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Does the lack of monitoring put elite swimmers at danger of overuse injuries?

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Purpose of the study: Extreme volumes of swim training are endured by competitive swimmers, which can potentially cause overuse injury by overloading soft tissue structures. The aim of the study is to determine whether overuse injuries are more common during the training phase or competition phase among competitive swimmers.

Methods: This study used a prospective longitudinal design with training history and self-reported measures of overuse questionnaire once each fortnight for nine months, from March 2023 to November 2023. The study included the participation of 54 competitive swimmers ranging from various swimming clubs in India. The Oslo Sports Trauma Research Centre Overuse Injury Questionnaire was utilised to collect data on prevalence of substantial overuse injuries.

Results: The median (IQR) prevalence of shoulder substantial overuse injuries during training is 27.5 (16–38) and in competition is 0 (0–14) with a *p* value of 0.001. The mean (SD) of recovery session during training is 4.1 (0.3) and during competition is 4.5 (0.5). The mean (SD) of strength sessions during training period is 4.7 (0.6) and during competition is 2.7 (0.4).

Conclusion: Implementing an effective athlete monitoring system for load management can play a crucial role in reducing these injuries. It is critical to treat the root causes of an overuse injury after a diagnosis as it is important for the swimmer, their parents, coaches, team doctor and physiotherapist to work together to identify potential risk factors and formulate a plan to prevent injuries.

Keywords: swimming, overuse injury, surveillance, load management, recovery

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Sports Medicine: research and practice

Является ли отсутствие контроля нагрузки у элитных пловцов фактором риска получения перегрузочных травм?

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Цель исследования: Пловцы соревновательного уровня подвергаются высоким нагрузкам во время тренировок, что может привести к травмам из-за перегрузки мягкотканных структур. В связи с этим цель исследования — сравнить частоту травм, связанных с перегрузкой, во время тренировочного и соревновательного периодов.

Материалы и методы: В этом проспективном продольном исследовании приняло участие 54 пловца соревновательного уровня из плавательных клубов Индии. Сбор данных по графику тренировок и субъективным отчетам по перегрузке проводился раз в две недели в течение девяти месяцев — с марта по ноябрь 2023 года. Для сбора данных о распространенности травм, связанных с перегрузкой, использовался Oslo Sports Trauma Research Centre Overuse Injury Questionnaire.

Результаты: Медиана (IQR) распространенности значительных проблем с плечом из-за перегрузки в тренировочный период составила 27,5 (16,0–38), в соревновательный период — 0 (0–14) (p = 0,001). Среднее (SD) количество восстановительных сессий в тренировочный период составило 4,07 (0,26), в соревновательный период — 4,46 (0,50). Среднее (SD) количество силовых тренировок в тренировочный период составило 4,70 (0,57), в соревновательный период — 2,74 (0,44).

Заключение: Внедрение эффективной системы мониторинга спортсменов для контроля получаемой нагрузки может сыграть ключевую роль в снижении травм, вызванных перегрузкой. Также крайне важно устранять первопричины таких травм после постановки диагноза. Важно, чтобы пловец, его родители, тренеры, командный врач и физиотерапевт совместно выявляли потенциальные факторы риска и разрабатывали план профилактики травм.

Ключевые слова: плавание, перегрузочные травмы, опрос, контроль нагрузки, восстановление

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1. Introduction

In India, there are approximately 10,000 to 20,000 registered competitive swimmers at various levels, including subjunior, junior, and senior teams. Over the years, swimming in India has experienced substantial growth and development. Historically, swimming was not as prominent in India as cricket or field hockey as a competitive sport. Indian swimming has the potential to achieve new heights and produce world-class athletes by continuing to invest in infrastructure, coaching, and grassroots development, as well as incorporating scientific approach. Elite swimmers are those who possess exceptional aptitude and are able to adapt to a high volume of training with unwavering dedication. Swimming is an sport that necessitates the exercise of both the upper and lower extremities, as well as a significant demand on the cardiopulmonary system. The regulating organization for swimming and other water sports, such as diving, water polo, open water swimming, artistic swimming, and high diving, is World Aquatics. Backstroke, breaststroke, freestyle, butterfly, and a combination of all four strokes are collectively referred to as individual medley, World Aquatics acknowledges these as distinct swimming styles that are appropriate for competing in prestigious events such as the Olympics and the World Championship. Swimming athletes train freestyle, also known as front crawl, for over 50 % of their swim session, regardless of their primary stroke performed in competition. Elite swimmers may experience musculoskeletal injuries in their shoulders, knees, and lower backs as a result of the continuous, repetitive motion of their upper and lower limbs during swimming [1]. Success in this sport requires not only physical strength and technique but also strategic planning and mental resilience. From early morning practices to intensive strength conditioning, professional swimmers embody the pursuit of excellence, often aiming for competing in prestigious events like the World Championships and the Olympics. Musculoskeletal injuries affecting the shoulder, knee, and vertebrae may be more likely to affect elite swimmers due to the repetitive nature of the normal swimming stroke. Repetitive strain and microtrauma are the primary causes of injuries in competitive swimming [2]. The practice of prescribing an extensive amount of low-intensity swim training to improve performance is well-known among coaches in competitive swimming [3]. Swimmers initiate their rigorous training regimen at a young age, typically between the ages of eight and eleven, and the volume of work involved can be excessive. Between 0.5 to 1 million arm cycles per arm per year are typically executed by an elite swimmer who is over the age of 13 [4, 5]. For this reason, overtraining has been associated with

