey amidst the restrictions but given the global situation that limited and altered participation in swimming-related activities, we chose to maintain a 6-month recall and the survey was open from April to September 2021. It is notable that during this period there were still restrictions on gathering sizes and international travel. It would be prudent to conduct a follow-up study in the post-pandemic time-period when access to training facilities and participation in training groups and event participation returns to an unrestricted state.

2.6.2 Sampling

As noted, the population of non-elite OW swimmers are quite diverse and there is currently no overarching group to which all OW swimmers belong. As such, finding a sampling frame of this population is difficult, and therefore a nonprobability sampling method must be employed. Nonprobability sampling methods introduce a subjective element to the sample selection and in the case of convenience sampling (a type of nonprobability sampling), it is the characteristics of the participants that will influence their participation (Henry, 1990). A convenience sample is a self-selected sample recruited through public advertisements and therefore, the assumptions of probability theory and sampling error do not apply and must be noted accordingly (de Vaus, 2014). Although this type of sample hinders the ability to generalize the results of the study, it is useful for exploratory research and when practical constraints must be considered (de Vaus, 2014).

2.6.3 Self-administered surveys

Self-administered surveys allow the participant to complete the survey without the guidance of another person and at a time of their choosing (Fowler, 2013). Further, if there are no time constraints on the survey, it allows participants time to complete it at their leisure and they can check with other sources before/during the survey completion. This was desirable for the current project because it provided participants the opportunity to consult medical records, diagnostic results, training logs or event details. Further, self-administered questionnaires are more cost-effective and allow a greater reach than one requiring personal administration (Fowler, 2013). A disadvantage of self-administered survey design is the inability of the researcher to clarify any ambiguous questions or survey directions for the participant (Fowler, 2013). Therefore, self-administered surveys must be designed with ease-of-use and clarity in mind.

2.6.4 Question design

Survey questions can broadly be grouped into open and closed formatted questions; respondents formulate their own responses to an open-ended question whereas they choose from a pre-set list of responses to a closed-ended question (Fowler, 2013). Open-ended questions allow respondents to formulate their own answers to questions; however, the answers may vary based on their interpretation of the question (Fowler, 2013). Fowler (2013) strongly recommends the use of closed-ended questions (where appropriate) in self-administered questionnaires to increase the usability of data through clarification and consistency. Closed-ended questions typically increase the ease of use of the survey, which may, in turn improve the likelihood of participation and completion of the survey.

Survey questions must maintain a consistent meaning to all respondents (Fowler, 2013). Variance in interpretation may be further compounded by the distribution of the survey across various cultures, given that the educational experience and cultural background will affect each participant's interpretation of the question (Fowler, 2013). For instance, a 'medic' typically refers to a medical doctor in the United Kingdom, whereas it typically denotes paramedic or emergency medical personnel in North America. Thus, the questionnaire must be culturally sensitive with ample descriptions and synonyms available. Cultural interpretation was addressed by having three OW swimmers from different countries (Canada, the United Kingdom, and the United States) review the survey before it was distributed.

There may be instances where the options available in a closed-ended question are not exhaustive. Therefore, open-ended response boxes were included throughout the questionnaire (where appropriate) to allow participants to respond with answers not listed in the pre-set list of responses. For example, perhaps they consulted a reflexologist for a foot complaint and this vocation was not listed in the pre-set list of options.

Chapter 3: Objectives & Hypothesis

The objectives of this study are as listed below:

1. To generate epidemiological data regarding injury prevalence within the non-elite OW swimming population during the COVID-19 pandemic.
2. To explore possible associations between reported injuries and identified risk factors and preventative strategies.

Given the paucity of research in OW swimmers, this study primarily aimed to generate data and information for use in further research (hypothesis-generating research). However, with consideration given to previous research within the pool-swimming population combined with anecdotal conversations with OW swimmers, it was hypothesized that: 1) there would be a similar or increased prevalence of lumbar spine and hip injuries reported within the OW swimmer population, and 2) there would be a similar prevalence of shoulder injuries reported within the OW swimmer population.

Chapter 4: Methods

The study design was rooted in a post-positivist epistemology and used a self-administered internet-based survey to generate data relating to reported injuries in OW swimmers. Survey studies ask questions and participant responses can be used for statistical exploration of trends within a population (Creswell & Creswell, 2018). Therefore, a population-based survey design was appropriate given that the purpose of this project was to estimate injury trends within the non-elite OW swimming population and explore possible associated risk factors. A cross-sectional design was chosen over a longitudinal study due to time constraints associated with a Master's project. As noted, a 6-month recall period was used to remain consistent with recreational running-related literature (Yamato et al., 2015). An internet-based survey was chosen in an effort to maximize the reach of the survey throughout the global population of OW swimmers.

This project received approval on ethical grounds by the University of Regina Research Ethics Board on April 14, 2021.

4.1 Definitions

Recently, Mountjoy et al. (2016) released a consensus statement in the British Journal of Sports Medicine and provided operational definitions and methodological recommendations for the reporting of aquatic sport-related illness and injury. In an effort to maintain consistency within the literature, the following definitions were used for the current study:

- Injury: Any physical complaint or observable damage to body tissue produced by the transfer of energy or sustained by an athlete during participation in training or competing in an aquatic discipline, regardless of whether it received medical attention or its consequences with respect to impairments in competition or training.
- Clinician: Anyone who is involved in the health care of athletes, reviews medical or physiological information, and/or implements an action plan to improve the athlete's health, where health is considered in a broad sense but must be more than just performance enhancement.
- Medical attention: An injury or illness where a qualified clinician assessed the athlete's medical condition.
- Time loss: A time-loss injury or illness leads to the athlete being unable to take full part in swimming-related activities. If the athlete misses the rest of the training or competition session but returns for the next training/competition, this should be recorded as a time-loss incident.
- Index injury: The first recorded injury in a series of injuries constituting a recurrent condition.

- Exacerbation: Injury to the same location and of the same type as the index injury, where the index injury has not completely healed.
- Reinjury: Injury to the same location and of the same type as the index injury, where the index injury has completely healed.
- Local injury: Injury to the same location but a different type from the index injury.

The cause, or mechanism of injury (MOI) (traumatic or overuse) may not present in congruence with its physiologic basis. For example, a lower back injury may be due to accumulated stress over time but may manifest as a single incident when an athlete exits the pool (Mountjoy, 2016). Because the physiologic definition is often difficult to discern, Mountjoy et al. (2016) have recommended that the definitions regarding MOI be operationally defined as:

- Traumatic injury: An injury caused by a single, clearly identifiable energy transfer. The mechanism of a traumatic injury can be further specified as (1) non-contact, (2) contact with another athlete/person or (3) contact with an object or animal.
- Overuse injury: Refers to a condition caused by multiple accumulative bouts of energy transfer without a single, identifiable event responsible for the injury.

