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Original Research

Design and Manufacture the Eccentric Smith Machine

Ali Ghaemmaghamy[1], Ali Fatahi[2*], Mehdi Majlesi[3]

1. Department of Sports Biomechanics, Centeral Tehran Branch, Islamic Azad University, Tehran, Iran. Iran., Email: Ghaemmaghamy@gmail.com, ORCID: 0009-0000-0154-4825

2. Department of Sports Biomechanics, Central Tehran Branch, Islamic Azad University, Tehran, Iran. Email: ali.fatahi@iauctb.ac.ir, ORCID: 0000-0002-8863-4061

3.Department of Sports Biomechanics, Hamedan Branch, Islamic Azad University, Hamdan, Iran. Email: majlesi11@gmail.com, ORCID: 0000-0003-2032-4937

ABSTRACT

The study focuses on the design and manufacture of an Eccentric Smith Machine, incorporating specialized mechanical components for enhanced athletic benefits, minimizing injuries, and promoting hypertrophy. The Eccentric Smith Machine comprises three main parts: A stable Smith machine adapted for electrical motor shocks, an electrical component with a panel and motor, and a transmission system using four pulleys and two cables. The mechanical design facilitates acute and smooth bar movement, ensuring safety and ease of use for athletes of varying heights and strengths. The Eccentric Smith Machine demonstrates resilience to electrical motor power, simplicity in usage, and safety advantages. Its adaptability makes it accessible to athletes with diverse physical characteristics, providing a tool for effective and safe resistance training. The designed device has the potential to enhance physical fitness, particularly muscle hypertrophy. It stands as a viable option for athletes, offering a reduced risk of injuries during workouts. The Eccentric Smith Machine presents itself as an alternative for those recovering from minor injuries, contributing to overall workout safety.

Keywords: Sport Equipment, Eccentric, Smith Machine, Manufacture

Corresponding Author: Ali Fatahi, *Department of Sports Biomechanics, Central Tehran Branch, Islamic Azad University, Tehran, Iran. Email: ali.fatahi@iauctb.ac.ir, fattahi.am@hotmail.com*

INTRODUCTION

Designing and manufacturing various sports equipment, including strengthening devices, is of particular importance to the public health [1]. Increasing muscle force producing capacity is a primary goal for strength and conditioning practice, as it can improve performance in a wide range of sporting activities [2-4]. Enhanced force production can be achieved by increased neural drive and the addition of contractile material via skeletal muscle hypertrophy, both of which can be achieved with resistance training [2,5,6]. Thus, highly resistance trained individuals may require greater or novel stimuli to elicit adaptation. Therefore, strength and conditioning, practitioners seek advanced training methods to facilitate continued adaptation, often by increasing the peak mechanical tension or volume of mechanical tension placed upon a muscle. One such advanced training method is eccentric resistance training [7], whereby the duration or loading of the eccentric (muscle lengthening) phase of a given exercise is manipulated by applying loads above the individual's concentric (muscle shortening) [8]. Compared to concentric or isometric (constant length) contractions, eccentric muscle actions possess several unique features that may be responsible for unique adaptations [9, 10]. Greater forces are generated during eccentric contraction compared to other contraction types for a given angular velocity [11]. In addition, eccentric contractions require less motor unit activation and consume less oxygen and energy for a given muscle force than concentric contractions. The force–velocity (F–V) relationship defines an important dynamic property of muscle contraction [9, 10]. In isolated muscles, eccentric forces during lengthening of an active muscle are known to be up to 80% greater than isometric forces. However, in vivo, where muscle forces are applied and measured as joint moments, the moment-velocity relationships display smaller and more variable differences between eccentric and isometric joint moments. The magnitude of this difference depends on the joints involved; for elbow flexion/extension 12–25%, for ankle dorsi/ plantar-flexion 12–18%, for knee extension 0–22%, and for hip extension 8–11% [11-16].

A Smith machine is designed for controlled barbell strength training. This exercise equipment consists of a barbell with weights that are secured between two steel rails, which allows for only vertical movements. However, there are some newer models that allow for a small amount of horizontal movement weight training, whether with or without a Smith machine, poses injury risks. A recent year-long study involving U.S. Army soldiers revealed a 4.5% incidence of lifting-related injuries in men and 0.6% in women.

Training with a Smith machine appears beneficial for injury reduction, acting as a spotter and preventing joint strain during movements. The Smith machine's versatility extends to various exercises, serving as a stabilizer for lunges, squats, shoulder presses, and deadlifts. While almost any lifting exercise can be performed with a Smith machine, a drawback is noted: the machine's stabilization in one plane may reduce the demand on stabilizer muscles. The research aimed to design an Eccentric Smith Machine with the goal of providing athletes the benefits of training in the eccentric phase, thereby enhancing muscle engagement and overall effectiveness.

