Submitted: 21 March, 2024 Accepted: 21 May, 2024 Online Published: 30 August, 2024 DOI:10.22514/jomh.2024.138

JOMH Journal of Men's Health

ORIGINAL RESEARCH

Effects of increasing isokinetic angular velocity on concentric and eccentric strength

Ali Tatlici[1], Sedat Özcan[2], Dogukan Hakan Atceken[1], Sercan Yilmaz[1], Berkay Lokluoglu[3], Ali Sacikara[1,*]

[1]Faculty of Sport Sciences, Selcuk University, 42100 Konya, Turkey
[2]Faculty of Sport Sciences, Suleyman Demirel University, 32200 Isparta, Turkey
[3]Faculty of Sport Sciences, Hatay Mustafa Kemal University, 31060 Hatay, Turkey

***Correspondence**
ali.sacikara@gidatarim.edu.tr
(Ali Sacikara)

Abstract

There is an inverse relationship between the ability to generate force during concentric muscle movements and the velocity of contraction. However, this relationship is not the same in eccentric muscle movements due to differences in mechanism. Therefore, the study aimed to investigate the effects of higher isokinetic angular velocity on concentric and eccentric strength in the hamstring and quadriceps muscles. Twenty-four students from the faculty of sports science, aged between 18 and 24, participated in the study voluntarily. The participants completed a 5-minute standard warm-up, followed by concentric and eccentric knee extension (quadriceps) and knee flexion (hamstring) movements in the dominant leg at slower (60°/s) and faster (180°/s) angular velocities on the Cybex device (Cybex NORM®, Humac, CA, USA, 2004). The isokinetic strength outputs at slower and faster angular velocities were compared a one-way repeated-measures analysis of variance. When comparing the forces involved in concentric knee extension and flexion at slower and faster angular velocities, it was found that the force decreased significantly at higher speeds both during extension and flexion ($p < 0.001$). However, there was no significant changes in eccentric knee extension and flexion force outputs between slower and faster angular velocities ($p > 0.05$). Eccentric force outputs were significantly higher than concentric force in both angular velocities ($p < 0.001$). These results show that there is an inverse relationship between the velocity of concentric contractions and strength outputs, but not in eccentric contractions. It emphasizes the importance of healthcare professionals considering suitable exercise methods for athletes, especially when it comes to improving muscle strength or aiding in rehabilitation processes.

Keywords

Angular velocity; Strength; Eccentric; Concentric

1. Introduction

A number of factors affect the sportive performance of athletes, including speed, agility, balance, power and strength [1]. In many types of sports, athletes must produce sufficient strength and power to be able to resist both their own body mass and the weight of their opponents and sports equipment [2]. Success in sports is the ultimate goal for both athletes and coaches. Adequately designed strength training regimens are necessary in addition to sport-specific training [3].

Muscular strength is defined as the ability of muscles to contract and apply resistance or force to an external object [4]. Three different types of contraction can be used in the production of muscular strength: isometric contraction, concentric contraction and eccentric contraction. Isometric contraction is a type of contraction in which there are no changes in muscle length [5]. If the muscle overcomes external resistance by shortening during contraction [6], the motion is described as concentric contraction [7]. Eccentric contraction occurs when the external load or force on the muscle is greater than the force that the muscle generates or can generate, resulting in the muscle lengthening while it is contracting [6, 8]. Eccentric contractions take place during routine motor tasks and are often responsible for two crucial aspects of natural movement. When the body is decelerating, as occurs while descending stairs or walking downhill, eccentric contractions enable the release of mechanical energy. Additionally, they allow kinetic energy to be converted into the elastic energy of tendons [9]. Muscles produce the greatest amount of force at the peak of their capacity, yet use the least amount of energy [10].

