SIN-CHN
SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2025, 22(3), 1468.
https://doi.org/10.62617/mcb1468

Article

The biomechanical and physiological strategies of for preventing leg cramps in adolescent swimmers

Jianwu Huang[1], Qin Yang[2,*]

[1] School of Physical Education and Health, Wuzhou University, Wuzhou 543000, Guangxi, China
[2] School of Physical Education, Beibu Gulf University, Qinzhou 535000, Guangxi, China
*** Corresponding author:** Qin Yang, 13558473341@163.com

CITATION

Huang J, Yang Q. The biomechanical and physiological strategies of for preventing leg cramps in adolescent swimmers. Molecular & Cellular Biomechanics. 2025; 22(3): 1468. https://doi.org/10.62617/mcb.1468

ARTICLE INFO

Received: 26 January 2025
Accepted: 18 February 2025
Available online: 26 February 2025

Abstract: Leg cramps are a important topics amongst young swimmers during practices and competitions regarding their performance and general health. This study investigates the physiological and biomechanical factors contributing to leg cramps, with a focus on electrolyte imbalance, dehydration, muscle fatigue, and improper swimming mechanics. Biomechanical analysis highlights the role of repetitive muscle movements, poor posture, and inefficient technique in increasing cramp susceptibility. Physiological factors such as deficiencies in magnesium, potassium, and sodium, coupled with dehydration, exacerbate muscle dysfunction. The study proposes preventive strategies grounded in biomechanical and physiological principles, including optimized nutritional intake, enhanced warm-up routines, targeted stretching exercises, and technique modifications to reduce muscle strain. Additionally, lifestyle adjustments such as improved sleep and hydration practices are recommended. This work identifies key preventive measures, discusses limitations, and suggests future research directions to enhance the performance and well-being of adolescent swimmers. In addition to the original research, this study also focuses on the prevention and methods of leg cramps in adolescent swimming.

Keywords: adolescent swimmers; prevention of leg cramps; biomechanics; prevention of electrolyte imbalance; exercise and physical activity muscle fatigue; prevention strategies

1. Introduction

Hopefully and most importantly, in the last few years, adolescent involvement in swimming has recorded an increase which is rather promising. Like any other recommended activity, swimming is a full body cardiovascular exercise which also enhances fitness, coordination, flexibility, and cardio-respiratory functions. Adolescent development has more integrated benefits as physical development during this stage is helpful. In addition, it builds self-esteem and helps with teamwork. In the Guangxi region of China, we have more and more parents who are more than willing for their children to go for swimming training and competitions. Another aspect, with the increased intensity and frequency of training, young swimmers are going to face a multitude of health challenges as well, including what is now considered one of the most common but most annoying health issues, leg cramps.

A leg cramp is described as a spontaneous and often excruciating pain that develops when one or more muscles in the leg abruptly contract giving a brief feeling of paralysis. In addition, it cuts training or exercise practice short. Cramping is an issue which has performance and psychological outcomes. If athletes begin to experience cramping in their legs too often, they may tend to develop a lot of fear for

training, low self-esteem, and lack interest in and motivation towards swimming. In addition, frequent and recurrent leg cramps are going to be disastrous for one's muscles in the future as they are going to affect them negatively, stunting their development in the teenage years [1].

For juniors in swimming, the phenomenon of leg cramps needs deeper examination, for it produces a two-pronged effect by improving swimmers' quality of life and enhancing their overall athletic skill. The study critiques existing literature on leg cramps and muscle cramping in limbs and discusses the physiology behind it, while also covering topics like poor style swimming, electro lyte imbalance, overwork, and over hydration. This paper also analyzes the current preventive measures for leg cramps which include nutritional supplements, warm-ups, appropriate exercises, and lifestyle changes. In the end, the problem statement outlines policies which can help to scientifically lessen the occurrence of this problem among adolescent swimmers, so their performance and health can improve [2].

Young swimmers face changes in their body significantly, making them more likely to experience spasms that can negatively impact their performance in practice and competition. This issue has serious ramifications on their health and their mental states. This can occur to athletes during extreme physical activity, therefore causing them to stop playing entirely—and disabling them from using their legs for a significant time period. This does pose a threat to their careers (**Figure 1**), as there are many competitions coming. This problem requires attention since it is very important to the young sportsmen's all-rounded growth [3].

Figure 1. Model of causes of overstrain in leg muscles associated with improper footstrike.

More worrisome is the fact that this may lead to aversion towards the very act of swimming itself. Cyclical cramps, which recur, can cause permanent damage to the muscles, inhibit proper physiological development and growth and eventually bring about more dire health issues [4]. This report aims to do a systematic review of literature regarding physiology and the causes of leg cramps in adolescent swimmers. Cramps which occur after exercise are usually observed to shower on sparse activities done after muscular overuse. And the muscle overuse post swimming with poor stroke mechanics tend to shower get the swimmer cramps [5].