METHODS

We utilized a robust conventional Smith machine with a strong structural framework capable of withstanding motor vibrations and heavy loads. Through the incorporation of a dual-cable four-pulley electric motor system, multiple handles, and an advanced control panel, we transformed the conventional Smith machine into a fully eccentric Smith machine. Additionally, a three-button switch is placed for easy use by the athlete, featuring buttons for upward movement, downward movement, and stop.

Description of different parts of the device

The designed and manufactured iron device consists of three general parts: A) A conventional Smith machine, B) An electric motor system with an advanced control panel and C) The transmission system, which includes a dual-cable four-pulley and multiple handles. These different parts are mounted on the first part, forming the fully eccentric Smith machine.

A. The desired Smith machine is composed of a sturdy structure with two vertical cylindrical columns, two bases, and an iron panel on the stable floor. In front of each column, there is an iron shaft connected by two cylinders to the halter bar, allowing vertical movement. The halter bar has extensions that can be placed at different heights, secured onto the vertical shaft.

B. A high-powered electric motor capable of lifting approximately 220 kilograms is employed, along with an electrical panel equipped with contactors and protective switches to control the motor's movement. It is worth mentioning that the power transmitted from the panel to the control switch is 12 volts.

C. The power transmission system consists of a gearbox and shafts with two cable-collecting cylinders. Two pulleys are installed at the top and two in the middle of the device, allowing the cable to vertically lift the halter. Grips are attached to the halter bar, and the cable attachment point to the halter is located on the bar. On the halter, a three-button switch is placed for easy use by the athlete, featuring buttons for upward movement, downward movement, and stop. At the extreme ends of the shaft, both top and bottom, there are two mechanical safety switches. These switches cut off movement when the halter reaches these points, ensuring safety.

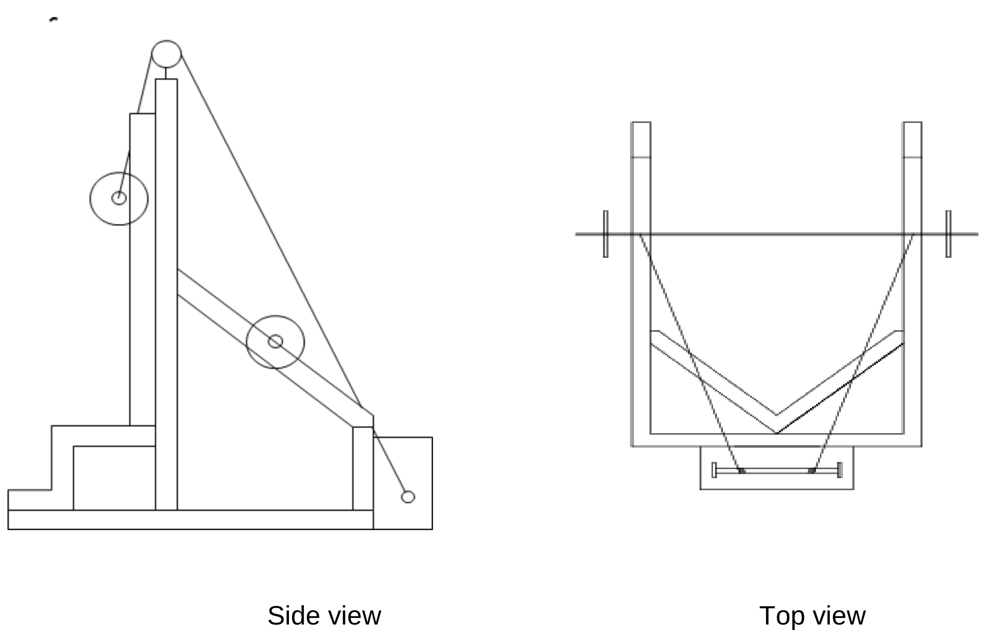

Fig.1. The side and top view of the eccentric Smith machine

RESULTS

The athlete, to utilize the apparatus, initially places the desired weights on the halter. After positioning themselves beneath the device relative to the muscle group and motion they intend to perform, they adjust the height of the halter. By pressing the upward movement button, the motor lifts the halter upward. When the halter reaches the appropriate height, the athlete presses the stop button. Then, by pressing the downward movement button, they eccentrically withstand the weight. Finally, pressing the upward movement button again repeats the process.

This apparatus is versatile, suitable for various Smith machine exercises such as squats, chest press, and incline chest press with a bench. It is usable by athletes of all strengths since the athlete determines the weight on the halter.