The capacity for producing force during eccentric contraction ranges from 140% to 160% of the force production capabilities exhibited during concentric contraction [11–13]. Concentric and eccentric contractions have different mechanisms at the level of contractile proteins during force generation in terms of the extent of motor unit activation and non-cross-bridge components (*e.g.*, titin) [10]; these mechanisms are among the main reasons for the higher force output of eccentric contractions compared to concentric contractions [9]. The generation of muscular force ensues from the interplay between contractile filaments [14]. Maximum force is generated where myosin and actin filaments overlap, allowing for the formation of the greatest number of cross-bridges [15, 16]. However, force is dependent not only on sarcomere length and cross-bridge formation but also on the velocity of the shortening or lengthening [9].

Eccentric and concentric contractions differ significantly in terms of mechanics, metabolism, and neural control [17, 18]. Due to the repetitive nature inherent in the sliding filament process, increased speed of motion results in a decline in the capacity for force generation. A connection between the sliding filament theory and reduction in the formation of cross-bridges during phases of higher-speed contractions has been established [19]. Accordingly, an inverse correlation exists between the capacity to produce force and the speed of contraction in concentric muscular actions, but this situation differs in the case of eccentric movements. In eccentric movements, as the velocity rises, force may either escalate [20] or remain consistent [21]. A previous study demonstrated that concentric force outputs were decreased with an increase in angular velocity, while eccentric force outputs did not show significant decreases [22].

The isokinetic dynamometer has high reliability and can measure peak torque at different velocities and throughout the complete range of motion [23]. Given that isokinetic dynamometer has been shown as a gold standard strength assessment method [24]. Few studies in the literature to date have addressed questions of eccentric muscle contraction velocity. Therefore, the aim of this study was to investigate the effects of increased isokinetic angular velocity on concentric and eccentric force outputs in the hamstring and quadriceps muscles of students enrolled in the Faculty of Sports Sciences.

2. Materials and methods

2.1 Subjects

Twenty-four male sport science faculty students (age 20.75 ± 1.29 years; height 178.33 ± 6.42 cm; body weight 70.96 ± 7.56 kg, Body mass index (BMI) 22.32 ± 2.34 (kg/m^2)) participated in this study.

2.2 Experimental design

The participants were instructed to refrain from engaging in any exercise 24 hours before the testing session. They were then brought to the sports science faculty laboratory at 10:00 AM. A standardized warm-up protocol lasting five minutes was performed on a cycle ergometer, maintaining a cadence of 60–70 rpm, immediately before beginning isokinetic strength testing. Following this, participants underwent isokinetic strength measurements using the Cybex isokinetic device (Cybex NORM®, Humac, CA, USA, 2004).

Isokinetic strength measurement: the measurements of isokinetic quadriceps and hamstring force were conducted using an isokinetic dynamometer at the kinapometry laboratory of Selcuk University. One testing session is sufficient to produce enough data [25]. Each participant went through a familiarization phase, which involved three repetitions at velocities of 60°/s and 180°/s in both eccentric and concentric movements with submaximal effort, before the testing phase [26]. The tests were conducted in randomly order. The participants were seated in the correct position within the testing apparatus. Straps were used to secure the participants' thighs and the middle sections of their thighs to the seat. Furthermore, they were permitted to grasp the handles on the right and left sides of the seat to support during the test [27]. The length of the level arm was regulated separately for each participant, and the resistance pad was set proximal to the medial malleolus. The other leg was hanging freely, without any forces exerted on it. So as to be in alignment with the axis of the dynamometer lever arm with the distal point of the lateral femoral condyle [28]. To assess quadriceps and hamstring concentric torque, three consecutive maximum contractions were performed in the concentric-concentric mode. These movements were executed at an angular velocity of 60°$\cdot$s^{-1} within a range of motion spanning from 90° to 10° of knee flexion. To assess quadriceps and hamstring eccentric torque, three consecutive maximal contractions were performed in the eccentric-eccentric mode. These movements were carried out at an angular velocity of 60°/s within a range of motion spanning from 10° to 90° of knee flexion. The same protocol was used in the 180°/s angular velocity tests as well. A 2-minute rest period was provided between each test conditions for minimize fatigue [29]. Throughout all trials, participants received verbal encouragement to exert their maximum effort. Real-time visual feedback from a computer screen was provided. The highest peak torque value achieved for each type of contraction was taken into account for statistical analysis [27].

