ACTIVE & SAFE

Evidence Summary: Swimming

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The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is *to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia.*

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Evidence synthesis tool

SPORT:	Swimming	**Target Group:**	Competitive (high schools and club-level to elite professionals) and recreational swimmers

Injury Mechanisms:	All Injury: Musculoskeletal or concussion injury sustained while swimming (competitive or recreational). Shoulder injury, lower back pain (LBP) and knee injury reported separately. Not including submersion or drowning injury.

Incidence/Prevalence	**Risk/Protective Factors**	**Interventions**	**Implementation/Evaluation**	**Resources**
All Injury (competitive) *Injury prevalence* in **elite swimmers (all ages)** is reported as between 32.2% and 74.6%. The shoulder accounts for the highest proportion of injury (30.8-62.4%), followed by the knee (12.9-49.9%) and lower back (6.2-17%). [1–7] In **elite competitive swimmers** (age 15-35y), *injury incidence* for all injury is 2.64 per 1000 AE, for acute injury is 1.1 per 1000 AE and for overuse injury is 1.48 per 1000 AE.[2] In **collegiate (NCAA) swimmers,** *injury incidence* ranges from 1.63 to 6.06 injuries per 1000 athlete exposures (AE) for females and from 1.48 to 4.97 injuries per 1000 AE for males.[4,5,8] Injury rate during **professional games** (competition and practice) is reported as 5.4% (2012 Olympics) and ranges from 21.8 to 60.1 per 1000 athletes in swimming and 94.6 to 117 injuries per 1000 athletes in open water	**Previous Injury** *History of any injury* increases **elite collegiate swimmer's** rate of injury (per 1000 AEs) more than 2.5 times (IRR= 2.74, 95% CI= 1.18, 6.37) after adjusting for the other risk factors (gender, years swimming). *History of injury to the same anatomical site* increases injury risk almost 2-fold in the adjusted model (IRR= 1.75, 95% CI= 1.25, 2.45).[4] Being a freshman in **elite collegiate swimmers** is a risk factor for injury. The risk of injury significantly decreased with subsequent *years of eligibility* for women (x^2, P = .03) and for combined men's and women's teams (x^2, P = .04).[8] Swimmers specializing in *strokes other than freestyle* exhibited a 33% greater risk (RR, 1.33 [1.001-1.77]) of injury than swimmers primarily specializing in freestyle.[8]	There have been **no** RCTs or other quality studies carried out to assess effectiveness of an injury prevention program on all musculoskeletal injury risk in competitive or recreational swimmers. Descriptive reviews have pointed to potential interventions based on biomechanical studies of injury risk: Careful monitoring of training volume, intensity, and duration by coaches and physicians will minimize overuse injuries and identify athletes at risk of swimming injury.[29] **Shoulder Injury** One RCT[30] has assessed a prevention program for shoulder pain (pain being a secondary outcome). Additional interventions are based on non-RCT tested interventions from descriptive reviews:	There is insufficient evidence for interventions to warrant studies on implementation/ evaluation. One study, measuring the attitudes and behaviours concerning shoulder pain in high school competitive club swimmers, found that the majority of swimmers believe that mild and moderate shoulder pain is normal in swimming and should be tolerated to complete practice. This may be a potential barrier to implementing an injury prevention program. The study suggests that education programs that are focused on informing athletes of the long-term consequences of practicing and competing with shoulder pain, the dangers of long-term pain medication usage, and the necessity of taking time off when injured may be effective in moderating their behaviours.[33]	**Websites** http://www.stopsportsinjuries.org/STOP/Prevent_Injuries/Swimming_Injury_Prevention.aspx **Australian Government Site** https://www.betterhealth.vic.gov.au/health/healthyliving/swimming-preventing-injury