4.2 Participants

The target population for this study was adult non-elite long-distance OW swimmers who self-identify as such and regularly compete or train in an OW setting.

Inclusion criteria included any English-speaking OW swimmer over the age of 18 years with access to the internet. Exclusion criteria included professional OW swimmers and those competing in the FINA international OWS circuit.

The target sample size was 250 participants to allow correlations to stabilize and provide ample power (Schöndrodt & Perugini, 2013). The survey was closed in September 2021 after 156 participants completed the survey due to time constraints and challenges imposed by the COVID-19 pandemic.

4.2.1 Participant Recruitment

Study information was dispersed through the following online avenues, and participation was via a voluntary opt-in basis by those who fulfilled study criteria.

1. Swimtrek monthly newsletter: Swimtrek is a British travel company specializing in OW swim vacations and their email reach includes swimmers from the United Kingdom, the European Union, North America, and Australia. This connection was made via personal communication with the company, and they distributed the survey link in their July 2021 newsletter.
2. Facebook posts: There are several OWS groups on the Facebook social media platform. These include the Dover channel training group, Dorset OW swimmers, the Lake Ontario Swim Team (LOST), the Southern Ontario Swim, the Chesapeake Bay OW swimmers, as well as the re-posts from members of these groups to other connected groups with similar populations.

3. Gatekeepers and snowball recruitment through word of mouth: A handful of prominent figures within the long-distance swimming community graciously volunteered to spread study information through their social media avenues.

4.3 Survey Design

The survey was an original design composed of five sections: swimmer demographics, training habits, injury reports, event participation, and injury prevention strategies. This study employed Qualtrics (Provo, Utah, USA) survey software, and the piloting procedure included an internal review of the questionnaire by three OW swimmers from various countries of residence as well as the author, supervisor, and one committee member.

4.3.1 Demographics

Demographic data collected included age, sex, height, weight, geographic location, employment status, highest level of education obtained, concurrent medical conditions and tobacco use. This was done to gain insight into variables which may be related to injury, and also to investigate the average demographics of the OW marathon swimming population.

4.3.2 Injury

Swimmers were asked to recall any episode of injury that they had experienced within their most recent 6-month period of unbroken training using the definitions provided by Mountjoy et al. in the 2016 consensus statement. Questions included the location; date; type (traumatic vs. overuse); diagnosis (if applicable); number of days that the injury resulted in the inability to train, modified participation or decreased performance; any previous history of injury to that site; and treatment received (if applicable). Results were categorized based on location and type of injury as outlined in the consensus statement by Mountjoy et al. (2016).

4.3.3 Training Habits

Questions concerning training habits included the number of years the swimmer has participated in swimming, then another specifying OWS, as well as their weekly estimate of meterage and swim duration broken up by season (i.e., periodization questions), water type (i.e., pool, fresh-water or salt-water), and the proportion of training completed in a wetsuit. We also queried the type and amount of cross-training, as well as their use of a training plan and/or coach and type of group (e.g., masters group, triathlon group, etc.).

4.3.4 Event Participation

Participants were asked about their participation in OWS events during the 2018, 2019, and 2020 seasons, as well as their plans for the 2021 season. They reported on each events' location, date and distance, and they elaborated on how COVID affected their 2020 participation as well as how it affected their plans for the 2021 season.

4.3.5 Injury Prevention Strategies

Injury prevention strategies queried included participation (and duration) in dryland warmup, resistance and/or core training, as well as any preventative health care sought out and the frequency of such treatment. There was also an open-ended question regarding any other concerted efforts the swimmers may employ to prevent injuries that wasn't addressed in the survey.

4.4 Data collection

Qualtrics survey software stores survey data and tabulates it into a spreadsheet format available for download from their servers. All data is encrypted and made anonymous by Qualtrics. The survey was opened in April 2021 and was closed in September 2021 (i.e., data collection took place over a 4.5 month time period).

4.5 Statistical Analysis

4.5.1 Data entry and data cleaning

The survey data was downloaded from Qualtrics via a Microsoft Excel file that was used for the initial process of data entry. The data were cleaned by manual inspection by the principal investigator, and outlying, abnormal or missing entries were checked against the Qualtrics output and corrected or omitted, as necessary. Data used for logistic regression were then transferred to an SPSS file for further analysis.

4.5.2 Descriptive Statistics

Continuous variables were described with means with standard deviations and medians. Where appropriate, minimum and maximum values were also reported. Categorical data were described with frequency and percentile proportions. Descriptive statistics were computed using Microsoft Excel (Version 16.65).

4.5.3 Factors associated with MSK injury

Logistic regression was computed using SPSS software (Version 27, SPSS, Inc., Chicago. IL) to explore the variables that may be associated with MSK injury. Logistic regression is appropriate when continuous or categorical independent variables are used to predict a binary categorical outcome (Field, 2009; Bewick et al., 2005). We chose to use a hierarchical method to build the regression model (, Field, 2009). The outcome variable used was whether participants reported at least one injury within the past six months. The predictor variables, listed in order of the steps used in the logistic regression were as follows:

- Step 1 included demographic variables (age, body mass index (BMI), sex, and training years). These were entered into the model first because age and sex have previously been reported to be associated with onset of injury as described in Chapter 2.1.1.2 (p.5), 2.2.1 (p.14) and 2.2.4 (p.17). BMI and training years were included in this section because the categorization fit within demographic variables.
- Step 2 included training variables (periodization and participating in cross-training). These were entered second into the model because of prior research suggesting a

potential association of these variables with injury risk as described in Chapter 2.3.2 (p. 18).

- Step 3 included the amount of time participants wore a wetsuit (never, sometimes or always). This was added into the model as a separate step because swimmers that follow MSF rules cannot wear a wetsuit during their swims, and we wanted to see if this variable would have an independent effect on the overall model.
- Step 4 included the amount of time participants trained in salt water (more or less than 50%). Salt water is more dense than fresh water, which affects human buoyancy and swimming mechanics (Harries, 1983). Therefore, this was also added in separately for the same reason as Step 3.
- Step 5 included whether or not the participants engaged in efforts related to injury prevention.
- Step 6 included whether the participants only competed in OWS as a triathlete.
- Step 7 included the total distance (metres) each participant completed as part of their competitive events during the 2018, 2019, and 2020 seasons. We chose to input the total event competition distance each participant completed within the 2018-2020 seasons as a continuous variable in the analysis (Zwingenberger et al., 2014).