In addition, sufficient rest and an appropriate diet taken in along with lifestyle changes will help improve a person's overall physique and reduce the chances of cramps occurring [6].

This research attempts to help adolescents, their coaches and parents to appreciate the magnitude of cramps while seeking solutions to the challenges. It is believed that the outcome will enhance all-around performance.This appeal is directed towards scholars and health professionals to start looking into the numerous health issues affecting adolescent athletes.

2. Symptoms of leg cramps in adolescent swimmers

2.1. Frequency of cramps

Among adolescent competitive athletes, leg cramps in swimmers appear to be an epidemic, or at least more frequent during times of increased competition and training. These types of events seem to be the result of unwanted muscle spasm contractions occurring very quickly and with no intention and are very painful, perhaps rated at the highest level. It is estimated that about 30%–50% proportion of junior swimmers have some incidence of leg cramping [7].

Cramps can be brought about by numerous factors which involve the length or intensity of one's training, environmental aspects, and personal characteristics. In particular, the overworking of muscles during prolonged activities of a high intensity will most likely lead to muscle fatigue and cramps, and this is more so in negative movements and with high strokes and kicks in swimming, especially in the freestyle events, 1500 m, where the prevalence of cramps is highest because of the increased demand during the length of time.

These muscles, calves composed of gastrocnemius and soleus, are of primary importance in swimming propulsion and delicate during kicking movements [8], which is why they are highly cramping. Similarly, some of the hamstring muscles, for example, biceps femoris, pierce over and become strong to remain for a long time, so they are tight and hard to kick, that is why they are also cramping during the kick [9].

Another important factor which affects the cramping population is the individual differences. The amount of cramping experienced by a person becomes a function of their fitness level, power, stamina, and other factors like these. People with lower physical fitness levels or less workouts will have to deal with cramping to a larger extent [10].

For example, younger swimmers tend to complain of leg cramps because of a specific intensity and phase of training, workloads, and physical characteristics. The prime movers that are most affected are the gastrocnemius and the biceps femoris. As far as athletes are concerned (**Figure 2**), such factors should be adequately dealt with during the training as well as competition when one's activity level is very high.

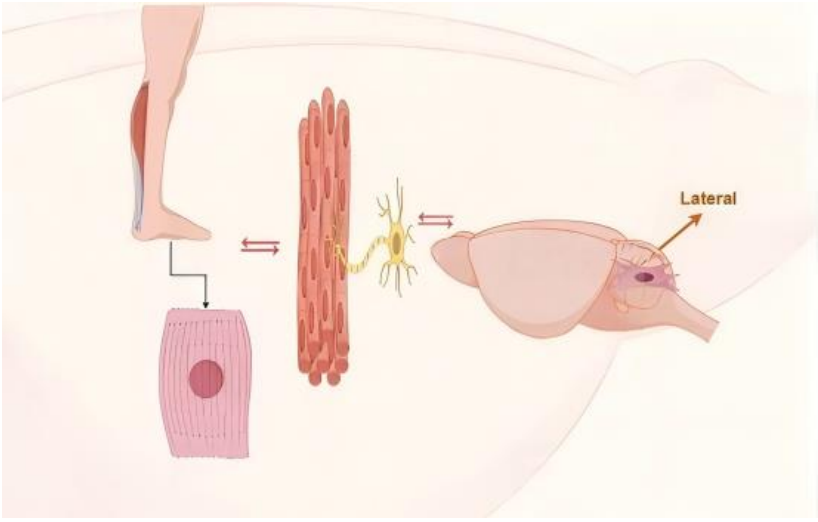

Figure 2. Symptomatology of leg cramps in adolescent swimmers.

2.2. The duration of cramps

The duration of leg cramps experienced by some young adolescent swimmers may vary greatly from individual to individual. The typical duration for discomfort in limbs and legs for these individuals is expected to last from several seconds to several minutes.

Research indicates that the average duration for a cramp is somewhere between 2 to 10 s while in some reported cases, cramping can last up to several minutes or longer. Longer lasting cramps are believed to be more painful and intense as opposed to the usual discomfort associated with cramping. In most cases, such athletes require immediate treatment [11–13].

Some of the case studies suggest that leg cramping post training or post competition at high levels tends to last painfully longer than necessary. This happens because muscles require a greater deal of energy and, if it is exposed to high intensity exercise, it gets fatigued and cramps longer than normal. Low water intake coupled with imbalances in the level of minerals, may also be other significant causes of prolonged cramps [9].