swimming (FINA World Championships 2009 and 2013).[9–11] *Prevalence* of injury in **elite Paralympic swimmers** with sight restriction is 64% or 0.3 injuries per athlete per competition.[12] **All Injury (Recreational)** A representative sample of US **emergency department reported swimming injury** reported 88,891 annually or 1 swimming injury every 6 minutes.[13] In Australia, there are 2.2 swimming-related trauma or death incidents per 100,00 participants per year.[14] **Shoulder Injury** In **competitive swimmers**, *point prevalence* of shoulder injury ranges from 12.3 to 91%, *annual prevalence* ranges from 23.9-25.9%.[15–18] Point *prevalence* in **masters swimmers** is 19.4%.[17] *Prevalence* of **shoulder impingement in competitive male swimmers** is 17% and increases with competition level - (state 12%, national 20% and international swimmers 35%).[19] Exposure-adjusted *incidence* rates for **competitive club swimmers** is 0.2 injuries per 1000 swim km for significant interfering shoulder pain and 0.3 injuries per 1000 swim km for a significant shoulder injury that lasted >2 weeks.[20]	**Shoulder Injury** From a systematic review, there is a moderate level of certainty that the following are risk factors for shoulder injury at **all competition** levels: clinical joint laxity and instability, decreased internal and increased external shoulder rotation range of motion, previous history of pain/injury and higher competitive level.[25] **Knee Injury** Breaststroke swimmers have a 5-fold higher risk of knee pain (relative risk, 5.06, CI 2.07-12.36; p=0.001). Swimming for more than four times a week has a higher risk for knee injuries (RR 2.06, CI 1.21-3.52).[6] **Protective Factors** Freestyle has a reduced relative risk (0.45, CI 0.27-0.77; p=0.03) for knee pain. Stretching is associated with a five- fold reduced risk for overuse knee injuries (RR 0.179; p=0.041).[6] **Lower Back Pain** Butterfly swimmers have an increased risk of lower back pain (RR, 2.49, CI 1.21-5.09.36; p=0.011).[6] Torso hyperextension during front crawl strokes is not a	Descriptive reviews suggest that coaches should encourage increased body roll and scapula retraction during forward crawl, aiming at normal strength and endurance of the cuff and scapular stabilizers, as well as improving the flexibility of the anterior capsule to prevent shoulder injury. This can be done through an endurance training and strengthening program for the shoulder and periscapular muscles with emphasis placed on the serratus anterior, rhomboids, lower trapezius and subscapularis.[29,31] An RCT investigating an *8-week stretching and strengthening programme* targeting periscapular muscles in **elite collegiate (NCAA) swimmers** improved posture over the course of the season. However, there was no significant change in pain and function scores following the intervention ($F(1,26)=0.853$; $p=0.389$; $1-\beta=0.145$; ES 0.34). These participants were not followed throughout the season or longer to assess to effectiveness of the intervention on prospective injury risk.[30] **Otorrhea** In **children aged 0-14 years following tympanostomy**, an RCT		

Lower Back Pain In **elite professional swimmers** (age 16-25y), there is no difference in *prevalence* of self-reported LBP compared to no sport controls (52% vs. 64%; p=0.41).[21] In **university swimmers**, LBP *prevalence* is 18.1% (point), 36.1% (4-weeks) 34.1% (1-year), 32.6% (sports-life) and 47.8-76.1% (life-time). [22,23] Odds ratio of LBP during lifetime was 3.26 (CI 1.41-8.01) compared to non-athletes and OR of degenerative disc in swimmers was 2.87 (CI 1.31-6.44) compared to nonathletes.[23] In **adolescent competitive swimmers**, swimmers had increased odds of LBP *prevalence* OR 1.61 (1.01-2.57), particularly in females OR 2.1 (1.08-4.06) compared to non-swimming controls.[24]	biomechanically viable major cause of LBP.[26] **Glaucoma** Frequently wearing swim goggles does not lead to an increased risk of glaucoma over time in adults.[27] **Otorrhea** Children who swim without ear protection following tympanostomy tube placement suffer the same number or fewer episodes of otorrhea than children who do not swim. Pooled RD -5.04 (-11.6 to 1.5).[28]	found a statistically significant reduction in the rate of otorrhoea from 1.2 episodes to 0.84 episodes in the year of follow-up (mean difference (MD) -0.36 episodes per year in those that wore *ear plugs* while swimming. The absolute reduction is unlikely to be clinically significant and equates to an average child having to wear ear plugs for 2.8 years to prevent one episode of otorrhea. In a second RCT, there was no evidence of a reduction or increase in the rate of otorrhea (1.17 episodes per year in both groups; MD 0 episodes, 95% CI -0.14 to 0.14) in those who *avoided water* versus those who swam as usual.[32] There are clear gaps in the literature with regards to injury prevention interventions in swimming. There is a requirement for large, high-quality RCTs to assess the effectiveness of injury prevention programs based on evidence-based risk factors for musculoskeletal injury.		
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Review of Sport Injury Burden, Risk Factors and Prevention