Statistical significance was set at $\alpha = 0.05$.

Chapter 5: Results

5.1 Response Rate

156 participants completed or partially completed the survey. However, because some questions did not apply to certain participants (for instance, minimum and maximum training meterage and duration did not apply to individuals who do not periodize their training), or because some participants did not answer all questions, the denominator used for the statistical analyses did not remain consistent at 156 (range 109-156).

5.2 Epidemiological data regarding injury

5.2.1 Injury Prevalence, Location and Causation

The 6-month prevalence of swimming-related MSK injury within this sample population was 30% (n=36), of which 18 (36.7%) resulted in a time-loss injury. Eleven individuals (9.2% of the total, or 30.6% of those reporting injuries) reported more than one injury and a total of 49 injuries were recorded. Table 1 provides further details regarding injury frequency and location; percentages are reported from the total number of injuries reported (n=49). Twenty-five (51.0%) involved the shoulder (including the clavicle), 6 (16.7%) involved the cervical spine (neck) and 3 (6.1%) involved the lumbar spine.

Table 1: Number and location of injury

Number of Injuries	n(%)
None	84(70.0)
One	25(20.8)
Two	9(7.5)
Three	2(1.7)
Location	
Shoulder (including the clavicle)	25(51.0)
Cervical Spine	6(12.2)
Lumbar Spine	3(6.1)
Upper Arm	2(4.1)
Thoracic Spine	2(4.1)
Elbow	2(4.1)
Head	1(2.0)
Chest, sternum or ribs	1(2.0)
Pelvis	1(2.0)
Forearm	1(2.0)
Wrist	1(2.0)
Hand	1(2.0)
Thigh	1(2.0)
Foot or toe	1(2.0)
Other (unspecified)	1(2.0)

Thirty-one (63.3%) injuries were not attributed to a clearly identifiable incident. The remainder were attributed to contact with another swimmer, object or animal (n=6; 12.2%), or a single, non-contact incident (n=12, 24.5%). Twenty-five (51.0%) of the injuries reported were a first-time injury to the area specified, while 5 (10.2%) were reported as a second-time injury and 19 (38.8%) were a reinjury that had occurred 'multiple-times' prior. Of the injuries that were recurrences, 13 (54.2%) had originally happened as a swimming-related injury, while 11 (45.8%) were original injuries that occurred elsewhere (e.g., work, other sports, etc.).

5.2.2 Treatment and Activity Modification

Sixteen (32.7%) injuries did not require treatment, 15 (30.6%) were treated by one health care practitioner (HCP), and 18 (36.7%) were treated by more than one HCP. Physical therapists were consulted most frequently (n=20; 40.8%), followed by medical doctors (n= 16; 32.7%) and massage therapists (n=14, 29.6%). A further breakdown of treatments sought by the participants is recorded in Table 2; percentages were calculated from the total number of injuries reported (n=49).

Table 2: Health Care Practitioners Consulted

Number of practitioners consulted	n(%)
None	16(32.7)
One	15(30.6)
Two	6(12.2)
Three	4(8.2)
Four	5(10.2)
Five	3(6.1)
Practitioner type	
Physical therapist	20(40.8)
Medical doctor	16(32.7)
Massage therapist	14(28.6)
Chiropractor	7(14.3)
Acupuncturist	6(12.2)
Orthopedic Surgeon	5(10.2)
Other	4(8.2)
Osteopath	2(4.1)
Athletic therapist	1(2.0)

Nine (18.4%) injuries required no modification to the swimmers training regime, 15 (30.6%) resulted in an initial period where the swimmer was unable to train followed by a period of modified training, 22 (44.9%) resulted in modified participation and 3 (6.12%) resulted in an inability to train. Of those that resulted in modified participation, 8 (21.6) lasted less than one week, 11 (29.7%) lasted between one week and one month, 11 (29.7%) lasted between one and six months, 6 (16.2%) lasted over six months, and 1 (2.7%) respondent was unable to remember the injury duration. Of those that resulted in an inability to train, 3 (16.7%) lasted less than one week, 8 (44.5%) lasted between one week and one month, and 7 (38.9%) lasted between one and six months.

5.3 Demographic Characteristics of the Study Population and Descriptive Statistics

5.3.1 Sociodemographic characteristics

Sociodemographic characteristics, including participant location, age, sex, self-reported body mass index (BMI), location and education level are presented in Table 3**.** Three males and five females did not provide their age, and one female did not provide their height or body mass. Nine individuals did not specify their sex. Age distribution ranged from 19 to 71 years of age with an overall average age of 47.7 (±12.4) years; the average age for males was 50.0 (±12.4) years, and the average age for females was 46.5 (±12.3) years. The majority of responses were from Canada (n=56; 38.1%) and the United States (n=46; 31.3%); 25 respondents (17.0%) were located in the United Kingdom and the rest (n=22; 14.9%) were from the European Union, Africa, South America and Oceana. One hundred and one (73.2%) swimmers reported to have obtained a post-secondary degree, and 87 (63.0%) swimmers reported they were employed on a full-time basis. Average BMI was 26.7 (±4.8) kg/m^2, with a median of 26.2 kg/m^2.