In one of the studies, it was found that when athletes did not replenish themselves with fluids and electrolytes after intensive workouts, the duration of body cramps was experienced for much longer. Following this, it was discovered that the amount of time swimmers could remain in cold water was met with leg cramping challenges. This was because the cold waters caused the muscle to contract, leading to a reduced blood flow in the body and increasing the chances of cramping.

2.3. Muscle tension, muscle tissue, and muscle stiffness

Adolescent swimmers, as they are with many young athletics, experience leg cramps that are caused by muscle tension during competition and training activities. A sudden and painful strong muscle cramp causes an increase in muscle tension. The level of pain experienced through the cramps is debilitating and leads to an athlete being incapable of training and exercising successfully [5].

Now, regarding the increase in muscle tension, muscle fibers will focus on strengthening, which can lead to cramping. What really happens is that an enormous amount of stimulation is combined with muscle contraction, relaxation, and nervous system coordination, which at that time, does not exist during cramps. This explains the fibers being persistently contracted and no control over relaxation. In this manner [8,9], the muscles are bound to remain very contracted, stiff, and painful, and to a very high degree for the athlete (**Table 1**).

Table 1. The intensity of pain associated with varying degrees of leg muscle cramping on a scale.

Pain Rating Scale	*Description*	*Pain Score Range*	*Typical Pain Score for Cramps*
VAS	Visual Analog Scale (0–10 cm)	0–10 cm	6–9 cm
NRS	Numeric Rating Scale (0–10)	0–10	6–9

The muscle cramps are accompanied by some other changes. Very succinctly, such contraction of muscle fibers will lead to severe hindrance in blood flow, leading to relatively low oxygen and nutrients being supplied to the muscles, thus increasing damage and fatigue of the muscle. Recurrent cramps for a long duration could result in micro tearing and inflammation of the muscle fibers making them weaker and easily destructible [6].

With the growing intensity in muscle stiffness comparison, leg cramping follows suit. It appears that the arms as well as the legs, the main muscle parts of the body, are always in a state of constant tension. Muscles that experience cramps are perpetually in a state of contraction, so the muscle fibers become too packed together. Consequently, the muscles are devoid of elasticity and become stiff. As the muscles are aggressively contracted, the athlete tends to suffer from immense muscle stiffness accompanied by pain, which makes recovery even harder. Increases in muscle stiffness mean an athlete can be hurt even while he is not playing due to getting injured even more, which makes him suffer [10].

In long swimming general, swimmers cramp on block of muscles in the legs including the calf and hamstrings. Competing in lengthier swimming competitions is also an additional catalyst. Also, during stiffness and fatigue, swimmers tend to cramp because these muscles are extremely strained during swimming. Moreover, pain in muscles can be treated with deep tissue massage and stretching since these methods help with muscle relaxation and recovery.

Understanding how these cramps create tension, damage tissue, and then result in some degree of muscle stiffness helps the athletes and the coaches to address it scientifically. With adequate training, warmups, exercises [14], nutrition, and rest, the likelihood of athletes suffering from cramps and the need to keep their muscles in a condition that allows them to play at their maximum level is reasonable.

2.4. Pain intensity

When attempting to quantify the pain that results from cramps, scientists note that Pain Rating Scales are the ones that are frequently used. These scales are greatly beneficial for sportsmen because they allow the measurement of pain that is very

important for rehabilitation and exercise. The following are two types of self-explanatory scales of measuring pain that are commonly used for evaluation [15]:

This method is referred to as a Visual Analog Scale (VAS) and it does not only determine pain, but it is also easy to implement. Here, the athlete is asked to determine how much pain that they are feeling by marking out a 12 cm scale line as follows: 0—no pain and 12—worst possible pain. The pain score from the athlete is marked between 0–12, with the number of centimeters from the mark on the line to the zero-point reflecting their pain score. VAS is simple and quick to apply, which makes it particularly suitable for the monitoring of athletes who are experiencing high levels of pain.

Unlike what was discussed above, the Numeric Rating Scale (NRS) is simpler. Athletes themselves have to indicate how they are feeling on a scale from zero to twelve, zero being no pain at all and twelve being unbearable pain. With NRS, athletes are required to provide a numerical score, which is based on the intensity of pain they suffered. NRS is uncomplicated and straightforward, and therefore ideal for detecting during a number of cramping situations, it is uncomplicated and effortless to measure the alterations of pain intensity over an extended period of time [16].