DISCUSSION

The aim of conducting research and designing/building this apparatus was to enable athletes to harness their maximum energy independently during the eccentric phase of muscle contractions, it is widely acknowledged that eccentric movements generate greater force compared to isometric and concentric contractions, while also incurring lower metabolic costs. The incorporation of the Eccentric Smith Machine empowers athletes to engage in more challenging training sessions, allowing for the utilization of heavier loads. This capability is substantiated by research findings, as indicated by Brazier et al (2019) [17] and the work of Hyldahl and Hubal (2014) [18]. These studies emphasize the significance of eccentric resistance training, showcasing its potential to enhance strength and muscle engagement. The advanced design of the Eccentric Smith Machine aligns with the evolving understanding of training methodologies, providing athletes with a tool to optimize their resistance workouts and achieve greater training adaptations.There is also evidence to suggest that properly conducted ECC training can prevent injuries [19, 20]. Moreover, concentric and eccentric contractions exhibit notable distinctions in terms of neural drive, as discussed by Duchateau and Enoka (2016) [21]. Additionally, the amplitude of electromyography signals tends to be higher during shortening contractions compared to lengthening contractions, as highlighted by Bollinger et al. (2022) [22]. Furthermore, due to the increased muscular capacity during lengthening contractions, fewer motor units are recruited, and the discharge rate is lower in comparison to shortening contractions [23]. The prevailing assumption is that eccentric resistance training yields greater effects than concentric resistance training due to the higher mechanical load associated with active lengthening. Although it is difficult to reach a consensus from the studies conducted so far about the effect of eccentric and concentric training on strength development, the majority of studies investigating the effects of these contractions on strength indicate that eccentric training improves muscle mechanical function more than other modalities [22-25]. By allowing athletes to exert their maximum effort in this phase eccentric without additional assistance, better results can be achieved [20].Considering that most sports injuries occur during the concentric phase of exercises, most sports injuries occur during the concentric phase due to various mechanisms and factors. The epidemiological study by Kay et al., (2017) highlights that severe injuries in sports occur through player contact, non-contact, and surface contact mechanisms, indicating the diverse nature of injury causation [26]. Jönhagen et al (1994) further explain that concentric contractions, where muscles contract during shortening, are common during sports activities [27]. This is supported by Patel et al., (2015), who emphasize that sports-related renal injuries can occur due to isolated blows sustained during sports activities [28]. Additionally, Knapik et al. (2018) note that soccer players often sustain injuries, particularly when kicking the ball with hyperextended knees and concomitant hip flexion, which involves the concentric phase of muscle action [29]. Furthermore, the study by Grindem et al (2014) provides detailed descriptions of sports injury mechanisms, offering insights into the specific causes of injuries, including those related to the concentric phase [30]. The multifactorial nature of sports -related injuries is highlighted by Nielsen et al., (2016), indicating that the etiological mechanism underpinning these injuries is complex [31]. Moreover, Davies et al (2020) suggest that certain sports and activities have a higher risk of severe injuries, shedding light on the factors contributing to injuries during the concentric phase [32]. In summary, the occurrence of sports injuries during the concentric phase is influenced by various factors such as player contact, muscle contractions, and specific sports activities [33, 34]. Understanding the multifactorial nature of these injuries is crucial for developing effective prevention and management strategies.

One of the advantages of this research is that the design and construction of the apparatus can be applied to other standard Smith machines, allowing for an upgrade of existing devices. All movements performed on a Smith machine can be executed in the eccentric phase using this apparatus, maximizing the benefits athletes derive from a purely eccentric exercise.

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Conflict of interests

The authors declared no conflict of interest.

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Nothing to declare.

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طراحی و ساخت دستگاه اسمیت اکسنتریک

علی قائم مقامی[۱*] ، علی فتاحی[۲]، مهدی مجلسی[۳]
۱. گروه بیومکانیک ورزشی، واحد تهران مرکزی، دانشگاه آزاد اسلامی، تهران، ایران.
۲. گروه بیومکانیک ورزشی، واحد تهران مرکزی، دانشگاه آزاد اسلامی، تهران، ایران
۳. گروه بیومکانیک ورزشی، واحد همدان، دانشگاه آزاد اسلامی، همدان، ایران

چکیده:

در تحقیق به طراحی و تولید دستگاه اسمیت اکسنتریک با رویکرد افزایش توده عضلانی و کاهش آسیب پرداخته شده است. این دستگاه از قسمتهای الکتریکی و مکانیکی و چهارچوب دستگاه تشکیل گردیده .تابلو کنترل و موتور الکتریکی این دستگاه امکان استفاده راحت و به تنهایی از آن را به ورزشکار می‌دهد که تمامی موارد ایمنی استفاده نیز رعایت شده است. با استفاده از این ترکیب قسمت کانسنتریک تمرین با کنترل ورزشکار با نیروی الکتریکی انجام می‌گردد و ورزشکار تنها قسمت اکسنتریک را انجام می‌دهد. با استفاده از این دستگاه ورزشکار بدون کمک مربی می‌تواند از مزیتهای یک تمرین کاملا اکسنتریک بهره‌مند گردد. زمانی که ورزشکار تمامی نیروی خود را در حالت اکسنتریک استفاده نماید با توجه به تحمل بار بیشتر در این حالت می‌تواند با کم کردن ریسک آسیب و یا حتی در حین آسیب‌دیدگی های جزیی به افزایش توده عضلانی بیشتری دست پیدا کند.

واژگان کلیدی: دستگاه ورزشی، تمرین اکسنتریک، دستگاه اسمیت، تولید