Table 3: Sociodemographic characteristics of the study population

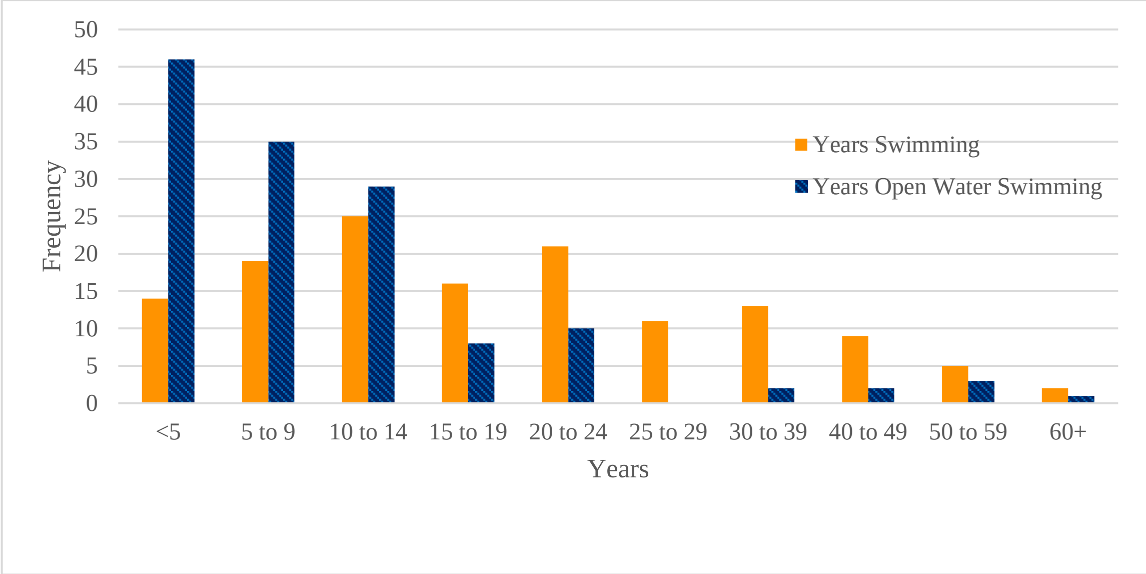
Sex:	n(%)
Male	52(33.3)
Female	95(60.9)
Did not answer	9(5.8)
Location:	
North America	
Canada	56(38.1)
United States	46(31.3)
United Kingdom	25(17.0)
European Union	9(6.1)
Oceania	9(6.1)
South Africa	3(2.0)
South America (Brazil)	1(0.7)
Education:	
No high school	5(3.6)
High school	8(5.8)
Some college	13(9.4)
College degree/diploma	11(8.0)
Bachelor’s degree	40(29.0)
Masters, Doctorate or Professional Degree	61(44.2)

Age:	Male, n(%)	Female, n(%)
19-29 years	3(6.1)	8(8.9)
30-39 years	8(16.3)	22(24.4)
40-49 years	9(18.4)	24(26.7)
50-59 years	17(34.7)	21(23.3)
60-69 years	10(20.4)	14(15.6)
70+ years	2(4.1)	1(1.1)
Total	49(100)	90(100)
Body Mass Index:		
Underweight (<18.5 kg/m^2)	0(0.0)	3(3.4)
Normal (18.5 to <25.0 kg/m^2)	9(18.4)	39(43.8)
Overweight (25 to <30.0 kg/m^2)	30(61.2)	29(32.6)
Obese (>30.0 kg/m^2)	9(18.4)	18(20.2)

5.3.2 Training Characteristics

The majority of swimmers (n=89; 69.0%) reported they started training as a swimmer when they were under 19 years of age; however, there was one respondent who began training at 60 years of age. The average age respondents began training as a swimmer was 18.1 (±14.6) years and the median was 10 years (range 3 to 60 years). The average number of years participants reported actively training was 19.4 (±13.9) years and the median was 15 years (range 1 to 62 years). The average number of years participants reported training as an OW swimmer was 10.1 (±11.0) years, with the median being 6 years (range 1 to 62 years). Figure 2 illustrates the frequency of swimming vs. OW swimming experience of the respondents and highlights the finding that although a large majority of the respondents had many years of swimming experience, most respondents were relatively new to OW swimming; roughly one-third of respondents had been OW swimming for under 5 years and over half had less than 10 years of OW experience.

Figure 2: Frequency of years of swimming experience



Note. Years of swimming and OW years swimming vs. Frequency of responses.

Eighty-six (63.7%) swimmers reported periodizing their training schedule either based on the season (n=39; 45.4%), their competition schedule (n=46; 53.5%), or on 'other' rationale and did not elaborate (n=1; 1.2%). Those that do not periodize their training reported swimming an average of 8560 (±6295) meters and 4.1 (±2.4) hours per week, with a range from 1000-25000 meters and .5 to 10 hours weekly. The minimum values for those that periodize their training (i.e., when they are training the least throughout the year) was an average of 5540 (± 7842) meters and 2.49 (±2.69) hours per week, with a range from 0 to 60000 meters and 0 to 18 hours; their maximal values (i.e., peak training season) was an average of 19390 (±15779) meters and 8.27 (±4.95) hours, with a range from 3000 to 80000 meters and 1.5 to 20 hours per week.

Fifty-two (38.7%) swimmers reported training either as an individual or with one group or team (i.e., masters swimming club, informal open-water group), with 32

(23.4%) of those only training individually. Eighty-four (61.3%) reported training with more than one group or team, or a combination of a team and individually. The results are reported further in Table 4; please note that the percentages are based on the number of individuals who answered the question rather than the total number of responses, thus giving the percentage of individuals that participate in each manner of training.

Fifty (41.3%) swimmers reported they never wear a wetsuit when training in OW, 50 (41.3%) reported they wear a wetsuit some of the time and 21 (17.4%) reported to wear it all the time.

Table 4: Modes of Training

	n(%)
Individual training	97(70.8)
Unorganized OW group (i.e., social group)	69(50.4)
Organized OW group	53(38.7)
Pool swimming group	46(33.4)
Triathlon-training swim group	18(13.1)
Other (unspecified)	2(1.46)

OW = Open water. Categorical variables are based on the number of respondents to the question (n = 137).

5.3.3 Event Participation

Data were collected for event participation occurring in 2018, 2019, 2020 and 2021. Data from the 2018 and 2019 seasons were considerably different than 2020 and 2021 data due to the onset of the COVID-19 pandemic and the resulting restrictions. In 2018 and 2019, 64.2% (n=77) and 63.5% (n=73) of respondents, respectively, had participated in at least one event. In 2020, this number decreased to 35.7% (n=40). However, 71.6% (n=78) of respondents reported that they were training for a 2021 event.

Of those who competed in 2018, there was an average of 2.39 (±1.31) events per participant (of those who reported participating in events); there was a similar average of 2.39 (±1.45) events per participant in 2019, and 2020 event participation dropped to 1.81 (±1.11) events per participant with 88 (80%) respondents noting that COVID-19 restrictions had affected their intended event participation. The data from 2021 were collected mid-season and were based on both past and future events; an average of 2.34 (±1.29) events per participant (of those who participate in events) was reported. Based on the events described and each participant's longest recorded event, 13 (11.3%) participants competed in OW events solely as multi-sport athletes (i.e., triathletes), 35 (29.7%) participated in events under 10km long, 23 (19.5%) participated in events from 10 to 20km long and 16 (13.6%) participated in events longer than 20km.