2.3 Statistical analysis

The Shapiro-Wilk test was used to determine if the dataset follows a normal distribution. Levene's test was used to check for homogeneity. Skewness and kurtosis values were checked for datasets that were not normally distributed, and those within ±2 were accepted to be normally distributed. A one-way repeated-measures analysis of variance was conducted to compare the outputs. One-way repeated-measures analysis of variance was conducted to compare the outputs of different angular velocities and contraction types. A Bonferroni adjusted pairwise comparison was undertaken. The index of effect size used was partial eta squared (η^2). Partial eta squared effect sizes were determined to be weak = 0.17, medium = 0.24, strong = 0.51, and very strong = 0.70 [30]. An a priori power calculation demonstrated that 24 participants given a type I error rate (α-level) of 0.05 and a power of 0.80 (by g-power 3.0). The ratio between conditions were calculated by using the formula Ratio = (c − e)/e or ratio = (60°/s–180°/s)/60°/s formula. All statistical tests were performed using the software package SPSS version 27.0 (SPSS Inc., Chicago, IL, USA). An alpha value of < 0.05 was considered to be statistically significant.

3. Results

Table 1 shows a significant decrease in concentric forces as angular velocity increased. However, eccentric forces did not show a statistically significant change. (Quadriceps conditions: F (151.67), $p < 0.001$. Hamstring conditions: F (110.45), $p < 0.001$).

In Table 2, it was found that in both the quadriceps and hamstring muscle groups, eccentric force was found to be statistically significantly higher than concentric force at all angular velocities (Quadriceps conditions: F (151.67), $p < 0.001$. Hamstring conditions: F (110.45), $p < 0.001$).

4. Discussion

Eccentric and concentric types of muscle contractions exhibit distinct differences in their operating mechanisms, leading to variations in force output [9]. Moreover, the potential force outputs of eccentric and concentric actions might vary in line with the contraction velocity [22]. In light of this information, the present study was designed to examine the effects of eccentric and concentric contractions at two different angular velocities. We found that an increase in angular velocity during concentric contractions led to a significant decrease in force in both the quadriceps (33.99%) and hamstring muscles (33.79%), while no significant difference was observed in eccentric contractions in the quadriceps (3.23%) or hamstring (4.53%). Significant differences in favor of eccentric force were found at both angular velocities in the quadriceps (21.27% torque at 60°/s and 36.86% torque at 180°/s) and hamstring (77.78% torque at 60°/s and 97.36% torque at 180°/s).

With respect to the effects of contraction types (*i.e.*, eccentric versus concentric actions) on force outputs, it was hypothesized that eccentric contractions would produce greater force outputs than concentric contractions. Previous studies indicated that eccentric contractions produce more strength than concentric contractions [21, 31–35]. In line with those findings, the force outputs obtained in this study during eccentric contractions were significantly higher than those during concentric contractions at angular velocities of both 60°/s and 180°/s. These two types of contractions involve different mechanisms for generating force at the level of contractile proteins, and this is one of the main reasons for greater force production during eccentric contractions compared to concentric contractions. Muscle strength development is the result of interactions between muscle fibers. When myosin and actin filaments overlap, maximum force is generated when the maximum number of cross-bridges form at the optimal sarcomere length [36]. According to the sliding filament theory, during concentric muscle movements, actin and myosin filaments bind to produce muscle contractions, and that connection is broken by Adenosine triphosphate (ATP). However, during eccentric muscle movements, the connection is broken mechanically rather than through chemical means [37]. During concentric muscle movements, ATP binds to myosin heads, triggering their release from actin filaments, and then their re-establishment occurs through chemical pathways. In contrast, during eccentric movements, the myosin heads are essentially forcefully (*i.e.*, mechanically) detached from actin, and it is believed that this could affect the efficiency of energy transfer, potentially influencing the strength of the contractions [38]. In the present study, the isokinetic tests took less than 6 seconds, which is noteworthy for indicating explosive loading characteristics [39]. Another possible explanation for the observed differences between eccentric and concentric contractions in terms of force output could be that eccentric contractions have different neural control strategies compared to concentric contractions. This is supported by Franchi *et al.* [9], as it was previously demonstrated that a deficit in voluntary activation

TABLE 1. Comparing the force outputs of hamstring and quadriceps at 60°/s and 180°/s in both contraction types.