The intensity of the pain in the leg muscles during cramping is very high. That point clearly illuminates the sheer intensity of discomfort one suffers while experiencing leg cramps and it is not easy to ignore. In very severe conditions, the number could go as high as 12 which means that these particular athletes go through extreme pain which will undo their training session and competitive performance and more importantly, their situation becomes psychological.

There are 12 levels of cramp pain, which are:

1) Unnoticeable pain, such as mosquito bites.
2) Pain that has just been noticed, such as preparing for surgery after anesthesia.
3) Very weak pain, such as being scratched by a knife.
4) Weak pain, such as being slapped in the face.
5) Mild pain, such as hitting the door, or being pinched by the door.
6) Moderate pain, such as gastroenteritis and stomach pain caused by unclean food.
7) Strong pain, such as being beaten with a stick.
8) Severe pain, such as dysmenorrhea in women.
9) Very strong pain, such as neck, shoulder, waist and leg pain, neuralgia.
10) Severe pain, such as a finger being cut off.
11) Extremely severe pain, such as appendicitis pain and other visceral pain.
12) Unbearable pain, such as pain during childbirth.

We can refer to the comparison!

There are unique cases which also show the differences in the degree of pain one can feel on any given day. For instance, some athletes after intensive training have a pain score of about 8 for their calf muscles cramps that they grade as ‘severe stabbing pain and tightness’ and it takes a lot of time to ease. On the other hand, some athletes have a pain score of about 7 for their hamstring muscle cramps experienced during the race. These athletes have described the cramps as ‘sudden intense spasms that do not allow them to move’. It is very important for the coaches and medical staff to understand the cramp pains so as to offer better support and

intervention methods for thea throbbing athletes [14]. Pain rating scales are a big help as they help the athlete quantify their pain thus aiding in the monitoring of pain levels and the efficiency of pain relief measures. The even more effective remedy is to employ a clinically effective training program, sufficient recovery, and effective pain relief techniques which will all contribute towards for the athlete better coping with the cramp pain and improving training and competitive results.

3. Mechanisms of leg cramps

Even though swimmers self-report their legs muscles cramps during their adolescent stages as painful (**Table 2**), they sort of accept it as part of the training pains. This is because the normal periods of growth and physical maturation regarding leg muscles are often interfered with by the sporting activities.

Table 2. Rutherford classification of leg cramps.

Level	***Symptom***	***Objective indicators***
0	Asymptomatic	Treadmill exercise test normal
1	Mild limp	Posterior ankle artery pressure is above 50 mmHg but at least 20 mmHg below resting value
2	Moderate lameness	Between Level 1 and Level 3
3	Severe lameness	Posterior ankle artery pressure below 50 mmHg
4	Rest pain	Resting ankle artery pressure below 40 mmHg and toe artery pressure below 30 mmHg
5	Minor tissue loss with nonhealing ischemic ulcers or focal gangrene with diffuse ischemia of the forefoot (including the toes)	Resting ankle artery pressure below 60 mmHg, ankle or midfoot blood flow volume tracing curve is almost pulseless, and toe artery pressure is below 40 mmHg
6	Extensive tissue loss—tissue loss above the plantar level	Resting ankle artery pressure below 60 mmHg, ankle or midfoot blood flow volume tracing curve is almost pulseless, and toe artery pressure is below 40 mmHg

To alleviate the effects of cramps and optimize the performance and general life quality of an athlete, efficient prevention and intervention strategies must be put in place through acquiring deeper understanding of these mechanisms [17].

3.1. Physiological causes

Leg cramps can be primarily attributed to an electrolyte imbalance within the body. Athletes tend to sweat profusely during vigorous physical activities such as competitive sports or during cross training sessions which lead to loss of important electrolytes like sodium, potassium, calcium, and magnesium. These electrolytes are necessary to be in proper concentration for muscle cells to function. The absence of specific muscle cells will increase their sensitivity, making it more prone to involuntary contractions which are muscle cramps. As an example, Sodium and potassium ions are important for maintaining the electrical potential of cells while calcium as well as magnesium are crucial in muscle contraction and relaxation [18]. If these electrolytes are insufficient to maintain desired normal levels, cramps will occur.

Another factor that has a great contribution to the physiological aspect of cramping is dehydration. Athletes can lose large amounts of water when they sweat

during training and competitions. Failure to replenish those loses can lead to dehydration, which can then lead to an increase in blood concentration, a decrease in blood flow, and a reduced amount of oxygen and nutrients to the muscles. Also, dehydration increases the chances of cramps occurring due to the disruption of electrolyte levels in the body. Research shows that cramps can be controlled by adequate intake of water [19]; therefore, during training, athletes need to drink sufficiently before, during, and after training to ensure water balance in the body.