5.3.4 Cross-Training and Injury Prevention

Ninety-nine respondents (82.5%) reported participating in cross-training activities. See Table 5 for a further breakdown of each type of activity. Percentages are based on number of participants who answered the question (n=120). The reasons behind participation in cross-training events included enjoyment (n=75; 62.5%), efforts to increase swimming performance (n=28; 23.3%), prevention of swimming-related injuries (n=18;15%), general fitness and health (n=7, 5.8%) and other (n=10; 8.3%) reasons.

Table 5: Respondents who participate in cross-training activities

	n(%)
Cycling	62(51.7)
Running	54(45.0)
Weight training	51(42.5)
Yoga or Pilates	29(24.2)
Walking or hiking	15(12.5)
Cross-country skiing	10(8.3)
Team sports	7(5.8)
Cross-fit	3(2.5)
Other	14(11.7)

With regards to injury prevention, 30 (27.5%) swimmers reported they make no effort to prevent swimming-related injuries, 55 (50.5%) reported they visit some type of preventative health care, and 42 (38.5%) reported they complete a dry-land warmup. Percentages are based on the number of respondents to the question (n=109). Other efforts are listed in Table 6 along with a further breakdown. The average duration of a dryland warmup was 10.6 (±6.9) minutes.

Table 6: Directed efforts to prevent swimming-related injuries

	n (%)
No effort	30(27.5)
Preventative sports health care	55(50.5)
Massage Therapy	46 (42.2)
Physical Therapy	25(22.9)
Chiropractic	17(15.6)
Acupuncture	13(11.9)
Athletic Therapy	6(5.5)
Other	5(4.6)
Dryland warmups	42(38.5)
Other (unspecified)	9(8.3)
Strength Training	5(4.6)
Stroke Improvement	5(4.6)
Pilates or Yoga	4(3.7)
Sports Psychology	3(2.8)
Stretch Cords	2(1.8)

5.3.5 Effect of the COVID-19 Pandemic

A series of questions were asked regarding how restrictions due to the COVID-19 pandemic affected each swimmer's training. Ninety-six (89%) respondents noted a period where their training was somehow affected by various COVID-19 restrictions; 76 (80%) reported there was a period they were unable to swim, with the average period being 21.1 (±16.9) weeks. Average distance and duration in the water was also affected; 81 (86.2%) swimmers reported their average meterage has changed and 83 (88.3%) respondents reported a change in duration. Not surprisingly, the way respondents train has also changed; 61 (64.9%) reported that they have had to alter who they train with. Other notable answers included 15 individuals who described increasing the time they were able to swim in OW and 5 individuals who reported they started OW swimming due to limited pool-availability or safety concerns with indoor swimming.

5.4 Prediction and Injury Risk Factors

A logistic regression was performed using a hierarchical entry method with 7 steps. Using MSK injury as the outcome variable, Step 1 included demographic information (age, BMI, Sex and Training Years) as the predictor variables for reasons described in Chapter 4.5.3 (p.33) (Table 7). For step 1, the overall model is not significant; however, there is a trend ($p < .10$) for age and sex (female) to be independent predictors in the final model.

Table 7: Step 1: Demographics

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.041 (0.020)	4.243	1.042 (1.002, 1.083)	0.039
BMI (kg/m^2)	<0.001 (0.044)	<0.001	1.000 (0.918, 1.089)	0.998
Sex (Female)	1.137 (0.512)	4.928	3.117 (1.142, 8.502)	0.026
Training Years (yrs)	-0.002 (0.016)	0.020	0.998 (0.967, 1.029)	0.887

R^2 = 0.082 (Cox & Snell), 0.118 (Nagelkerke). Model $X^2(4) = 9.111$, $p = 0.058$.

16.7% of injured correctly classified; 94.7% of non-injured correctly classified.

Training information (periodization and cross training) were included in Step 2 as the predictor variables (Table 8). This step did not make a significant contribution to the model ($p = .570$), and both variables that were added to the model were not significant independent predictors ($p > .2$).

Table 8: Step 2: Demographics + Training

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.039 (0.020)	3.807	1.040 (1.000, 1.082)	0.051
BMI (kg/m^2)	-0.005 (0.044)	0.015	0.995 (0.912, 1.084)	0.902
Sex (Female)	1.119 (0.518)	4.668	3.063 (1.110, 8.455)	0.031
Training Years (yrs)	-0.006 (0.016)	0.124	0.994 (0.963, 1.027)	0.725
Periodization (Yes)	-0.514 (0.489)	1.107	0.598 (0.230, 1.558)	0.293
Cross Train (Yes)	-0.189 (0.617)	0.094	0.828 (0.247, 2.775)	0.759

R^2 = 0.092 (Cox & Snell), 0.132 (Nagelkerke). Step: $X^2(2)$ = 1.124, p = 0.570. Model $X^2(6)$ = 10.234, p = 0.115.

10.0% of injured correctly classified; 96.1% of non-injured correctly classified.

The amount of time spent training in a wetsuit (never, sometimes, always) was the predictor variable included in Step 3 (Table 9), and the amount of time spent training in salt water (more or less than 50%) was included in Step 4 (Table 10). Neither step made a significant contribution to the model ($p > .7$), nor was either of the new variables found to be a significant independent predictor ($p > .4$).

Table 9: Step 3: Demographics + Training + Wetsuit

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.041 (0.020)	3.960	1.041 (1.001, 1.084)	0.047
BMI (kg/m^2)	0.003 (0.047)	0.003	1.003 (0.915, 1.099)	0.955
Sex (Female)	1.101 (0.521)	4.468	3.006 (1.083, 8.342)	0.035
Training Years (yrs)	-0.005 (0.016)	0.103	0.995 (0.963, 1.027)	0.749
Periodization (Yes)	-0.436 (0.505)	0.744	0.647 (0.240, 1.741)	0.388
Cross Train (Yes)	-0.096 (0.646)	0.022	0.908 (0.256, 3.219)	0.881
Wetsuit (Sometimes)	0.077 (0.545)	0.020	1.080 (0.371, 3.144)	0.888
Wetsuit (Always)	0.433 (0.688)	0.397	1.542 (0.400, 5.939)	0.529

R^2 = 0.096 (Cox & Snell), 0.137 (Nagelkerke). Step: $X^2(2)$ = 0.427, p = 0.808. Model $X^2(8)$ = 10.662, p = 0.222.

16.7% of injured correctly classified; 94.7% of non-injured correctly classified.

