A Narrative Review of Overuse Injuries, Risk Factors, and Monitoring Tools in Youth Swimmers

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Abstract

Swimming has gained significant popularity in the past decade. As per USA Swimming's 2024 membership demographics report, 290,239 year-round competitive swimmers are registered. There has been a steady increase in competitive participation in age group and high school swimming. Youth swimmers under 18 years of age make up 97.5% of registered swimmers. As competition has increased, so has the risk of injury in athletes, especially overuse injuries which are most common in swimming. Studies show that more than 50% of competitive swimming injuries are classified as overuse injuries. Youth swimmers are more susceptible to overuse injuries due to their ongoing musculoskeletal development, high training volume, and limited professional monitoring.

Although factors affecting overuse injuries in swimmers are well documented, there are no practical methods developed for early detection and prevention of such injuries in youth swimmers. Existing studies either focus on complex data collection and analysis methods using wearables and machine learning, or require medical oversight to evaluate injury risk. These methods are seldom available to youth swimmers, making this group highly vulnerable. This narrative review explores existing research on self-reported workload, training, and recovery metrics in youth swimmers and how these factors influence overuse injuries in this group. The aim is to find a simple approach that youth swimmers can adopt to track early signs of overuse and take timely action, ultimately reducing injury severity and minimizing time lost from training and competition.

Introduction

Athletes are exposed to high physical stress when playing a competitive sport which often makes them susceptible to increased risk of injury. Acute and traumatic injuries that lead to immediate time loss and affect an athletes' return to play have received the most attention. In contrast, overuse injuries that take time to present themselves are constantly overlooked.

Overuse injuries occur due to repetitive strain on the musculoskeletal system over an extended period of time without adequate recovery. These types of injuries may be ignored as not requiring immediate attention, however, if left unattended, may lead to time loss in practices and competitions[2].

Overuse injuries are especially common in swimming due to its biomechanical nature. Swimmers perform repetitive body movements, for example, overhead shoulder abduction, undulating back movement, circular outward sweeping of the legs, etc., to move through water. These stroke mechanics put considerable strain on the musculoskeletal system leading to microtrauma over time. Studies show that in competitive swimming 51.3% of injuries in collegiate women, 42.6% of injuries in collegiate men, and 58% injuries in youth swimmers are classified as overuse injuries[5][6][7]. Studies have established how swimming stroke mechanics lead to overuse injuries in swimmers[3][4]. Among youth swimmers, shoulder injury is the most

prevalent (48.6%) followed by the knee (8.9%) and the lower back/lumber-spine/pelvis (7.3%)[5].

Various factors affect overuse injuries in athletes including stroke mechanics, training volume and intensity, fatigue, sleep patterns, and mood states. These factors make youth swimmers more vulnerable than adults as they go through puberty and psychosocial changes. While wearables and physical tests have been used for monitoring, these methods are seldom available to youth swimmers. The key aspect in predicting and preventing overuse injuries in this group is to understand how to monitor and correlate these factors to determine injury predisposition.

Although there are various self reporting tools to monitor and analyze factors affecting overuse injuries, like OSTRC-H2, Hooper Index, PSQI, ESS, and POMS-A, work is yet to be done to put these together to develop a methodology to predict overuse injuries in youth swimmers. These proven methods present an opportunity to develop a simple, self reliant process for monitoring overuse injuries that can be easily adopted by youth swimmers.

Methods

Literature review was done by searching PubMed and PubMed Central for research papers between the period of 1965 to August 2025. First, a literature review was conducted to understand the types and prevalence of overuse injuries in swimming using keywords like “swimming overuse injuries”, “swimming epidemiology”, “youth overuse injuries”, etc. This information provided the basis of searching for research on factors that influence such injuries and how to record and analyze them. Then, a literature review was performed to review existing methods for predicting overuse injuries in athletes, specifically in youth swimmers. All relevant articles with free access were included in the narrative review, including, but not limited to, systematic reviews, epidemiological studies, and validation studies.

Common Swimming Overuse Injuries

Overuse injuries in swimming is a well documented topic with detailed information on prevalence and causes of various types of injuries involving the shoulders, knees, spine, etc. The most common among them is the swimmer’s shoulder, followed by the breaststroker's knee and lower back pain.