Parameters (Torque)	Angular velocities		95% Confidence Interval for Difference		p	Partial η^2
	60°/s Mean (Torque)	180°/s Mean (Torque)	Lower Bound	Upper Bound		
Quadriceps Con	222.38 ± 24.04	146.79 ± 29.11	60.86	90.30	*$p < 0.001$	0.86
Hamstring Con	123.54 ± 23.05	81.79 ± 19.48	29.94	53.55	*$p < 0.001$	0.82
Quadriceps Ecc	269.67 ± 45.25	260.96 ± 36.84	−4.22	21.64	0.38	0.86
Hamstring Ecc	169.08 ± 30.43	161.42 ± 26.80	−5.51	20.84	0.64	0.82

**Significant differences (p < 0.001).*

TABLE 2. The comparison of eccentric and concentric forces at 60°/s and 180°/s angular velocities of quadriceps and hamstring.

Parameters	Contraction Types		95% Confidence Interval for Difference		p	Partial η^2
	Con Mean (Torque)	Ecc Mean (Torque)	Lower Bound	Upper Bound		
60°/s Quadriceps	222.38 ± 24.04	269.67 ± 45.25	−67.49	−27.08	*$p < 0.001$	0.86
60°/s Hamstring	123.54 ± 23.05	169.08 ± 30.43	57.21	−33.87	*$p < 0.001$	0.82
180°/s Quadriceps	146.79 ± 29.11	260.96 ± 36.84	−133.60	−94.72	*$p < 0.001$	0.86
180°/s Hamstring	81.79 ± 19.48	161.42 ± 26.80	−98.31	60.93	*$p < 0.001$	0.82

**Significant differences (p < 0.001).*

occurs during eccentric contractions in the course of maximal voluntary contraction. Due to the greater force capacity of the muscle during lengthening contractions, fewer motor units are recruited and the discharge rate is lower during lengthening contractions compared to shortening.

The literature on this topic agrees that in concentric contractions the maximum force output decreases with increasing contraction speed while this is not the case in eccentric contractions, without the contraction speed having any influence on the force output [22, 40]. Considering physiological explanations for these different effects of contraction speed in concentric and eccentric contractions on force output, acute neuronal adaptations in response to muscle contraction speed can be noted as one of the underlying reasons. In the study of Oliveira [41], velocity-dependent changes in the behavior of the tibialis anterior motor units during concentric and eccentric contractions were investigated at 10% and 25% maximal voluntary isometric contraction and the authors reported a significant difference in the mean discharge rates of the tracked motor units between the concentric and eccentric phases. In that study, it was shown that the concentric phase had higher discharge rates during dynamic contractions than the eccentric phase, leading to force degradation. However, evaluations performed with a different human limb showed that torques could change as angular velocity increased during eccentric contraction. Griffin [42] revealed that the peak eccentric torque of the elbow flexors increased with increasing velocity between 0 and 120°/s but then decreased between 120°/s and 210°/s. Those results could be interpreted to mean that performance does not decrease with increasing contraction speed; rather, performance can be maintained or increased up to a certain optimal angular velocity and increasing the angular velocity beyond that optimal value can lead to a loss of performance. Findings in the literature support this view of concentric force. Caiozzo *et al.* [43] reported that, an increase was reported in the concentric peak torque of the knee extensors when velocity increased from 45 to 96°/s, while typical decreases in peak torque were observed at velocities above 96°/s. However, as a conflicting result, Cress *et al.* [44], found no significant changes in eccentric force between velocities of 30, 60, 90, 120, 150, 180 and 210°/s. In light of the literature, it can be deduced from our findings that concentric force decreases while eccentric force production may remain constant from angular velocities of 60°/s to 180°/s. Drury *et al.* [31] concluded, based on their findings, that the eccentric actions of biceps muscles are somewhat resistant to force decrement as the result of an increase in velocity, whereas concentric contractions are unable to maintain force as velocity increases. Due to time constraints, only two angular velocities were considered in the present study and only two muscle groups were examined. These are limitations of the study.