Table 10: Step 4: Demographics + Training + Wetsuit + Salt Water

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.041 (0.021)	3.929	1.042 (1.000, 1.085)	0.047
BMI (kg/m^2)	0.002 (0.047)	0.001	1.002 (0.914, 1.098)	0.970
Sex (Female)	0.976 (0.548)	3.172	2.654 (0.907, 7.767)	0.075
Training Years (yrs)	-0.004 (0.016)	0.065	0.996 (0.964, 1.028)	0.799
Periodization (Yes)	-0.448 (0.510)	0.771	0.639 (0.235, 1.737)	0.380
Cross Train (Yes)	-0.184 (0.666)	0.076	0.832 (0.225, 3.071)	0.783
Wetsuit (Sometimes)	0.137 (0.555)	0.061	1.146 (0.386, 3.401)	0.805
Wetsuit (Always)	0.432 (0.723)	0.357	1.541 (0.373, 6.356)	0.550
Salt Water (<50)	0.307 (0.559)	0.301	1.359 (0.455, 4.063)	0.583
Salt Water (>50)	0.465 (0.657)	0.501	1.593 (0.439, 5.776)	0.479

R^2 = 0.101 (Cox & Snell), 0.144 (Nagelkerke). Step: $X^2(2)$ = 0.573, p = 0.751. Model $X^2(10)$ = 11.235, p = 0.340.

16.7% of injured correctly classified; 94.7% of non-injured correctly classified.

In Step 5, the predictor variable included was whether the individual engaged in other efforts related to injury prevention (Table 11). This step made a significant contribution to the model ($p = .008$); however, the overall model was not significant ($p > .05$).

Table 11: Step 5: Demographics + Training + Wetsuit + Salt Water + Other Efforts

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.036 (0.021)	2.868	1.037 (0.994, 1.082)	0.090
BMI (kg/m^2)	-0.003 (0.050)	0.003	0.997 (0.905, 1.099)	0.956
Sex (Female)	0.976 (0.565)	2.981	2.655 (0.876, 8.042)	0.084
Training Years (yrs)	-0.001 (0.017)	0.001	0.999 (0.967, 1.033)	0.973
Periodization (Yes)	-0.733 (0.554)	1.750	0.480 (0.162, 1.423)	0.186
Cross Train (Yes)	-0.417 (0.701)	0.354	0.659 (0.167, 2.604)	0.552
Wetsuit (Sometimes)	0.129 (0.581)	0.049	1.138 (0.364, 3.554)	0.824
Wetsuit (Always)	0.520 (0.763)	0.465	1.682 (0.377, 7.507)	0.495
Salt Water (<50)	0.410 (0.590)	0.482	1.507 (0.474, 4.794)	0.487
Salt Water (>50)	0.867 90.702)	1.525	2.380 (0.601, 9.424)	0.217
Other Efforts (Yes)	1.599 (0.688)	5.726	4.946 (1.335, 18.320)	0.039

R^2 = 0.158 (Cox & Snell), 0.227 (Nagelkerke). Step: $X^2(1) = 6.978$, p = 0.008. Model $X^2(11) = 18.213$, p = 0.077.

26.7% of injured correctly classified; 92.1% of non-injured correctly classified.

Step 6 included whether participants only competed in triathlons as a predictor variable (Table 12), and Step 7 included the total event competition distances completed by the athletes (Table 13). Once again, neither step made a significant contribution to the model ($p > .5$) and neither of the new variables was significant ($p > .5$). In the final model, there was a non-significant trend for age (OR [95%CI] = 1.039 [0.996, 1.084], Wald = 3.093, $p = .079$) and sex (female) (OR [95%CI] = 2.614 [0.852, 8.021], Wald = 2.821, $p = .093$) to be independent predictors. The only significant independent predictor was the athlete engaging in an effort related to injury prevention (OR [95%CI] = 5.004 [1.356, 18.465], Wald=5.843, p=0.016). The final model correctly classified 30.0% of injured individuals and 90.8% of those who did not report at least one injury.

Table 12: Step 6: Demographics + Training + Wetsuit + Salt Water + Other Efforts + Triathletes

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.036 (0.021)	2.836	1.037 (0.994, 1.081)	0.092
BMI (kg/m^2)	-0.003 (0.050)	0.004	0.997 (0.904, 1.099)	0.948
Sex (Female)	0.965 (0.568)	2.893	2.626 (0.863, 7.989)	0.089
Training Years (yrs)	-0.001 (0.017)	0.001	0.999 (0.967, 1.033)	0.975
Periodization (Yes)	-0.711 (0.563)	1.597	0.491 (0.163, 1.480)	0.206
Cross Train (Yes)	-0.422 (0.701)	0.362	0.656 (0.166, 2.591)	0.547
Wetsuit (Sometimes)	0.154 (0.592)	0.067	1.166 (0.366, 3.717)	0.795
Wetsuit (Always)	0.560 (0.785)	0.508	1.750 (0.394, 8.154)	0.476
Salt Water (<50)	0.407 (0.589)	0.477	1.503 (0.473, 4.771)	0.490
Salt Water (>50)	0.861 (0.703)	1.500	2.365 (0.596, 9.375)	0.221
Other Efforts (Yes)	1.596 (0.669)	5.698	4.935 (1.331, 18.301)	0.017
Triathletes (Yes)	-0.177 (0.831)	0.045	0.838 (0.164, 4.273)	0.831

R^2 = 0.158 (Cox & Snell), 0.227 (Nagelkerke). Step: $X^2(1) = 0.046$, p = 0.830. Model $X^2(12) = 18.259$, p = 0.108.

30.0% of injured correctly classified; 93.4% of non-injured correctly classified.

Table 13: Step 7: Demographics + Training + Wetsuit + Salt Water + Other Efforts + Triathletes + Event Distances

	B (SE)	Wald	OR (95% CI)	P value
Age (yrs)	0.038 (0.022)	3.093	1.039 (0.996, 1.084)	0.079
BMI (kg/m^2)	-0.008 (0.050)	0.025	0.992 (0.899, 1.095)	0.875
Sex (Female)	0.961 (0.572)	2.821	2.614 (0.852, 8.021)	0.093
Training Years (yrs)	-0.002 (0.017)	0.018	0.998 (0.965, 1.032)	0.893
Periodization (Yes)	-0.679 (0.566)	1.438	0.507 (0.167, 1.538)	0.230
Cross Train (Yes)	-0.455 (0.707)	0.415	0.634 (0.159, 2.535)	0.519
Wetsuit (Sometimes)	0.050 (0.612)	0.007	1.051 (0.316, 3.490)	0.936
Wetsuit (Always)	0.460 (0.800)	0.331	1.584 (0.331, 7.595)	0.565
Salt Water (<50)	0.442 (0.594)	0.555	1.557 (0.486, 4.985)	0.456
Salt Water (>50)	0.871 (0.708)	1.514	2.389 (0.597, 9.568)	0.218
Other Efforts (Yes)	1.610 (0.666)	5.843	5.004 (1.356, 18.465)	0.016
Triathletes (Yes)	-0.256 (0.843)	0.092	0.774 (0.148, 4.038)	0.761
Event Distances (m)	<0.001 (<0.001)	0.392	1.000 (1.000, 1.000)	0.531

R^2 = 0.161 (Cox & Snell), 0.232 (Nagelkerke). Step: $X^2(1) = 0.409$, $p = 0.523$. Model $X^2(13) = 18.668$, $p = 0.134$.