3.2. External factors

Overexertion is another major external factor that can trigger leg cramps. After long durations of rigorous training or tough competitiions, the muscles of athletes are often overtrained and exhausted, which makes cramps more likely. Muscle fatigue occurs due to the accumulation of metabolic waste products, like lactic acid, which impair the normal function of muscle cells and increase their chances of cramping. Modifications of training programs must be done in conjunction with sufficient rest to combat muscle fatigue and cramps.

Improper techniques while swimming is also another external factor which causes cramps in the lower limbs. Swimming is a body coordinated act and at times inappropriate posture of any one body part may increase the strain on certain muscles and thus increase chances of cramping. For instance, during breaststroke and freestyle, if the leg action is not appropriately synchronized, the muscles in the calf and hamstrings can become too contracted and exhausted and thus, cramping results [20]. People should learn how to swim and try to accomplish the various strokes with the help of a coach in order to minimize cramps which sometimes occur.

Some muscles cramps might also be induced by external factors like very low temperature of the water. The muscles risk being stimulated too easily in cold water which causes blood vessels to tighten (**Figure 3**), making cramping more likely. When engaged in activities like swimming, athletes should ensure that they are adequately dressed while in water so that the risk of muscles cramps is minimized [1–4].

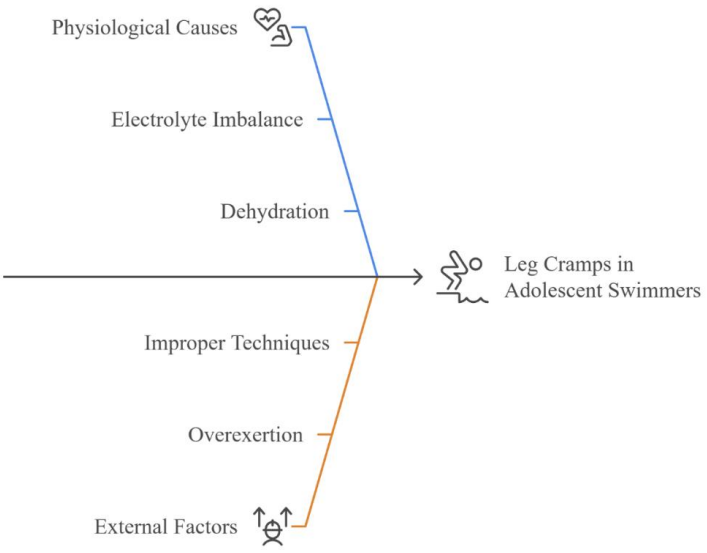

Figure 3. Causes of leg cramps in adolescent swimmers.

4. Evaluation of existing prevention methods

Leg cramps are a common occurrence amongst adolescent swimmers which makes it absolutely necessary to evaluate and put into action efficient preventive measures that can reduce their prevalence, improve their performance, and generally preserve their quality of life. This evaluation will be focused on dietary supplements, exercise, and other lifestyle changes [5,7].

4.1. Nutritional supplements

Nutrients such as magnesium, potassium, and calcium are crucial when it comes to reducing the prevalence of leg cramps, making cramping and leg cramp prevention a must for athletes. Magnesium is used in the contraction and relaxation of muscles which puts it at an advantageous position for preventing cramps, helping to control muscle spasms, and stabilizing a nervous system [17,19]. Expanding diets to include magnesium rich foods such as nuts, seeds, leafy greens, and whole grains can prevent cramps in great effectiveness. These foods also need to be eaten by athletes to proper magnesium.

Potassium plays a crucial role in muscle contraction. A deficiency can led to muscle weakness, cramps, and other associated problems. Athletes must include potassium rich food in their diet like bananas, oranges, potatoes, and spinach to minimize the chances of muscle cramps.

Calcium plays an important role in muscle contractility as well. Its deficiency can negatively impact muscle activity and increase chances of cramps during athletics. Dairy products, legumes, and green vegetables are good calcium sources, and athletes should ensure they consume these to maintain sufficient calcium levels.[14]

4.2. Exercises and physical activities

Applying appropriate warm-up techniques and exercises can reduce the probability of muscle cramps. Performing better warm-up exercise before training or competion can increase muscle temperature and blood flow, enchancing muscle flexibility and endurance. Here are some basic types of warm-ups and stretching exercises:

Dynamic Warm Up: This includes jogging, broad jumping and jumping jacks. These exercises increase heart rate and muscle temperature, thus activating muscles and preparing them for vigorous exercise [20].

Static Stretching: During stretching of the muscles in the legs, I relax by performing calf stretches as well as hamstring stretches which help in improving muscle relaxation and flexibility. I suggest static stretches be done by the athletes before and after any training session while holding each pose for at least 15–30 s and repeating the pose three times.

