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REVIEW ARTICLE

Does chewing impact performance in sports activities? A systematic review

Qian Zhou. *College of Traditional Chinese Medicine. Tianjin University of Traditional Chinese Medicine. Tianjin, China.*
Manabu Tsukamoto. *Department of Orthopaedic Surgery. School of Medicine. University of Occupational and Environmental Health. Kitakyushu, Japan.*
Kin-Ya Kubo. *Graduate School of Human Life Science. Nagoya Women's University. Nagoya, Japan.*
Kazuha Kizaki. *Department of Orthopaedic Surgery. AR-EX Medical Group. Tokyo, Japan.*
Kagaku Azuma ✉ **.** *Department of Anatomy. School of Medicine. University of Occupational and Environmental Health. Kitakyushu, Japan.*

ABSTRACT

Chewing is a simple and effective method for managing psychological stress and maintaining optimal physical and mental health. This study aimed to systematically review the potential benefits and disadvantages of chewing in sports. We conducted a comprehensive literature search for all relevant articles sourced from the Cochrane Central Register of Controlled Trials, MEDLINE, and PUBMED. We used "*chewing OR mastication OR masticatory*" and "*sport OR sports OR training OR exercise OR physical fitness OR athletic OR athlete OR performance*." We adopted a three-step screening process for titles, abstracts, and full-texts to select eligible articles. After applying our inclusion and exclusion criteria, we performed a full-text screening of 101 articles. The results showed that chewing could improve muscle activation, force production, muscle strength, and postural stability, positively affecting sports performance, especially in rugby, judo, kendo, and climbing. The beneficial effects of chewing on sports performance may be associated with the activation of central nervous system circuits, an increase in arousal level and alertness, and improvements in cognitive ability. In contrast, chewing gum poses a potential risk of laryngeal spasm during activities, such as swimming or cricket. Attention should be paid to chewing gum while engaging in sports.
Keywords: Chewing, Mastication, Sports activities, Athletic performance.

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✉ **Corresponding author.** *Department of Anatomy, School of Medicine, University of Occupational and Environmental Health, Iseigaoka, Yahatanishi-ku, Kitakyushu 8078-555, Japan.*
E-mail: kazuma@med.uoeh-u.ac.jp
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INTRODUCTION

Participation in sports activities is the cornerstone of maintaining a healthy lifestyle. Beyond the thrill of competition and the joy of victory, engaging in regular physical activity through sports has a myriad of positive effects on overall well-being (Malm et al., 2019). Physical health benefits include improved cardiovascular health, enhanced muscular strength, and better coordination. Sports activities not only burn calories, but also contribute to weight management, reducing the risk of obesity and related health is-sues (Pojednic et al., 2022). Moreover, endorphins released during exercise act as natural mood enhancers, alleviate depression and anxiety, lead to feelings of euphoria, and promote mental well-being (Singh et al., 2023). Sports offer a holistic approach to health by addressing both the physical and mental aspects of well-being.

Chewing is a seemingly simple yet essential human activity that plays a crucial role in both nutritional intake and overall well-being. It is a fundamental part of the digestive process and marks the initial step in breaking down food into smaller, more manageable components for further processing (Prinz & Lucas, 2001). Chewing, also known as mastication, begins in the mouth with the action of the teeth and jaw. Chewing involves intermittent rhythmic behavior in which the tongue, face, and masticatory muscles act in coordination. During chewing, the food is mixed with saliva, which contains enzymes that initiate the breakdown of carbohydrates and facilitate swallowing. This enzymatic activity not only facilitates digestion but also enhances nutrient absorption during the subsequent stages of the digestive system. Chewing stimulates saliva secretion and keeps the mouth moist, which has hydrating effects (Okuma et al., 2017). Chewing is not merely a mechanical process but also a sensory experience. The sensory information from the oral cavity generated by chewing movements is transmitted through the neuronal circuit to the brain, signaling the release of digestive enzymes and preparing the stomach for the incoming food (Falardeau et al., 2023). Additionally, the sensation of chewing contributes to a feeling of satiety, helping regulate food intake and potentially aiding weight management (Hollis, 2018).

Chewing has notable benefits beyond its role in digestion. It promotes oral health by stimulating saliva production, which helps to cleanse the mouth, neutralize acids, and prevent tooth decay (Banakar et al., 2022). Chewing gum, in particular, has gained popularity not only as a breath freshener but also as a means of enhancing focus and reducing psychological stress (Kubo et al., 2015). Chewing gum is effective in relieving psychological stress and anxiety by decreasing the circulating levels of the stress hormones, glucocorticoids and noradrenaline (Luo et al., 2022).