30.0% of injured correctly classified; 90.8% of non-injured correctly classified.

Chapter 6: Discussion

The current study was the first to investigate injury prevalence in a non-elite OW swimming population. The primary aim was to generate data regarding the characteristic injuries sustained within this population and their associated 6-month prevalence. A secondary objective was to investigate possible risk factors associated with injury onset.

6.1 Injury Prevalence

This study aimed to generate epidemiological data concerning 6-month injury prevalence within a non-elite population of OW swimmers and to explore possible associations between injury and risk factors/preventative strategies. Our findings suggest a 6-month injury prevalence of 30.0% with most injuries occurring to the shoulder complex (51.0%). Shoulder injuries are commonly reported to be the most prevalent among swimmers, presumably due to the shoulder generating much of the propulsive force when moving through the water (Wanivenhaus et al., 2012).

The second highest prevalence (12.2%) was injuries to the cervical spine (neck). This is rather inconsistent with the previous literature of pool swimmers and other aquatic athletes with either the lower back (lumbar spine) or knee being the second most prevalent area of injury (Wanivenhaus et al., 2012; Prien et al., 2017; Baker et al., 2019). Upon closer examination of the article by Mountjoy et al. (2015) that investigated the injuries in the four weeks leading up to and during the 2013 FINA world championships, "head and neck" accounted for the greatest number of new-onset injuries among the OW swimmers. This was conveyed within a figure and not discussed within the body of the article's text. Interestingly, there were 5 reports of head and neck injuries among 87 OW swimmers that responded to the surveys (one retrospective and one prospective), which would indicate that 5.7% of OW swimmers reported a head or neck injury (Mountjoy et al., 2014). In comparison, there were 23 head and neck injuries reported among the 329 water polo players that responded to the surveys (7.0%) and 4 head and neck injuries reported among 464 pool swimmers (0.9%) (Mountjoy et al., 2015). Common among water polo and OWS is the possibility of physical contact between athletes, as well as the necessity to look forward while swimming (as discussed in *Section 2.1.2.2*). It would be interesting to note the mechanism (i.e., overuse vs. Contact) to provide more information regarding the etiology of the cervical injury in these populations.

Lumbar complaints composed the third most common injury in the current study (n = 3, 6.1%), which did not support the hypothesis that low back and hip pain may be of increased prevalence within the OW population.

6.2 Sociodemographic Characteristics

It appears that the sociodemographic characteristics of swimmers and triathletes is rather varied. In most studies of triathletes, young (30-40 years), male participants were the majority; however, in studies involving masters swimmers, the majority was often female and slightly older (average age reported from 47.1-55.3 years) (Baker et al., 2019; Wicker et al., 2012; Kruger et al., 2012; Villavicencio et al., 2006). In the current investigation, there was a predominance of female swimmers (64.6%) and an average age of 47.7 (±12.4) years, which appears to align with other studies of masters pool swimmers. Two studies concerning OW swimmer demographics were found for comparison; however, both studies involved a sub-set of the wider demographic.

Nuckton et al. (2014) studied 103 recreational OW swimmers who were members of a winter swimming club in San Francisco; 76 were men and only 27 female. Nikolaidis et al. (2018) assessed the performances of successful triple crown swimmers from 1875-2017, and only 553 (29%) of the 1875 finishers were female. It must be noted that both of these populations would be classified as a sub-set of OW swimmers (ice swimmers and channel swimmers), and their summer-swimming and shorter distance counterparts may have a larger proportion of females.

In the current study, the average BMI was 26.7 (±4.8) kg/m^2, which would be categorized as ‘overweight’. This was slightly higher than that found among the 103 cold-water swimmers in San Francisco (25.9 kg/m^2) and the pool-swimmers at the 2009 World Masters Games (25.8 ±2.8 kg/m^2) (Crow et al., 2014; Walsh et al., 2013). Perhaps OW swimmers have a slightly higher BMI than their pool-swimming counterparts due to cold tolerance; elevated BMI was found to be associated with greater cold tolerance and longer time spent in the water among a sample of OW swimmers (Nuckton et al., 2014). Notably, our population is not confined to a single club, country or continent. It is also important to note that our survey was open from April to September 2021, which was after several COVID-19 lockdowns world-wide. As documented by two studies, one in China and another study in the United States, a significant proportion of participants in both studies reported weight gain during the COVID-19 pandemic (Mulugeta et al., 2021; Zhu et al., 2021). A retrospective study analyzing the anthropometric data within the files of 11534 adults in Massachusetts, reported the average weight gain of those who gained weight (95% CI) was 3.41 (3.29, 3.58) kg in men and 3.09 (2.98, 3.19) kg in women (Mulugeta et al., 2021). This resulted in an average increase (95% CI) of 1.12

(1.05, 1.18) kg/m^2 among the men and 1.19 (1.15, 1.24) kg/m^2 among women (Mulugeta et al., 2021). From a sample of 889 survey respondents in China, Zhu et al. (2021) reported that 30.6% of the population reported an average weight gain of 0.5 (±2.8) kg. Therefore, the elevated BMI found in the current study may have been a by-product of the COVID-19 pandemic rather than being indicative of the general OWS population.

The educational level reported by our respondents was consistent with that of Canadian Master's pool swimmers, triathletes, and a broader group of "endurance athletes" (Larson et al., 2021, Wicker et al., 2012; Kowalski, 1999). The population appears to be highly educated, with all studies reporting 29.0 to 39.0% of respondents having obtained a Bachelor's degree, 23.0 to 28.1% having obtained a Master's degree and 10.0 to 15.9% of respondents having obtained a PhD or Professional degree (Larson et al., 2021; Kowalski, 1999). Larson et al. (2021) suggested that the socioeconomic profile of the swimmers may reflect characteristics of the youth population that carry over into adulthood.