Sport-Specific Stretching: Stretches and other warm up procedures that are exercise-specific and tailored for swimmers can reduce the incidence of cramps caused by some movements of the body. For instance, in my case, when I am going to swim, I can reduce the chances of cramps if I do exercises such as adductor stretches before breastroke kicks and shoulder stretches before backstroke.

4.3. Lifestyle adjustments

Prevention of leg cramps has a lot to do with lifestyle were sleeping enough and having healthy eating habits are focal points for leading a healthier life and thus reducing the occurrence of cramps.

Sleep has a big role in the recovery of the body and repairing muscles. Adolescent athletes should target sleeping for 7 to 9 h daily and avoiding very late nights or a mixed-up schedule helps with better shape [20].

Having a wholesome balanced diet nourishes the body and muscles, which improves muscle performance and endurance while lowering the chances of getting cramps. Athletes have to ensure that there is enough intake of protein, carbohydrates, fats, as well as vitamins and daily minerals so that their nutrition is balanced [6].

These preventive steps allow young swimmers to reduce the frequency of leg cramps while training and competing, which allows them to constantly maintain both physical and mental wellbeing. Implementing these measures using the scientific approach previously discussed has proven to greatly improve the focus of athletes towards swimming by reducing the baseline and intensity of cramps [7].

5. Discussion

5.1. Main findings

From the research done on adolescent swimmers suffering leg cramps, it's sufficient to say that there are a great number of preventative methods one can use. The most crucial would-be proper nutrition, especially for minerals such as magnesium, potassium, and calcium as they are key in preventing cramps. Nuts, leafy greens, and bananas alongside all dairy products are rich in those and would definitely help in lowering cramp risks. Although it's true that changes to one's diet can be done easily, some athletes tend to be picky eaters or suffer allergies which makes it extremely hard to gain sufficient nutrition [4].

Equally important steps to take to prevent cramps are proper warm up exercises as well as stretching. Warm-up activities help in increasing muscle temperature, blood circulation, and flexibility, thus enabling greater endurance and reducing the chances of cramps occurring. Stretching aids reducing muscle tightness and improves flexibility as well. On the other hand, incorrect stretching and warm up exercises may lead to injury. They are also easy to carry out as they do not need any special appliances but do require a coach's supervision. Likewise, warm up and stretching exercises need time, which may prolong training and competition preparation periods [9].

Leg cramping can also be avoided if adjustments are made to one's lifestyle. Getting enough rest as well as eating well helps in keeping the body fit, hence lowering the chances of getting cramps. Adopting regular timetables and proper nutrition enables the body to have sufficient energy and nutrients, which enhances the performance and recovery ability of the muscles. While lifestyle adjustments are effective long term preventive strategies [8], changes to bad habits need time and willpower, and barriers such as schedule conflicts and environmental changes may make it difficult for athletes to implement.

Preventive measures significantly reduce the risk of leg cramps for young swimmers. Internal muscle functioning is improved by nutritional supplements while external muscle endurance and flexibility is enhanced through warm-up and stretching exercises. These lifestyle changes will always enhance and maintain health. By using a combination of these methods, athletes can decrease significantly the intensity and number of cramps experienced which allows for more productive and fulfilling swimming activities [9].

5.2. Limitations of research

There are a number of gaps that ought to be filled in the research on leg cramps within the population of adolescent swimmers. First, the sample size in most current research is usually small, so the scope of the findings is often limited [6]. As a result of this gap, a comprehensive picture of the situation of leg cramps in swimmers in this age group may not be realized. These constraints of sample size are an issue of many studies and need more research to solve.

This bias means that subjects did not seek a more diverse group of subjects that can be generalized to all adolescent swimmers with regard to the factors that have been studied at hand. This is not unique to a single topic; many researchers concentrate their efforts on particular athletes of a designated geographical region or training level and all others are left unconsidered. This lack of focus restricts the breadth of the research to be concluded on other adolescent swimmers. In their own words, there has to be more put into consideration from now on to obtain a more comprehensive outcome from the research papers.

Second, it is interesting that most of the current research are done using questionnaires and self-reported data collection methods [4]. While these methods have their advantages, like capturing the subjective world, they are not without their problems. Questionnaires and self-reports are prone to incorrect recollections and personal biases affecting their responses that can question the validity of the data gathered. In addition, these approaches are incapable of addressing particular physiological changes triggered during cramps, due to a lack of subjective physiological indicators to back them up. Cramps prevention and management is a dynamic issue deeply rooted in the athlete’s training and lifestyle habits and therefore necessitate long term follow-up studies to understand how effective and sustainable the different prevention measures put in place are [16].