Swimmer’s shoulder

Swimmer’s shoulder is the term used to describe the various types of shoulder injuries resulting from repetitive shoulder movements carried out during swimming. Studies have found that shoulder injury is the most common type of overuse injury in swimming and accounts for 40% - 91% of overuse injuries in collegiate swimmers[5]. It is prevalent in swimmers who swim strokes requiring full range of overhead arm motion that greatly abduct and adduct the shoulder throughout the pull and recovery phases, like freestyle, backstroke, and butterfly. The common type of shoulder injuries are supraspinatus (rotator cuff) tendinitis, subacromial bursitis, biceps tendinitis, and glenohumeral instability.

Chronic overuse of the supraspinatus muscle can cause a degenerative tear of the supraspinatus tendon causing supraspinatus (rotator cuff) tendinitis. This is the leading cause of shoulder injuries in swimming[10]. When arm abduction motion is repeated extensively, for

example during the recovery phase of the freestyle pull, it causes the subacromial bursa to be pinched, leading to the inflammation of the bursa - a condition called subacromial bursitis. Anterior shoulder pain caused by biceps tendinitis and shoulder vulnerability caused by glenohumeral instability are other factors impacting shoulder injury in swimmers.

Breaststroker's Knee

Breaststroker's knee often occurs as a strain of the medial collateral ligament. During the breaststroke kick, the hips forcefully adduct and the lower leg experiences a large force away from the midline. These two forces oppose each other causing valgus stress on the knee joint. This leads to stretching, inflammation, and eventually tearing of the medial collateral ligament.

Lower Back Injuries

Some swimming strokes, like the butterfly, involve repeated arching and bending of the lower back in order to achieve a wave-like pattern. The dolphin kick amplifies the undulating motion of the lower back leading to hyperextension of the lumbar spine. These repetitive movements over an extended period of time can stress the lower back causing the intervertebral discs in between the lumbar vertebrae to deteriorate. This can eventually cause lumbar intervertebral disk degeneration.

Factors Affecting Overuse Injuries

Stroke Mechanics

Swimming is an intensely biomechanical sport with performance directly related to stroke mechanics. In general, the human body is not well suited to move in water unlike aquatic animals. A swimmer has to rely completely on their technique and musculoskeletal system to propel their body forward. As noted in a study, the arm pull movement is responsible for up to 90% of the body propulsion[3]. For example, a typical 5000 m freestyle session with a distance per stroke (DPS) of 2.0 implies approximately 2500 shoulder rotations. This highlights the sheer amount of physical strain the stroke mechanics put on swimmers and predispose them to overuse injuries.

Training Volume

In swimming, training volume is defined as the number of hours per week spent on training. Competitive youth swimmers typically swim anywhere between 4000 m to 7000 m a day with the greatest swim training volume recorded at 17.27 ± 5.25 h/week[9]. They may practice 5 to 7 days a week, sometimes twice a day. One study found that there was significant correlation between large amounts of swim training volume and supraspinatus tendon thickness in swimmers. All swimmers with increased tendon thickness had impingement pain and supraspinatus tendinopathy. This study also found that swimmers who practiced more than 15 h/week were predisposed to supraspinatus tendinopathy[10]. A systematic review on swim-training volume and shoulder pain found that the training volume and intensity increased

with increase in competition level, thus predisposing youth swimmers to a higher risk of injury and shoulder pain[16].

Training Intensity

Training intensity is another factor that comes into play in addition to training volume with respect to overuse injuries. Training intensity is defined as the amount of external and internal training load an athlete is subject to during one or more training sessions. Training load can be monitored by using session rating of perceived exertion (session-RPE) method[23]. In swimming, training intensity is determined by the volume swum at or above a threshold pace. A study characterized training intensity into low, medium, and high zones, and found that swimmers' shoulder function decreased immediately after a high intensity training session, indicating risk of injury[11].

Rest and Recovery

Although training volume and intensity are the predominant causes of overuse injuries in swimming, lack of rest and recovery, such as inadequate sleep and chronic fatigue, exacerbate these conditions. Sleep disturbances are more common in youth athletes as they go through puberty and experience bioregulatory, societal, and psychosocial pressures[30]. Muscle strength and power greatly impact a youth swimmer's performance[8]. Rest and recovery periods, such as adequate sleep and rest time between training sessions, allow muscles to recover from training stress. Hence, sleep disturbances and overtraining predispose youth athletes to overuse injuries.