5. Conclusions

In this study, concentric contractions produced less force than eccentric contractions in two different muscle groups and at two different angular velocities. Furthermore, considering the angular velocities, although concentric strength decreased as movement speed increased, the same effect was not observed for eccentric contractions. It can contribute to the development of approaches aimed at improving muscle strength in sports training and rehabilitation programs based on the differences in force outputs between eccentric and concentric types of muscle contractions. Particularly, considering the distinct effects between concentric and eccentric contractions, it is important to take these findings into account when designing training programs.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

AT, SÖ—designed. AT, DHA, AS, SY—performed the experiments. SÖ, BL, SY—analyzed the data. AT, SÖ, AS, BL—wrote the paper.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the local ethics committee (Protocol number 39, 24 April 2023, Ethics Committee of Selcuk University, Faculty of Sports Science, Konya, Turkey) in accordance with the Declaration of Helsinki. Before the assessment, every participant received the same detailed information about the testing procedure. Every participant signed the informed consent.

ACKNOWLEDGMENT

Thanks to all the participants for their effort.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Özer Ö. Investigation of strength, flexibility and balance parameters with performance dimension in basketball players. Journal of Education and Learning. 2019; 8: 225–231.

[2] Suchomel TJ, Nimphius S, Stone MH. The importance of muscular strength in athletic performance. Sports Medicine. 2016; 46: 1419–1449.

[3] Zouita A, Darragi M, Bousselmi M, Sghaeir Z, Clark CCT, Hackney AC, *et al*. The effects of resistance training on muscular fitness, muscle morphology, and body composition in elite female athletes: a systematic review. Sports Medicine. 2023; 53: 1709–1735.

[4] Basumatary B. A study assessing on health-related physical fitness of school children with the components of muscular strength and endurance. Vidhyayana. 2023; 8: 1–20.

[5] Bauer P, Gomes JS, Oliveira J, Santos P, Pezarat-Correia P, Vaz JR. Torque regulation is influenced by the nature of the isometric contraction. Sensors. 2023; 23: 726.

[6] Gash MC, Kandle PF, Murray IV, Varacallo M. Physiology, Muscle Contraction. 2023. Available at: https://www.ncbi.nlm.nih.gov/books/NBK537140/ (Accessed: 23 February 2024).

[7] Poteiger J. ACSM's Introduction to exercise science. 4th edn. Lippincott Williams & Wilkins: Philadelphia. 2023.

[8] Nuzzo JL, Nosaka K. Eccentric muscle actions add complexity to an already inconsistent resistance exercise nomenclature. Sports Medicine-Open. 2023; 9: 118.

[9] Franchi MV, Reeves ND, Narici MV. Skeletal muscle remodeling in response to eccentric *vs*. concentric loading: morphological, molecular, and metabolic adaptations. Frontiers in Physiology. 2017; 8: 447.

[10] Tomalka A. Eccentric muscle contractions: from single muscle fibre to whole muscle mechanics. PflüGers Archiv: European Journal of Physiology. 2023; 475: 421–435.

[11] Nuzzo J, Pinto M, Nosaka K, Steele J. How much stronger are muscles eccentrically than concentrically?: meta-analysis of the influences of sex, age, joint action, and velocity. To be published in SportRχiv. 2022. [Preprint].

[12] Nuzzo JL, Pinto MD, Nosaka K, Steele J. The eccentric: concentric strength ratio of human skeletal muscle *in vivo*: meta-analysis of the influences of sex, age, joint action, and velocity. Sports Medicine. 2023; 53: 1125–1136.