Chewing has gained popularity in sports; for instance, many major league baseball pitchers chew gums during games. However, the benefits and disadvantages of chewing during sports activities have not been well examined. This study aimed to systematically review the potential benefits and disadvantages of chewing in sports activities.

METHODS

Comprehensive literature search

We registered this protocol a priori on PROSPERO (identification number: blinded for reviewers) and conducted a systematic comprehensive literature search for all relevant studies using the following three electronic databases: Cochrane Central Register of Controlled Trials (The Cochrane Library 2023, Issue 2), MEDLINE (1946 to April 21, 2023), and PUBMED (1990 to April 21, 2023).

We chose the following key search terms: "*chewing OR mastication OR masticatory*" and "*sport OR sports OR training OR exercise OR physical fitness OR athletic OR athlete OR performance*." A systematic literature search yielded 10904 studies. We used a three-step screening process (title, abstract, and full text) to select eligible articles. After excluding duplicated and animal studies, two board-certified orthopedic surgeons independently screened the titles of 9843 studies and abstracts of 1779 studies (Figure 1). If either reviewer included an article during title or abstract screening, it proceeded to the next stage of full-text screening. During full-text screening of the 101 studies, discrepancies were resolved through discussion and consensus with the senior author. Two reviewers independently extracted the following data from each article: article type, journal, authors, publication year, country, benefits of chewing, and chewing downside. Differences were resolved through discussion.

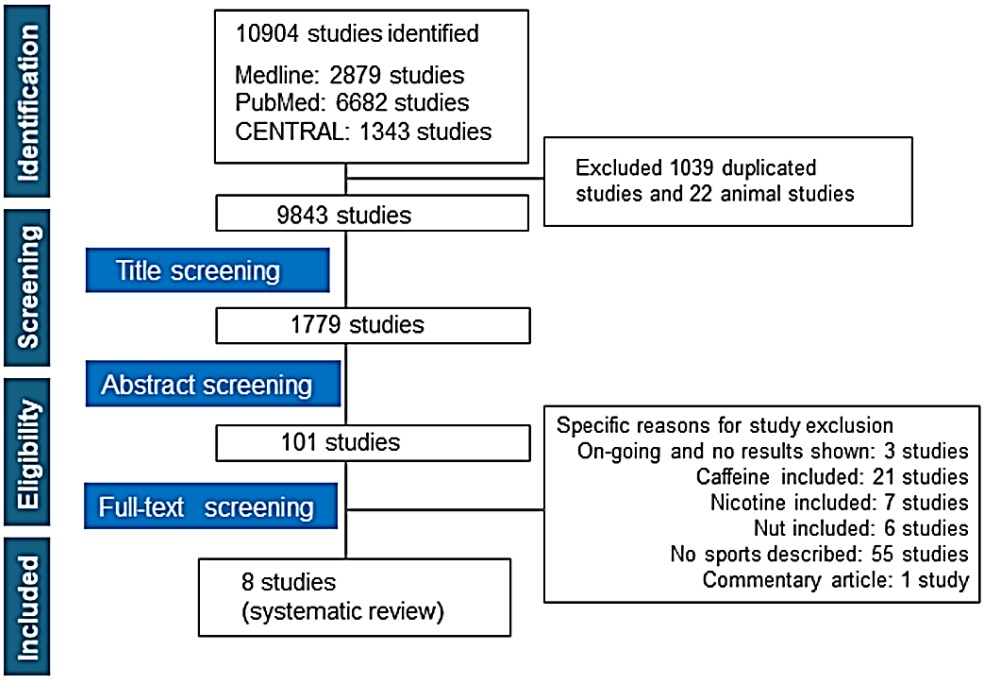

Figure 1. The flow diagram of the systematic literature review.

Criteria for study inclusion

In this review, we included studies in which individuals chewed while they exercised in all sports activities. We captured all types of sports, regardless of the sports activity threshold. The eligibility criteria are detailed as follows.

Inclusion criteria:

- Individuals who are chewing when they are exercising in all sports activities.
- All kinds of sports, regardless of the sports activity threshold.

Exclusion criteria:

- Animal studies.
- Studies with no description of chewing behaviour and sports activities.

The primary and secondary outcomes are as follows.

Primary outcome:

- Benefit of chewing behaviour during sports activities.