Psychosocial Factors

Swimming has become an early specialization sport, where athletes choose it as their main sport and train year round to be competitive. Many psychological factors like aspirations to reach elite levels, desire to secure college scholarships, etc. put tremendous pressure, both social and psychological, on the athlete to push forward[13]. These psychosocial pressures may encourage athletes to ignore early pain. A recent systematic survey on psychosocial risk factors for overuse injuries in competitive athletes found that many intra-personal (competitiveness, athletic identity, passion and dedication, overtraining, etc.), inter-personal (coach-athlete relationship, communication, etc.), and sociocultural (pain normalization, social norms, etc.) factors predisposed athletes to overuse injuries[14].

Growth Factors

Youth athletes have a developing musculoskeletal system where their bones and soft tissue are growing constantly. However, bone growth and soft tissue growth may happen at different times, causing some body areas to be less flexible than others. Hence, youth athletes are predisposed to overuse injuries, especially during growth spurts. Another factor is the active growth cartilage that attaches muscles and tendons to the bones. The areas where growth cartilage is present may be more vulnerable to overuse due to repetitive movements, thus making them susceptible to injuries[12].

In summary, biomechanical load, training volume and intensity, inadequate recovery, psychosocial pressure, and growth-related vulnerabilities interact to create a high-risk environment for youth swimmers, underscoring the need for multidimensional monitoring tools.

Predicting Overuse Injuries

Predicting overuse injuries requires identifying the underlying factors that cause such injuries and documenting the relevant extrinsic and intrinsic risk factors. Some studies have used wearables to measure various intrinsic (heart rate, blood pressure, sleep quality, sweat, and sodium concentration in the blood) and extrinsic (swim volume, acceleration, speed, distance, and session-RPE) factors and analyze the data using machine learning, while other studies have used wearables and additional pre/post session tests, like the jump-test, and use data mining or statistical models to predict overuse injuries in a sport[17][18]. Although some predictive models have been developed for other sports, a recent systematic review on clinical evaluation techniques for injury risk assessment revealed that there is a gap in injury risk assessment methods in elite swimmers[19].

Since youth swimmers may not have access to wearable or professional oversight by athletic trainers and/or medical professionals to monitor overuse injuries, alternative methods of self-reporting injuries and risk factors are desirable[15]. Unlike wearables that primarily track physical metrics, self-reporting tools also capture perceptual and psychological dimensions that often precede physical symptoms. Extensive research has established questionnaire based monitoring strategies to capture health problems and injury risk factors in athletes. For example, the Oslo Sports Trauma Research Center Questionnaire on Health Problems was developed to monitor health problems in youth athletes. The Hooper Index, the Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and Profile of Mood States-Adolescents questionnaires were developed to track athlete well-being[21][25][26][27][29]. The session rating of perceived exertion (session-RPE) method is a validated approach for estimating training load which in turn can be used to compute acute to chronic workload ratio (ACWR) to flag overtraining[23]. Each tool measures a distinct but complementary aspect of overuse injury risk, ranging from self-reported health problems and training load to sleep quality and psychological well-being. Collectively, these questionnaires provide a practical, low-cost framework for continuous monitoring in environments where professional medical or technological resources are limited. They are particularly feasible for youth swimmers training in school or club settings due to their self-reporting nature.

The next sections detail these self-reporting methods, their relevance to youth swimmers, and their scoring methods for individualized training management.

Oslo Sports Trauma Research Center Questionnaire on Health Problems (OSTRC-H2)

The OSTRC-H2 Questionnaire is a well established method to self-report and assess health problems including injuries, illness, pain, or mental health conditions in athletes[21]. This questionnaire was adapted and validated for adolescents[22]. Youth athletes answer four key questions related to health problems with an additional option to detail the health problems they experienced. Each question has four response choices which have a total score between 0-100, with 0 meaning full participation without health problems and 100 meaning no participation at all. Responses to question 1 are scored as 0, 8, 17, and 100, and responses to questions 2, 3, and

4 are scored as 0, 8, 17, and 25 respectively. A high score indicates significant health problems. This questionnaire enables weekly health monitoring without clinical oversight.

Session Rating of Perceived Exertion (Session-RPE)

Session-RPE is a proven method to monitor athlete training load after a training session. The athlete answers one question every seven days - “How was your workout?” - using the Borg CR-10 rating scale of 0-10[23]. The training load is calculated by multiplying this rating with the training session duration in minutes for that seven day period. This method takes into account both the training intensity and the duration to calculate training load. Once the session-RPE is recorded for four consecutive weeks, ACWR is calculated by dividing acute (7-day) by chronic (28-day) average session-RPE. Values >1.5 may indicate sudden increase in training load, which may lead to injury.