Swimming

Incidence and Prevalence

Swimming is one of the most popular competitive Olympic sports with events in backstroke, butterfly, breaststroke, freestyle and individual medley. In addition, swimming is an extremely popular recreational sport, with participants across all age groups. Due to the non-load bearing nature of swimming, the most common injury type is overuse injuries (Kerr et al., 2015).

Elite Swimmers

The prevalence of in elite swimmers across all ages is reported as between 32.2% and 74.6%. The shoulder accounts for the highest proportion of injury (30.8-62.4%), followed by the knee (12.9-49.9%) and lower back (6.2-17%) (Chase et al., 2013; de Almeida et al., 2015; Kerr et al., 2015; Knobloch et al., 2008; Ristolainen et al., 2010; Sambanis et al., 2013; Venancio & Tacani, 2012). In elite competitive swimmers (ages 15-35 years), the incidence of all injury is reported as 2.64 per 1000 athletic exposures (AE), acute injury at 1.1 per 1000 AE and overuse injury at 1.48 per 1000 AE (Ristolainen et al., 2010). In collegiate (NCAA) swimmers, the injury incidence range from 1.63 to 6.06 injuries per 1000 AE for females and from 1.48 to 4.97 injuries per 1000 AE for males (Chase et al., 2013; Kerr et al., 2015; Wolf et al., 2009).

The injury rate during professional games (competition and practice from the 2012 Olympic games) is reported to range from 21.8 to 60.1 per 1000 athletes in swimming and 94.6 to 117 injuries per 1000 athletes in open water swimming (FINA World Championships 2009 and 2013) (Engebretsen et al., 2013; Mountjoy et al., 2010, 2015). The prevalence of injury in elite Paralympic swimmers with sight restriction is 64%, or 0.3 injuries per athlete per competition (Silva et al., 2013)

Shoulder injury is the most common site of injury in swimmers. In competitive swimmers, the point prevalence of shoulder injury ranges from 12.3 to 91%, and the annual prevalence ranges from 23.9-25.9% (McKenna et al., 2012; Mohseni-Bandpei et al., 2012; Sein et al., 2010; Tate et al., 2012). The point prevalence in masters level swimmers is reported at 19.4% (Tate et al., 2012). The prevalence of shoulder impingement in competitive male swimmers is reported at 17% and increases with competition level (state 12%, national 20% and international swimmers 35%) (Bansal et al., 2007). Exposure-adjusted incidence rates for competitive club swimmers is 0.2 injuries per 1000 swim km for significant interfering shoulder pain and 0.3 injuries per 1000 swim km for a significant shoulder injury that lasted >2 weeks (Walker et al., 2012).