Secondary outcomes:

- Downside of chewing behaviour during sports activities.

Risk of bias assessment

Two researchers independently evaluated the risk of bias in the included studies using the Methodological Index for Nonrandomized Studies appraisal tool. The literature review process is illustrated in Figure 1.

Synthesis of results

We descriptively summarized the positive and negative aspects of chewing behaviour in sports activities.

RESULTS

Benefit of chewing in sports activities

Chewing with masticatory muscle activity can alter many physiological activities throughout the body, including force production, muscle activity, and joint fixation. Therefore, masticatory muscle activity is important in competitive sports. Ginszt et al. compared the bioelectrical activity of the masticatory muscles in sport climbers and non-climbers. The results showed significantly higher bioelectrical activity in the masticatory muscles during maximum intercuspation clenching and maximum voluntary clenching in sport climbers, indicating a positive relation between chewing ability and sport climbing activity (Ginszt et al., 2020).

Kurokawa et al. compared the physical movement response times between individuals playing sports with and without chewing gum. They measured the response time by jumping motion, which is an important element for many sports performances. They found that chewing gum shortened the movement response time and reaction time of the long fibular muscles in athletes (Kurokawa et al., 2008). These findings suggest that chewing provides athletes with a competitive advantage and positively impact sports performance.

Chewing organs are influenced by various parts of the body, such as the brain and jaw joints, and they play a coordinated role. Abnormalities in the chewing organs may adversely affect various parts of the body. Therefore, the chewing state is considered an important indicator of general physical health. Chewing force is an important indicator of chewing function. Iwasaki et al. compared the maximal chewing forces of 82 athletes and 12 non-athletes, and demonstrated that the maximal chewing forces was significantly higher in athletes than in non-athletes (Iwasaki et al., 1994). Maximal chewing force was significantly higher in rugby and judo players. Further analyses revealed a predominantly positive relation among chewing force, grasping power, and back muscle strength in athletes. In addition, there is a significant positive correlation between chewing force, the number of pull-ups, and the number of repeated horizontal jumps among rugby, judo, and kendo players (Iwasaki et al., 1994).

It has been reported that when individuals pay attention to their own postural control during quiet standing, postural stability would decrease (Vuillerme & Nafati, 2007). Kushiro and Goto examined the effects of masticatory chewing on the postural stability of healthy adults standing upright. The results suggest that mastication of chewing gum could enhance postural stability during upright standing, possibly by improving mental health (Kushiro & Goto, 2011).

Maintaining physical fitness and masticatory function is critical in older individuals. Gaszynska et al. analysed the chewing ability of 259 individuals aged 65 years and older in Central Poland (Gaszynska et al, 2014).

They found a positive correlation between the chewing capacity and physical strength in older individuals (Gaszynska et al., 2014). These findings indicated that decreased physical strength is usually accompanied by chewing dysfunction in older individuals. Maintaining the function of the stomatognathic system can help promote physical fitness in older adults.

Downside of chewing in sports activities

Some researchers, however, hold the opposite view, stating that chewing gum during task exercise poses certain risks. Siroka and Knobel reported a 4-year-old boy who drowned while swimming. A medicolegal autopsy showed that a piece of chewing gum was present in the larynx, suggesting that the cause of death was laryngeal spasm induced by the irritating effects of a foreign body, such as chewing gum (Siroka & Knobel, 1991). Thus, it is strongly recommended that parents and sports supervisors ensure that children do not participate in sporting activities while chewing gum or other foreign objects. Chewing gum while playing sports, such as swimming or cricket may cause it to become lodged in the respiratory tract and induce infections and/or bronchial asthma. If it gets stuck in the trachea or bronchus, suffocation or sudden death may occur. There is a risk for cricket players during sudden inspiration; when hit in the chest or abdomen while batting, they will be at greatest risk when they take a sudden inspiration, as when hit in the abdomen or chest while reaching for a high catch or batting (Bourke, 1979). Thus, it is dangerous for cricketers to chew gum while playing. Green also considered that the act of chewing gum poses a certain risk during games, such as cricket and swimming (Green, 1979).

Both benefits and downsides of chewing in sports activities were summarized in Figure 2.