6.3 Risk Factor Analysis

This study used logistic regression to explore the relationship between thirteen possible predictor variables and a report of at least one injury in the prior 6 months (the outcome variable). The only significant independent predictor of injury was the respondent having reported to engage in efforts to prevent injury (OR [95%CI] = 5.004 [1.356, 18.465], Wald=5.843, p=0.016). The reason for this is unknown. However, since the start date of the injury prevention efforts was not requested in the survey, perhaps those that had sustained an injury are the individuals that are currently participating in efforts to prevent injuries in the future. Another explanation may be the reverse; those that have injured themselves in the past may be more likely to engage in injury prevention because of past experiences, but also may have been more likely to be injured again (hence, the current injury). It would be prudent to explore this potential association with more in-depth analyses in future studies.

The final model also included two variables that displayed a non-significant trend to predict injury; age (OR [95%CI] = 1.039 [0.996, 1.084], Wald = 3.093, $p = .079$) and sex (female) (OR [95%CI] = 2.614 [0.852, 8.021], Wald = 2.821, $p = .093$). Baker et al. (2019) also reported a 1.6% per-year increase in the odds of sustaining an injury among the 499 master's swimmers they surveyed ((OR = 1.016, 95 % CI = 1.001-1.030; $p < 0.05$). An association of increasing injury with age has also been reported in the recreational running population (Johnston et al., 2018). Both Kruger et al. (2012) and Tate et al. (2012) did not find a relationship between age and shoulder injury; however, Tate et al. Grouped master's swimmers into one category and compared them to brackets of younger age-group swimmers, and Kruger et al. used 10-year age brackets and found a non-significant association between age and shoulder pain above 55 years of age.

Female swimmers may also be at an increased risk of injury. This association has been demonstrated in other swimming populations and is a relatively well-established phenomenon in other populations for certain characteristic injuries. For instance, ACL rupture and bone stress injuries occur at higher rates among adolescent female populations as compared to their male counterparts (Lin et al., 2018). Explanations for this are quite varied. As previously discussed, the smaller average body size among females leads to more repetition required to travel a pre-determined distance (Bak & Fauno, 1997; Gupta et al., 2020). Other explanations may include anatomical variance (e.g., smaller ligament size or decreased femoral notch width), physiologic differences (e.g., age of menarche, hormonal factors), or differences in neuromuscular control or biomechanical risk factors (e.g., landing mechanics) (Lin et al., 2018). Although it is important to note the phenomenon, it must be linked to a specific risk factor and cause in order to establish effective prevention strategies (for instance, prevention programs for ACL injuries being implemented in female soccer programs).

Chapter 7: Strengths and Limitations

The current study utilized a cross-sectional design asking participants to recall injuries sustained during the most recent 6-month period on a self-administered internet-based survey. This design has been chosen due to practical limitations of time and money, as well as an effort to maximize the reach of the survey. Due to the retrospective nature of the survey questions, a limitation of this study is the phenomenon of recall bias. There appears to be no literature comparing the effects of recall bias between 6 and 18-months; however, Gabbe and Finch (2003) noted discrepancies in recall in as little as 2-months, and Junge and Dvorak (2000) noted that discrepancies may not only include occurrence, but the severity of injury as well. Therefore, due to recall bias, the reported prevalence in this study may underestimate the actual injury rate in this population (Swimming Canada, 2020; Griffiths, 2020). Further, a cross-sectional design differs from a longitudinal study because it represents injury prevalence at a snapshot in time, and therefore, one cannot infer causation from any conclusions drawn (Creswell & Creswell, 2018).

As with any voluntary survey data, response bias (i.e., a difference between respondents and non-respondents) may also be a limitation. To investigate this possibility, Creswell and Creswell (2018) recommend conducting a wave analysis where select questionnaire items are analyzed on a week-by-week basis to determine if the average responses are changing throughout the course of the study. This was not done, but recruitment was staggered with the first social media recruitment post being made on April 22, 2021 and revisited monthly until August 2021.

Nonprobability samples are comparable to samples that result from very low response rates (Fowler, 1993). This is because respondent characteristics influence whether or not the individual will respond (Fowler, 1993). Fowler (2013) has identified many studies that conclude that individuals who are inherently interested in the research subject (e.g., have been injured in the past or are interested in research) are more likely participate in the study. Therefore, it is important to identify and highlight such characteristics.

Since there were some missing data points, the resulting analysis might not be representative of the sample population. This could have been mediated by increasing the sample size of the study. Ideally, the sample size would have been over 400 participants, as recommended by Bewick et al., (2005). However, this was not possible due to time limitations with the project.

As noted, survey questions are subject to interpretation by the respondent. During data cleaning, it was apparent that some questions required clarification or were poorly understood by some of the respondents. For instance, participants were asked if and how they periodized their training and one respondent selected ‘no’ to indicate that their training was not periodized, and therefore remained stable throughout the year. Yet later, they indicated they “…only swim in the sea. In the summer I swim 5 miles in a week. In the winter, maybe 100m per week”. Therefore, the respondent clearly misunderstood the question and the data provided was not congruent with other responses.

Chapter 8: Conclusion

This study aimed to investigate the MSK injury profile of non-elite OW swimmers and gain insight into possible risk factors associated with such injury. Currently there is no published data specific to OW swimmers for the athlete, coach or the health care professionals to consult when building training and competition schedules. Rather, injury prevalence and epidemiologic data are generalized from the pool swimming population, which negates the differences in distance, venue characteristics and the unpredictable environmental conditions in which OW swimmers compete and train. The results of this study indicate our respondent characteristics are congruent with other studies with a few minor differences. Similar to most swimming literature, shoulder injury prevalence was reported as highest in this population. Surprisingly, injuries to the cervical spine were the second most common injury. Future consideration should be given to developing comprehensive shoulder and cervical injury prevention strategies; however, it would be beneficial to conduct further investigation into etiology and associated risk factors before doing so. Statistical analysis indicated a trend towards injury risk increasing with age and in females (sex). The only significant independent predictor of injury in our model was whether or not the swimmer engages in efforts of injury prevention. However, there are many confounding variables that may be associated with this finding. Future plans include disseminating pertinent findings to the OW swimming population, not only through peer-reviewed literature accessible to health care providers, but also through media outlets popular among the OW population (e.g. *Outdoor Swimmer* magazine).

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