Lastly,Some researchers have limitations in experimental design and data analysis.There are some studies that do not have control groups, making it impossible to counter other variable influences, which raises issue of the credibility of the results. The very first choice and even the manner in which the different methods of data analysis are employed affects the findings in the most definitive way. In the future, changes and improvements need to be made with regards to experiment design and data analysis in order to achieve the scientific validity and reliability of the results.

Despite improvements in the understanding of leg cramps in adolescent swimmers, factors such as a small population sample, unrepresentativeness, poor methodology, and short follow-up period still remain issues. To enable a clearer understanding for

prevention of the cause of cramps, future studies should focus on these issues and present data in a more accurate, comprehensive, and constructive manner, so that effective preventive methods are provided for adolescent swimmers [15].

5.3. Future research directions

Further research ought to have a greater number of participants. A number of studies conducted have small sample sizes which do not truly represent the real status of adolescent swimmers. This will help make the findings more general and credible. It is likely that the absolute number of cramps experienced, and the causative factors will be better evaluated alongside the comprehensive efficacy of different preventative measures [14].

Investigation of additional methods for prevention is also important. At present, most of them are nutritional supplementation, physical exercise, and even changing lifestyle behavior. Alongside this, the development of technologies offers many other ways that could be taken advantage of in terms of prevention. One example is that athletes can use biofeedback technology to alter how tense their muscles are in order to reduce cramps [13]. Additionally, new sports clothing and equipment may provide improved support and protection against muscle cramping.

More studies on athletes from other countries and training levels should be conducted. Athletes from a particular region or particular training level are usually the participants for most studies which limits the scope of the study. Athletes of different regions, genders, and levels of competition can be used to gain a deeper understanding of the cramping problem along with more effective preventative measures [20].

Other areas of focus that require additional attention are long-term follow-up studies. Much of the available literature focuses on short-term measurement and monitoring of cramps and is devoid of any longitudinal studies. With the ability of long-term follow-up studies to evaluate athletes' cramping patterns at various levels of training, one can more accurately measure the effectiveness and durability of different types of preventive measures and develop better strategies for prevention based on empirical evidence.

6. Conclusion

Nutrition-based prevention measures such as proper diet, warm up, strengthening and stretching exercises, and general lifestyle adjustments for cramp control are effective. Supplementing magnesium, potassium, and calcium helps muscle maintain its functions and reduce cramp occurrences. Warm up and stretching improves muscle flexibility and endurance, muscle tension, and muscle stiffness. Adequate sleep and a healthy diet provide nourishment to the body, muscle function improves, and muscle recovery happens faster.

This research establishes that the mechanisms behind Leg Cramps have many layers and require a number of physiological and external elements for it to happen. As stated, the logic of the preventive measures is straightforward, however, to the most efficiency must be covered hollistically.

Preventive measures can help improve and maintain the good physical and psychological state of adolescent swimmers. In turn, this will help reduce the occurrence of leg cramps and improve overall performance in both training and competition. Improving these athletic metrics helps increase the swimmer's confidence levels and fuels their interest in competing. The potential benefits of these measures can also serve as motivation for emerging young athletes starting to venture into different sports disciplines.

Future research directions encompass enlarging the sample sizes to increase the heterogeneity of findings, investigating other possible techniques of biofeedback and sophisticated sporting goods, concentrating on athletes of other demographic and skill levels to pinpoint specific preventive measures, performing longitudinal studies to assess the enduring results as well as the effectiveness of all the methods used, and refining experimental and statistical techniques to enhance credibility and validity of the research findings.

Author contributions: Conceptualization, JH and QY; methodology, JH and QY; software, JH and QY; validation, JH and QY; formal analysis, JH and QY; investigation, JH and QY; resources, JH and QY; data curation, JH and QY; writing—original draft preparation, JH and QY; writing—review and editing, JH and QY; visualization, JH and QY; supervision, JH and QY; project administration, JH and QY; funding acquisition, JH and QY. All authors have read and agreed to the published version of the manuscript.