excessive swimming exposure [6, 7] and increases the likelihood of pain, soft tissue injury and dissatisfaction [8, 9–11]. The prevalence of shoulder pain is particularly high, with rates as high as 91 % [11] and is a major cause of missed practice [5]. The arm strokes of female swimmers are, on average, shorter than those of their male counterparts. This puts them at a higher risk of developing an overuse injury from a biomechanical standpoint, as they perform more arm revolutions per lap [4]. Various factors, including physical development, fitness level, biomechanics, and the specific conditions of the sport, are likely to influence the optimal equilibrium between training intensity and recovery to facilitate adaptation in athletes while minimizing the risk of injury.

Elite Indian swimmers engage in ten two-hour workouts per week, a high-volume and less-recovery training phase from March to May and competition phase from June to November, During the competitive phase, which consists of an average of five to six competitions ranging from state level to national level, Swimmers undergo a distinctive taper period that lasts for 2 to 6 weeks prior to each championship meet, during which they reduce their volume by 50 % to 90 % and significantly reduce the intensity of their workouts. This demanding schedule is maintained, often without interruption. Furthermore, all of these athletes engage in weight training, which typically involves four to five (30 to 50 minutes) sessions per week during the training period and two to three (30 to 40 minutes) sessions per week during the competition period.

Developing nations like India, there is a dearth of research on the prevalence and prevention of acute and overuse sports injuries. The aim of the study is to determine whether overuse injuries are more common during the training phase or competition phase among competitive swimmers.

2. Methodology

Study design

For nine months, from March to November 2023, this study utilized a prospective longitudinal design with training history and self-reported measures of overuse questionnaires every two weeks to ascertain whether overuse issues are more prevalent among competitive swimmers during the training phase (March — May 23) or competition phase (June — November 23).

Participants

The team coaches of the 6 different Indian swimming club were contacted to inquire if they would be interested in participating in the study. Each athlete on the squad and their team physiotherapist were informed about the study in a group online session if they showed interest. Initially, 69 swimmers from the 6 different clubs who were contacted were found to be eligible to participate. Of these, 7 swimmers who were originally included in the study made the decision to cease participating, 3 swimmers suffered an acute injury during the competition phase,4 swimmers were removed due to insufficient data, and 1 swimmer withdrew due to illness. Finally, 54 swimmers participated in the study.

Inclusion criteria:

1) five years or more of training experience;
2) age between 15–25 years;
3) should achieve eight or more swim workouts a week and planned to adhere to this level of training;
4) should participate a minimum of 3 (State or National or international level) competition per season.

Exclusion criteria:

1) past medical history of shoulder dislocation or surgery, lower back or knee surgery;
2) a musculoskeletal injury should not have prevented them from competing or missing more than three weeks of training in the past. Additionally, they must not have any injuries diagnosed during the initial musculoskeletal screening performed by a sports medicine Physician;
3) any traumatic injury within the 3 months of the study or during the study period.

Data Description

The study began with a questionnaire that covered informed consent and participant demographics. Following this, the team physiotherapist walked swimmers through the process of completing Google forms. These forms included the Oslo Sports Trauma Research Centre Overuse Injury questionnaire (OSTRC-O) and questions about their recent training, such as the average distance and duration of each session, as well as the number of strength training done and recovery sessions taken in the past week once each fortnight on Sunday mornings, which was the week's final training session. The survey took approximately five minutes to complete. Those who failed to respond automatically received a reminder. If necessary, a second reminder was given one day after the first request. If a participant did not respond after two reminders, the first author contacted them individually to encourage them to continue participating in the survey. Throughout the data collecting period, participants were asked to report any new traumatic injuries that required medical attention and to note the amount of time lost when the swimmer was unable to train or compete.