Lower back pain (LBP) is also commonly reported in all levels of swimming. In elite professional swimmers (ages 16-25 years), there was no difference in the prevalence of self-reported LBP compared to no sport controls (52% vs. 64%; p=0.41) (Folkvardsen et al., 2016); however, in university swimmers, LBP point prevalence is 18.1%, 36.1% at 4-weeks, 34.1% at 1-

year, 32.6% for sporting-life and 47.8-76.1% for life-time prevalence (Hangai et al., 2009; Noormohammadpour et al., 2016). Compared to non-athletes, the odds of LBP during a swimmers lifetime was 3.26 higher (95% CI 1.41 to 8.01) compared to non-athletes and the odds of degenerative disc disease in swimmers was 2.87 (95% CI 1.31 to 6.44) higher compared to non-athletes (Hangai et al., 2009). In adolescent competitive swimmers, swimmers had an increased odds of LBP [Odds Ratio (OR)=1.61, 95% CI 1.01 to 2.57], particularly in females (OR=2.1, 95% CI 1.08 to 4.06), compared to non-swimming controls (Zaina et al., 2015).

Finally, the incidence of knee injury in competitive high school male swimmers/divers is reported as 1.5 per 1000 AE and in females as 2.5 per 1000 AE (Swenson et al., 2013).

Recreational Swimming

The injury incidence rates for recreational swimmers are more difficult to calculate due a lack of reporting or variability in reporting standards. A representative sample of US emergency departments treating swimming injuries reported 88,891 injuries annually or 1 swimming injury every 6 minutes (Pollard et al., 2013). In Australia, there are 2.2 swimming-related trauma or death incidents per 100,00 participants per year (Andrew et al., 2012).

Risk and Protective Factors

Many risk factors have been reported for all injury risk in swimmers. In elite collegiate swimmers, previous history of any injury increases the risk of injury (per 1000 AEs) more than 2.5 times [Incidence rate ratio (IRR)= 2.74, 95% CI 1.18 to 6.37] after adjusting for the other risk factors (such as gender and years swimming). Previous history of injury to the same anatomical site increases the risk of injury almost 2-fold (IRR= 1.75, 95% CI 1.25 to 2.45) (Chase et al., 2013).

Being a freshman in elite collegiate swimming is a risk factor for injury. Freshman men and women had a mean of 1.20 injuries per swimmer compared to 0.57 injuries per senior swimmer (P = .04) (Wolf et al., 2009). Swimmers specializing in strokes other than freestyle demonstrated a 33% greater risk of injury [Relative risk (RR)=1.33, 95% CI 1.00-1.77] compared to swimmers primarily specializing in freestyle (Wolf et al., 2009).

Specific risk factors have been reported for shoulder injury in swimmers. A critical systematic review on all swimming competition levels reported that clinical joint laxity and instability, decreased internal and increased external shoulder rotation range of motion, previous history of pain/injury and higher competitive level are moderate risk factors for shoulder injury (Hill, Collins, & Posthumus, 2015).

For knee injury, breaststroke swimmers are reported to have a 5-fold higher risk of knee pain (RR=5.06, 95% CI 2.07 to 12.36) compared to other strokes (Knobloch et al., 2008). Additionally, swimming more than four times a week was associated with a higher risk for knee injuries (RR=2.06, 95% CI 1.21 to 3.52) relative to less than four times a week (Knobloch et al., 2008). Freestyle swimming reduces the risk of knee pain (RR=0.45, 95% CI 0.27 to 0.77) relative to other strokes while stretching is reported to be associated with a five- fold reduced risk for overuse knee injuries (RR=0.179; p=0.041) compared to no stretching (Knobloch et al., 2008).

For back injuries, butterfly swimmers have been found to have an increased risk of lower back pain (LBP) compared to other strokes (RR=2.49, CI 1.21 to 5.09) (Knobloch et al., 2008). Torso hyperextension was previously thought to be a risk factor for LBP during front crawl strokes; (Du et al, 2016) however, an experimental study of experienced collegiate swimmers reported that hyperextension was not a biomechanically viable cause of LBP, since no swimmer extended beyond their active torso range of motion during front crawl (Du et al., 2016).

Previous literature has reported concerns regarding swimming and goggle use with eye injury. Recent literature has shown that frequent goggles use does not lead to an increased risk of glaucoma in adults (Franchina et al., 2015). Similar concerns have been reported for otorrhoea (discharge from the ears) in young swimmers; however, children who swim without ear protection following tympanostomy tube placement suffer the same number or fewer episodes of otorrhoea than children who do not swim [Pooled Risk difference (RD)= -5.04, 95% CI -11.6 to 1.5] (Lee et al, 1999).