[13] Nuzzo JL, Pinto MD, Nosaka K. Connective adaptive resistance exercise (CARE) machines for accentuated eccentric and eccentric-only exercise: introduction to an emerging concept. Sports Medicine. 2023; 53: 1287–1300.

[14] Szikora S, Görög P, Mihály J. The mechanisms of thin filament assembly and length regulation in muscles. International Journal of Molecular Sciences. 2022; 23: 5306.

[15] Hamilton B. The effect of series elasticity on the force-length relationship of skeletal muscle [master's thesis]. Northern Arizona University. 2023.

[16] Tamborrini D, Wang Z, Wagner T, Tacke S, Stabrin M, Grange M, *et al*. Structure of the native myosin filament in the relaxed cardiac sarcomere. Nature. 2023; 623: 863–871.

[17] Hirono T, Kunugi S, Yoshimura A, Holobar A, Watanabe K. Acute changes in motor unit discharge property after concentric versus eccentric contraction exercise in knee extensor. Journal of Electromyography and Kinesiology. 2022; 67: 102704.

[18] Pakosz P, Konieczny M, Domaszewski P, Dybek T, Gnoiński M, Skorupska E. Comparison of concentric and eccentric resistance training in terms of changes in the muscle contractile properties. Journal of Electromyography and Kinesiology. 2023; 73: 102824.

[19] Billeter R, Hoppeler H. Muscular basis of strength. In Komi PV (ed.) Strength and Power in Sport (pp. 50–72). 2nd edn. Routledge: New York. 2003.

[20] Armstrong R, Baltzopoulos V, Langan-Evans C, Clark D, Jarvis J, Stewart C, *et al*. Determining concentric and eccentric force-velocity profiles during squatting. European Journal of Applied Physiology. 2022; 122: 769–779.

[21] Kelly SB, Brown LE, Hooker SP, Swan PD, Buman MP, Alvar BA, *et al*. Comparison of concentric and eccentric bench press repetitions to failure. The Journal of Strength & Conditioning Research. 2015; 29: 1027–1032.

[22] Westing SH, Seger JY, Karlson E, Ekblom B. Eccentric and concentric torque-velocity characteristics of the quadriceps femoris in man. European Journal of Applied Physiology and Occupational Physiology. 1988; 58: 100–104.

[23] Lago-Rodríguez Á, Domínguez R, Ramos-Álvarez JJ, Tobal FM, Jodra P, Tan R, *et al*. The effect of dietary nitrate supplementation on isokinetic torque in adults: a systematic review and meta-analysis. Nutrients. 2020; 12: 3022.

[24] Muñoz-Bermejo L, Pérez-Gómez J, Manzano F, Collado-Mateo D, Villafaina S, Adsuar JC. Reliability of isokinetic knee strength measurements in children: a systematic review and meta-analysis. PLOS ONE. 2019; 14: e0226274.

[25] Nugent EP, Snodgrass SJ, Callister R. The effect of velocity and familiarisation on the reproducibility of isokinetic dynamometry. Isokinetics and Exercise Science. 2015; 23: 205–214.

[26] Van Cingel E, Kleinrensink G, Rooijens P, Uitterlinden E, Aufdemkampe G, Stoeckart R. Learning effect in isokinetic testing of ankle invertors and evertors. Isokinetics and Exercise Science. 2001; 9: 171–177.

[27] Alvares JBdAR, Rodrigues R, de Azevedo Franke R, da Silva BG, Pinto RS, Vaz MA, *et al*. Inter-machine reliability of the Biodex and Cybex isokinetic dynamometers for knee flexor/extensor isometric, concentric and eccentric tests. Physical Therapy in Sport. 2015; 16: 59–65.

[28] Mandroukas A, Michailidis Y, Metaxas T. Muscle strength and hamstrings to quadriceps ratio in young soccer players: a cross-sectional study. Journal of Functional Morphology and Kinesiology. 2023; 8: 70.