OSTRC-O questionary

Three anatomical areas: the shoulder, knee, and lower back would be the focus of 12 questions with four questions dedicated to each site.

Severity score

Each of the four questions is assigned a numerical value between 0 and 25, and the sum of these values is used to determine a severity score for each overuse injury ranging from 0 to 100. For every question, the response values were assigned in the following manner: 0 denotes no issues, while 25 represents the highest level. The intermediate response values were selected to ensure that the distribution from 0 to 25 was as even as feasible while continuing to use whole numbers. Consequently, questions 1 and 4 are rated 0–8–17–25,

while questions 2 and 3 are rated 0–6–13–19–25 respectively [12] athletes who reported injuries leading to moderate or severe reductions in training volume, or moderate or severe reductions in sports performance or complete inability to participate in sport (ie, athletes who selected option 3, 4 or 5 in either Question 2 or Question 3). This is referred to as the prevalence of substantial overuse injuries [12].

Statistical analysis

Data was collected using questionnaire from the study participants using google form. It was then exported to Microsoft excel and analysed using SPSS Version 21. Data analysis was performed using descriptive and inferential statistics. The demographic variables, including age, height, weight, and body mass index (BMI, were summarized using mean, standard deviation (SD), and frequencies where appropriate.

1. Descriptive Statistics: The participants' characteristics such as age, height, weight, and BMI were analysed using mean and standard deviation. The distribution of categorical variables, such as gender, was expressed as frequency and percentage.

2. Paired *t*-tests: Paired *t*-tests were conducted to compare mean scores for continuous variables measured in both training and competition phases. This test was used to analyse variables like:

a. Strength: Mean (SD) for training phase and competition phase.

b. Recovery: Mean (SD) for training phase and competition phase.

c. OSTRC-O score for training and competition phases.

Significant differences between training and competition phases for variables like strength and recovery were evaluated at a significance level of $p < 0.05$. The shoulder and low back overuse scores during training and competition were also compared using a paired t-test, showing significant differences.

3. Wilcoxon Signed-Rank Test: For variables that were not normally distributed, such as knee overuse scores, the Wilcoxon signed-rank test was employed to evaluate differences between the training and competition phases. This non-parametric test was appropriate for these data due to their skewed distribution.

4. Significance Level: A *p*-value of < 0.05 was considered statistically significant for all tests conducted. All analyses were performed using standard statistical software.

3. Results

The swimmers in this study had an average age of 18.8 years and a mean BMI of 25.7, 35 % of the elite swimmers were female, and 65 % were male. There were 33 swimmers who competed in freestyle, 9 in butterfly, and just 6 in backstroke and breaststroke (Table 1). The sample size for this study was not pre-calculated. Instead, all elite swimmers who were available, feasible, and met the inclusion criteria during the study period were included. This approach was necessary due to the limited number of elite-level swimmers in India, making the population inherently small and specialized.

The average training distance per session was doubled during the training phase 9225.9 ± 1049.6 meters as compared with the competition phase 4750 ± 373 meters (Table 2), and the average total OSTRC-O scores were higher during the training phase 31 ± 18 than during the competition phase 14.3 ± 19.1. Furthermore, there were also more strength sessions during the training phase with a mean of 4.7 ± 0.6 per week than during competition phase 2.7 ± 0.4 per week. The training phase showed a reduction in weekly recovery sessions, with a mean of 4.1 ± 0.26 compared to the competitive phase 4.5 ± 0.5. (Table 3). The median difference in the OSTRC-O shoulder score between the training and competition phases was statistically significant using Wilcoxon signed-rank test with a *p* value of 0.001({Median (IQR) — During training — 27.5 (16–38) & competition is 0 (0–14)}). Similarly, the median (IQR) for overuse in the lower back during training was 0 (0–2.3) & competition is 0 (0–3) with a *p* value of 0.03, and the knee {Median (IQR)-during training & competition is 0 (0-0)} with a *p* value of 0.719 (Table 4).

Study's findings demonstrate that overuse injuries are more severe during the training phase than during the competition phase. Higher volume of swimming was observed during the training phase compared to the competition phase (Figures 1 and 2).

4. Discussion

To date, no research has concurrently assessed overuse injury in elite Indian swimmers. This prospective longitudinal research was conducted with 54 participants and is intended to address the gap in the literature.