Although impairments associated with injury and pain in swimmers have been studied, there is a lack of prospective research identifying the risk factors and protective factors for the development of overuse injury. Moreover, it is not clear to what extent these associated factors are the cause or effect of the swimmers' pain or if the impairment is a sport-specific adaptation needed for high-level swimming performance (Struyf et al., 2017).

Opportunities for Prevention: Effective Interventions, Cost-Effectiveness, Implementation and Evaluation

There have been no randomized controlled trials (RCTs) or other quality studies carried out to assess the effectiveness of an injury prevention program on musculoskeletal injury risk in competitive or recreational swimmers. The heterogeneity of 'swimmers' shoulder' and the lack of knowledge regarding the etiology of swimming injury have reduced the ability to define and develop successful interventions. Descriptive reviews have pointed to potential interventions based on biomechanical studies of injury risk including careful monitoring of training volume, intensity, and duration by coaches and physicians. These interventions are deemed to minimize overuse injuries and identify athletes at risk of swimming injury, (Wanivenhaus et al., 2012) but have not been rigorously tested.

One RCT (Lynch et al., 2010) assessed a prevention program for shoulder pain (pain as a secondary outcome) but did not follow-up with the swimmers at the end of the season. Additional interventions are based on non-RCT tested interventions from descriptive reviews. An RCT investigating an 8-week stretching and strengthening programme targeting periscapular muscles in elite collegiate (NCAA) swimmers improved posture over the course of the season; however, there was no significant change in pain and function scores following the intervention ($F(1,26)=0.853$; $p=0.389$; $1-\beta=0.145$; ES 0.34). These participants were not followed throughout the season or longer to assess to effectiveness of the intervention on prospective injury risk (Lynch et al., 2010).

Descriptive reviews suggest that coaches should encourage increased body roll and scapula retraction during the forward crawl, aiming at normal strength and endurance of the cuff and scapular stabilizers, as well as improving the flexibility of the anterior capsule to prevent shoulder injury. This can be done through an endurance training and strengthening program for the shoulder and periscapular muscles with emphasis placed on the serratus anterior, rhomboids, lower trapezius and subscapularis (Bak, 2010; Wanivenhaus et al., 2012).

In relation to otorrhoea, an RCT with children ages 0-14 years following tympanostomy found a statistically significant reduction in the rate of otorrhoea from 1.2 episodes to 0.84 episodes in the year of follow-up [mean difference (MD) -0.36 episodes per year] in those that wore ear plugs while swimming. The absolute reduction is unlikely to be clinically significant and equates to an average child having to wear ear plugs for 2.8 years to prevent one episode of otorrhea (Moualed et al., 2016). In a second RCT, there was no evidence of a reduction or increase in the rate of otorrhoea (1.17 episodes per year in both groups; MD 0 episodes, 95% CI -0.14 to 0.14) in those who avoided water versus those who swam as usual (Moualed et al., 2016).

There are clear gaps in the literature with regards to injury prevention interventions in swimming. There is a requirement for large, high-quality RCTs to assess the effectiveness of injury prevention programs based on evidence-based risk factors for musculoskeletal injury.

Implementation/Evaluation

There is insufficient evidence for interventions on swimming injury to permit studies on factors that may facilitate implementation and/or evaluation. One study; however, measured the attitudes and behaviours concerning shoulder pain in high school competitive club swimmers. This study found that the majority of swimmers believe that mild and moderate shoulder pain is normal in swimming and should be tolerated to complete practice. This may be a potential barrier to implementing an injury prevention program. The study suggests that education programs that are focused on informing athletes of the long-term consequences of practicing and competing with shoulder pain, the dangers of long-term pain medication usage, and the necessity of taking time off when injured may be effective in moderating their behaviours (Hibberd & Myers, 2013).

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