[29] Magris R, Nardello F, Bombieri F, Monte A, Zamparo P. Characterization of the vastus lateralis torque-length, and knee extensors torque-velocity and power-velocity relationships in people with Parkinson's disease. Frontiers in Sports and Active Living. 2024; 6: 1380864.

[30] McKinley-Barnard SK, Andre TL, Gann JJ, Hwang PS, Willoughby DS. Effectiveness of fish oil supplementation in attenuating exercise-induced muscle damage in women during midfollicular and midluteal menstrual phases. The Journal of Strength & Conditioning Research. 2018; 32: 1601–1612.

[31] Drury DG, Stuempfle KJ, Mason CW, Girman JC. The effects of isokinetic contraction velocity on concentric and eccentric strength of the biceps brachii. The Journal of Strength & Conditioning Research. 2006; 20: 390–395.

[32] Hollander DB, Kilpatrick MW, Ramadan ZG, Reeves GV, Francois M, Blakeney A, *et al*. Load rather than contraction type influences rate of perceived exertion and pain. The Journal of Strength & Conditioning Research. 2008; 22: 1184–1193.

[33] Hollander DB, Kraemer RR, Kilpatrick MW, Ramadan ZG, Reeves GV, Francois M, *et al*. Maximal eccentric and concentric strength discrepancies between young men and women for dynamic resistance exercise. The Journal of Strength & Conditioning Research. 2007; 21: 37–40.

[34] Doan BK, Newton RU, Marsit JL, Triplett-McBride NT, Koziris LP, Fry AC, *et al*. Effects of increased eccentric loading on bench press 1RM. The Journal of Strength & Conditioning Research. 2002; 16: 9–13.

[35] Hather B, Tesch P, Buchanan P, Dudley GA. Influence of eccentric actions on skeletal muscle adaptations to resistance training. Acta Physiologica Scandinavica. 1991; 143: 177–185.

[36] Huxley AF, Simmons RM. Proposed mechanism of force generation in striated muscle. Nature. 1971; 233: 533–538.

[37] Flitney F, Hirst D. Cross-bridge detachment and sarcomere 'give' during stretch of active frog's muscle. The Journal of Physiology. 1978; 276: 449–465.

[38] Linari M, Lucii L, Reconditi M, Casoni ME, Amenitsch H, Bernstorff S, *et al*. A combined mechanical and X-ray diffraction study of stretch potentiation in single frog muscle fibres. The Journal of Physiology. 2000; 526: 589–596.

[39] Taşkuyu E. Effects of Dietary Nitrate Supplementation on Anaerobic Performance. Gaziantep university journal of sport science. 2020; 5: 428–442.

[40] Hanten WP, Ramberg CL. Effect of stabilization on maximal isokinetic torque of the quadriceps femoris muscle during concentric and eccentric contractions. Physical Therapy. 1988; 68: 219–222.

[41] Oliveira AS, Negro F. Neural control of matched motor units during muscle shortening and lengthening at increasing velocities. Journal of Applied Physiology. 2021; 130: 1798–1813.

[42] Griffin JW. Differences in elbow flexion torque measured concentrically, eccentrically, and isometrically. Physical Therapy. 1987; 67: 1205–1208.

[43] Caiozzo VJ, Perrine JJ, Edgerton VR. Training-induced alterations of the *in vivo* force-velocity relationship of human muscle. Journal of Applied Physiology. 1981; 51: 750–754.

[44] Cress NM, Peters KS, Chandler JM. Eccentric and concentric force-velocity relationships of the quadriceps feimoris muscle. Journal of Orthopaedic & Sports Physical Therapy. 1992; 16: 82–86.

How to cite this article: Ali Tatlici, Sedat Özcan, Dogukan Hakan Atceken, Sercan Yilmaz, Berkay Lokluoglu, Ali Sacikara. Effects of increasing isokinetic angular velocity on concentric and eccentric strength. Journal of Men's Health. 2024; 20(8): 126-130. doi: 10.22514/jomh.2024.138.