The higher incidence of overuse injuries observed during the training phase could potentially be attributed to the significantly greater swim distance covered in each session compared to the competition phase. Increased training volume places greater stress on musculoskeletal structures, leading to repetitive microtrauma that, progresses to overuse injuries. Additionally, the training phase was characterized by fewer recuperation sessions, further compounding the risk of overuse injuries. This result is consistent with the findings of Sein ML et al., who concluded that supraspinatus tendinopathy is a common cause of shoulder discomfort in elite swimmers and is caused by a large amount of swim training [11]. In addition, Chandran et al. reported that the majority of swimming-related injuries (51.3 %) were caused by overuse, with shoulder injuries accounting for the largest proportion of these injuries [13].

Of the three joints in our study, the overuse of the lower back was shown to be the second most common issue among swimmers, prompting greater concern. which is corroborated by Capaci et al., lower back overuse injuries ranked second to shoulder pain with an incidence of 18.4 % [14]. 37 % of swimmers reported having low back pain, according to Mutoh et al in his study [15].

Table 1

The number of swimmers competing in each stroke, their anthropometric parameters, and years of training their primary stroke

Таблица 1

Количество пловцов, выступающих в каждом стиле плавания, их антропометрические параметры и тренировочный стаж в основном стиле плавания

Parameter	Freestyle	Backstroke	Breaststroke	Butterfly
No of swimmers	33	6	6	9
Height (cm)	169.9 ± 5.2	169.3 ± 3.2	169.3 ± 6.5	173.6 ± 5.3
Weight (Kg)	73.3 ± 5.1	68 ± 2.9	75.3 ± 6.9	72 ± 4.6
BMI	25.5 ± 2.5	23.8 ± 1.3	26.3 ± 2.2	23.9 ± 2.4
Years of training their primary stroke	11 ± 2.4	9.25 ± 2.5	12.3 ± 3.4	8.6 ± 1.5

Table 2

Comparison of the Training Phase and the Competition Phase

Таблица 2

Сравнение тренировочного и соревновательного периодов

	Training phase	Competition phase	Effect size (Cohen's d value)	*p* value
Average swimming distance per session (meters)	9225.9 ± 1049.6	4750 ± 373	5.7	0.001
Average swimming hours per session	2.6 ± 0.2	2.1 ± 0.2	2.5	0.001
Average OSTRC-O over All score	31 ± 18	14.3 ± 19.1	0.9	0.001

- **Small Effect**: $d = 0.2$, Indicates a small but noticeable difference between groups.
- **Medium Effect**: $d = 0.5$, Suggests a moderate difference
- **Large Effect**: $d = 0.8$, Reflects a large and significant difference between groups.

Table 3

Average Number of strength session done and recovery session taken per week

Таблица 3

Среднее количество силовых и восстановительных тренировок в неделю

	Training phase	Competition phase	Effect size (Cohen's d value)	*p* value
Average Strength Sessions Per Week	4.7±0.6	2.7±0.4	3.9	0.001
Average Recovery Sessions Per Week	4.1±0.3	4.5±0.5	1	0.001

Paired *T* test

- **Small Effect**: $d = 0.2$, Indicates a small but noticeable difference between groups.
- **Medium Effect**: $d = 0.5$, Suggests a moderate difference
- **Large Effect**: $d = 0.8$, Reflects a large and significant difference between groups.

Table 4

Three joints median (IQR) OSTRC-O scores during the training and competition phase

Таблица 4

Медиана (IQR) оценки OSTRC-O в тренировочном и соревновательном периодах

	Training Phase Median (IQR)	Competition Phase Median (IQR)	*p* Value (Paired *t* test)
Shoulder	27.5 (16–38)	0 (0–14)	0.001
Lower Back	0 (0–2.3)	0 (0–3)	0.03
Knee	0 (0–0)	0 (0–0)	0.719

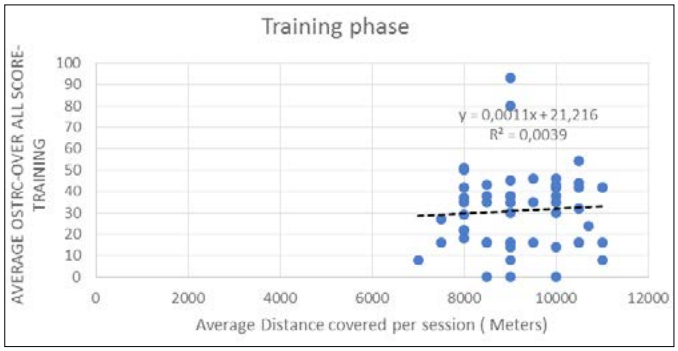

Fig. 1. Average training distance covered and Average OSTRC-O score during training phase
Рис. 1. Средняя пройденная дистанция за тренировку и средний балл OSTRC-O в тренировочном периоде