Sports activity	Benefit	Risk
Judo and Kendo	A significant positive correlation between bite force and the number of pull-ups	////
rugby	A significant positive correlation between bite force and the number of repeated horizontal jumps and the number of pull-ups.	////
Climbing	Higher bioelectrical activities of masseter muscles during clenching in sport climbers can be associated with this sports activity.	///
Cricket and Swimming	///	Chewing-gum while playing cricket, swimming, or other sports, may become lodged in one of the bronchi and cause wheezing or infection. If it gets stuck in the trachea, asphyxia and sudden death may ensue.

Figure 2. The benefit and risk with chewing in sports activities.

DISCUSSION

This review summarized the benefits and disadvantages of chewing in sports activities. Several studies showed that chewing improves muscle activity, force production, and rate of force development (Ginszt et

al., 2020; Iwasaki et al., 1994). Chewing gum affects postural control by enhancing postural stability (Kushiro & Goto, 2011). In addition to physical improvement, chewing can help individuals cope with psychological stress, leading to mental health improvements (Azuma et al., 2017). It has been reported that chewing gum significantly decreases the circulating levels of the stress hormones glucocorticoids and noradrenaline (Kubo et al., 2015), leading to a reduction in stress and drowsiness, contributing to enhanced sports performance.

Functional magnetic resonance imaging and functional near-infrared spectroscopy studies have demonstrated that the kinetic and sensory information from the oral organs generated by the masticatory movement of chewing activated the central neuronal circuits, induced an increase in brain blood flow, and enhanced activation in certain regions of the brain, including the anterior cingulate cortex and pre-motor cortex, for the executive network and motor-related regions for both attentional networks during chewing (Hirano et al., 2013; Kanzaki et al., 2019). These results suggest that chewing increases the activity level of the brain, improves cognitive function, and enhances arousal levels and alertness, leading to improvements in physical response and indirectly facilitating physical activity and sports performance.

Chewing has several potential disadvantages. Chewing gum can cause laryngeal spasms induced by the irritating effect on the larynx of a foreign body on the larynx, followed by neurogenic cardiac arrest and instantaneous death (Fukumasa et al., 2020). To prevent potential disadvantages, athletes may have to avoid participating in sporting activities while chewing gum. If chewing gums with sugar, caries of teeth should be considered, while sugar-free chewing gum prevents caries of teeth through a variety of mechanisms, including oral cleaning environment, mouth acid neutralization, inhibition of the proliferation of pathogenic bacteria, inhibition of cariogenic bacterial growth, and reduction of food intake (Yeung et al., 2023).

Chewing gum has been endorsed as a dental caries preventive measure by the FDI World Dental Federation, American Dental Association, and European Food Safety Authority. A mini-review discusses the potential mechanisms and provides an update on the use of chewing gum. Chewing gum comprises a water insoluble chewing gum base, water soluble chewing ingredients, and active chewing ingredients (Yeung et al., 2023). There are sugar-free or sugar-containing chewing gums, and medicated or non-medicated chewing gums.

This study had several limitations. First, this was a qualitative systematic review; therefore, a quantitative evaluation with cumulative evidence was not completed to capture the effects of chewing during sports activities. Second, in the screening process, several studies were ruled out because of the presence of additional nutrients, such as caffeine and nicotine, in chewing gum. In this review, all studies on chewing gums, including caffeine and nicotine, were excluded. Therefore, this review might have omitted several studies on the effects of chewing during sports activities.

Chewing has been reported to induce alterations in the brain, endocrine system, and autonomic nervous system, which subsequently enhance sports performance in rugby, judo, kendo, and sport climbing activities. The effects of chewing caffeine and nicotine gum include the functions of both mastication and caffeine or nicotine. Further research is required to enhance our understanding of the behavioural effects of chewing gum. The impacts of chewing behaviour on baseball hitting performance, attack accuracy in football and volleyball players, performance of archery athletes, and other sports activities require further clarification. Currently, medical imaging tools, including ultrasound and magnetic resonance imaging are widely applied to evaluate muscle quality and quantity, including masticatory muscles. Therefore, future studies should include masticatory muscle imaging.

CONCLUSION

This review examined the benefits and disadvantages of chewing during sports activities. Chewing improves muscle activity, force production, rate of force development, and postural stability; however, chewing gum has the potential risk of choking.

AUTHOR CONTRIBUTIONS

Conceptualization, K.K., K-Y.K. and K.A.; methodology, K.K., K-Y.K. and Q.Z. Investigation: K. K., Q. Z., and M. T.; writing—original draft preparation: K. K. and Q. Z.; writing—review and editing: Q. Z., K. K., K-Y.K., M. T., and K. A. All authors have read and agreed to the published version of this manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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