Ethical approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

References

1. Peulić J, Obradović A, Vukadinović Jurišić M, Obradović J. The influence of anthropometric characteristics on swimming speed in adolescent swimmers. Exercise and Quality of Life. 2023; 15(2): 33–40. doi: 10.31382/eqol.231204
2. Gulati A, Jain R, Khan A, Dhingra M. Comparison of anthropometric parameters between indian adolescent male swimmers and non-swimmers: A cross-sectional study. European Journal of Physical Education and Sport Science. 2021; 7(2). doi: 10.46827/ejpe.v7i2.3858
3. Alifrangis A, Suzan M, Kipps C. 115 The incidence of injuries and illness during open-water swimming events: Optimising swimmer safety. British Journal of Sports Medicine. 2020; 54: A50–A50.
4. Arazi H, Najafdari A, Eghbali E. Effect of Big Bear energy drink on performance indicators, blood lactate levels and rating of perceived exertion in elite adolescent female swimmers. Progress in Nutrition. 2016; 18(4): 403–410.
5. Cengizel E, Dölek BE. Investigation of the Relationship Between Maximal Strength and Swimming Performance in Adolescent Swimmers. International Journal of Applied Exercise Physiology. 2020; 9: 89–97.
6. Taylor D. Effects of different in-water and dry-land recovery strategies on repeated 100m freestyle performance, physiological responses and perceptual status of competitive adolescent swimmers. International Journal of Environmental Research and Public Health (IJERPH). 2019.
7. Delisle AT, Brechue WF, Garzarella L, et al. Leg strength, anaerobic power, and swim kick performance in adolescent swimmers. Medicine & Science in Sports & Exercise. 1995; 27: S117. doi: 10.1249/00005768-199505001-00663
8. Altai Z, Hayford CF, Phillips A, et al. Lower limb joint loading during high-impact activities: Implication for bone health. JBMR Plus. 2024; 8(11). doi: 10.1093/jbmrpl/ziae119
9. Vlachopoulos D, Barker AR, Ubago-Guisado E, et al. The effect of 12-month participation in osteogenic and non-osteogenic sports on bone development in adolescent male athletes. The PRO-BONE study. Journal of Science and Medicine in Sport. 2018; 21(4): 404–409. doi: 10.1016/j.jsams.2017.08.018

10. Atar Ö, Özen G, Koç H. Analysis of relative age effect in muscular strength of adolescent swimmers. Pedagogics, psychology, medical-biological problems of physical training and sports. 2019; 23(5): 214–218. doi: 10.15561/18189172.2019.0501
11. Pind R, Mäestu E, Purge P, et al. Internal Load From Hard Training Sessions Is Related to Changes in Performance After a 10-Week Training Period in Adolescent Swimmers. Journal of Strength and Conditioning Research. 2021; 35(10): 2846–2852. doi: 10.1519/jsc.0000000000003237
12. Laski V, Ureczky D, Wilhelm M. Investigation of Factors Related to Sport-Specific Compulsory Element Execution in Artistic Swimming. Sports. 2024; 12(4): 96. doi: 10.3390/sports12040096
13. Mohamadi R, Sadeghi H, Barati AH. Effect of Aquatic and Land-base Plyometric Exercise on Selected Biomechanical Parameters of Butterfly Swimming in Elite Male Adolescent Swimmers10–14 years. Research in Sport Medicine and Technology. 2015; 13(9): 13–22. doi: 10.18869/acadpub.jsmt.13.9.13
14. Erlandson MC, Sherar LB, Mirwald RL, et al. Growth and Maturation of Adolescent Female Gymnasts, Swimmers, and Tennis Players. Medicine & Science in Sports & Exercise. 2008; 40(1): 34–42. doi: 10.1249/mss.0b013e3181596678
15. Duncan CS, Blimkie CJR, Cowell CT, et al. Bone mineral density in adolescent female athletes: Relationship to exercise type and muscle strength. Medicine and Science in Sports and Exercise. 2002; 34(2): 286–294. doi: 10.1097/00005768-200202000-00017
16. Nikolaidis P. Age- and Sex-Related Differences in Force-Velocity Characteristics of Upper and Lower Limbs of Competitive Adolescent Swimmers. Journal of Human Kinetics. 2012; 32(2012): 87–95. doi: 10.2478/v10078-012-0026-4
17. Sokołowski K, Bartolomeu RF, Krężałek P, et al. Underwater and surface tethered swimming, lower limb strength, and somatic traits as the basic indices of young swimmers' sprint performance. Acta of Bioengineering and Biomechanics. 2023; 25(4): 81–91. doi: 10.37190/abb-02336-2023-04
18. Abd Wahab NA. Relationship between lower body strength and power on swimming performance in male adolescent swimmers [Master's thesis]. Universiti Teknologi Mara; 2012.
19. Bond D, Goodson L, Oxford S, et al. The Association between Anthropometric Variables, Functional Movement Screen Scores and 100 m Freestyle Swimming Performance in Youth Swimmers. Sports. 2015; 3(1): 1–11. doi: 10.3390/sports3010001
20. Armstrong N, Davies B, Heal M. The specificity of energy utilisation by trained and untrained adolescent boys. British Journal of Sports Medicine. 1983; 17(3): 193–199. doi: 10.1136/bjsm.17.3.193