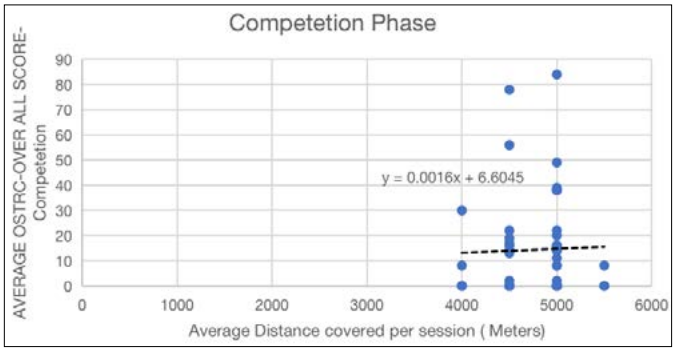

Fig. 2. Average training distance and Average OSTRC-O score during competition phase
Рис. 2. Средняя дистанция тренировки и средний балл OSTRC-O на этапе соревнований

The swimmers in our study who chose the breast stroke as their competition stroke experienced knee pain, which is corroborated by Keskinen et al. study, which concluded that swimmers who swim breaststroke had more knee pain than other swimming strokes [16]. Swimming-related knee pain is most frequently caused by patellar compression. The second most common reason is damage to the medial collateral ligament, also known as swimmer's or breaststroker's knee, which is caused by the knee's excessive valgus and rotatory stress during breaststroke kicking, which stretches the ligament [17].

This study is in line with previous research that has shown that elite swimmers are susceptible to overuse injuries due to amount of swimming they do. It underscores the significance of training load management in an approach to reduce training-related injuries, as supported by Tim J Gabbett. In his study, he emphasizes the importance of monitoring training load, including the load that athletes are prepared for, as a best practice approach to the long-term reduction of training-related injuries [18].

Particularly at the elite level, athletes' natural tendency to push through training and competition in spite of physical symptoms or functional restrictions, highlights the importance it is to utilize appropriate injury monitoring methods.

The primary limitations of the study are absence of elaborate clinical examinations and imaging techniques, such as ultrasonography or MRI, to identify the specific structures that are involved during overuse injury reporting. This level of specificity not only improves diagnostic accuracy but also enables the development of personalized treatment plans and more profound insights into injury mechanisms, rehabilitation strategies, and preventative measures, thereby enhancing the outcomes of individuals who have been impacted.

Future research should focus on psychological monitoring as athletes are far more vulnerable to injury when they experience psychological load (stressors) such as negative life events and everyday hassles. Clinical practical recommendations include the following; they focus on proactive stress management education for athletes, coaches, and support personnel, as well as the reduction of state-level stresses [19]. Athletes' training and/or competition loads can be adjusted by implementing regular stress assessments (such as the hassle and uplift scale [20] or the life events survey for collegiate athletes [21]). To avoid potential tiredness, injuries, or burnout, an athlete who reports high levels of daily hassle or stress may benefit from a training load reduction during a specific time frame of time [19].

5. Conclusion

In comparison to acute injuries, overuse injuries frequently remain undiagnosed due to their gradual development, which is not precipitated by a specific traumatic event. Overuse injuries are the consequence of repetitive stress on tissues, which results in microtrauma over time. Swimmers may ignore early symptoms, which can exacerbate the condition.

1) It is advised to track an athlete's swim training year-round in order to maintain a well-balanced program.

2) Recognizing and avoiding a sudden and significant increase in swimming volume is important for developing athletes.

3) Implementing an effective athlete monitoring system for load management can play a crucial role in reducing these injuries.

4) As part of any injury evaluation, make note of any previous injuries, as they are known to increase the likelihood of overuse injuries.

5) It is critical to treat the root causes of an overuse injury after a diagnosis as it is important for the swimmer, their parents, coaches, team doctor and physiotherapist to work together to identify potential risk factors and formulate a plan to prevent injuries.

Authors contribution:

Muthu Kumar Sridhar — conceptualization of the study, design of the methodology, interpretation of results, data analysis, and manuscript drafting and editing.

Ramesh Chandrasekarapandyan — oversight of data collection, and critical revisions of the manuscript.

Arvind Shanmugam — literature review, oversight of data collection.

Harish Narayanan — literature review, oversight of data collection.

Deepak Ram Thulasi Raman — supervision of the research process, communication with study participants, and final approval of the manuscript.

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Дипак Рам Туласи Раман — контроль за проведением исследования, коммуникация с участниками исследования и окончательное утверждение рукописи.

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