Hooper Index

The Hooper Index is a measurement used to monitor athletes' readiness for training. It is based on the Hooper & MacKinnon Questionnaire that consists of five items related to athlete well-being. Each item is rated on a 7-point Likert scale from 1-7 and a total score, which is between 1-35, is calculated by adding the individual scores[25]. A higher score indicates risk of overtraining. In swimmers, elevated Hooper scores may flag inadequate recovery during high-volume or taper periods. Athletes can record their answers daily for more accurate results, however weekly responses are acceptable.

Pittsburgh Sleep Quality Index (PSQI)

The PSQI questionnaire is used to self-report sleep disturbances on a monthly basis and consists of nineteen items spread across seven components - subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction[26]. Each component is scored between 0-3, with 0 meaning no difficulty and 3 meaning severe difficulty. Then a global PSQI score, which is between 0-21, is calculated by adding the individual component scores. A score of over 5 indicates poor sleep.

Epworth Sleepiness Scale (ESS)

The ESS questionnaire is used to self-report ‘daytime sleepiness’ by answering eight questions pertaining to the chance of dozing off or falling asleep while performing eight different activities on a monthly basis[27]. Each question is rated on a scale of 0-3 and a total score, which can be between 0-24, is calculated by adding the individual ratings. A score over 10 indicates excessive daytime sleepiness.

Profile of Mood States-Adolescents (POMS-A)

The POMS-A questionnaire is a shortened version of the original Profile of Mood States (POMS) questionnaire used to self-report mood states in adolescents on a monthly basis[29]. It was specifically developed for adolescents aged between 11-18 years. It has twenty four items to

assess mood states with four items each pertaining to anger, confusion, depression, fatigue, tension, and vigor[]. Each item is scored on a 5-point Likert scale from 0-4, with 0 meaning “Not at all” and 4 meaning “Extremely”. Anger, confusion, depression, fatigue, and tension are part of the negative mood scale, and vigor is part of the positive mood scale. A total mood disturbance (TMD) score is calculated as a total of negative mood scale scores minus vigor. A higher TMD score indicates higher degree of mood disturbance.

In summary, while OSTRC-H2, session-RPE, and Hooper index focus on a swimmers injury status, training, and fatigue, PSQI, ESS, and POMS-A provide complementary information on sleep quality, daytime functioning, and mood states, all of which have been linked to injury risk in youth athletes.

Table 1. Self-reporting tools summary

Tool	Domain	Frequency	Key Cutoff	Youth Validation
OSTRC-H2	Health problems	Weekly	≥25 = high risk	Wik et al., 2025
Session-RPE	Training load	Weekly	ACWR >1.5	Foster et al., 2001
Hooper Index	Fatigue/readiness	Daily/weekly	Higher = overtraining risk	Hooper et al., 1995
PSQI	Sleep quality	Monthly	>5 = poor sleep	Buysse et al., 1989
ESS	Daytime sleepiness	Monthly	>10 = excessive	Johns 1991
POMS-A	Mood states	Monthly	Higher TMD = disturbance	Terry et al., 1999

Conclusion

As noted in this narrative review, prediction of overuse injuries in youth swimmers is an underresearched and challenging area due to various hurdles in data collection in this age group. Challenges range from availability of technology and medical oversight to data privacy concerns in this vulnerable population. However, with competition rising year after year, youth swimmers need a structured support system that helps them reduce time loss and achieve their highest potential. This can be made possible by using established self-reporting approaches such as OSTRC-H2, session-RPE, Hooper index, PSQI, ESS, and POMS-A, that are readily available and help capture the swimmers' well-being. Such an athlete-led monitoring approach can promote early detection and self-awareness of overuse injuries in this population. Widespread use of such questionnaires could empower swimmers, coaches, and programs to

identify developing overuse patterns before they result in major injury, thereby promoting sustainable training and long-term participation.

Future Work

Further studies should validate the self-reporting tools described in this narrative review by conducting a longitudinal cohort study of youth swimmers. Weekly injury, training, and fatigue metrics should be collected using OSTRC-H2, session-RPE, and Hooper index questionnaires and monthly sleep and mood related metrics should be collected using the PSQI, ESS, and POMS-A questionnaires. Principal Component Analysis (PCA) could reduce multidimensional wellness and workload variables into key components, enabling regression or classification models to generate personalized risk profiles (low, medium, high). Finally, developing a simple mobile application to collect swimmer responses would encourage adoption by youth swimmers for consistent data collection.

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