Explosive strength of knee extensors: influencing factors and the acute effect of dynamic stretching

Sang-Woo Pyun, Ji-heon Hong
Dept. of Physical Therapy, Sunmoon University
e-mail: pyun3333@gmail.com, hgh1020@hanmail.net

폭발적인 무릎 폄근의 근력: 동적 스트레칭의 급성 효과

변상우, 홍지헌
선문대학교 물리치료학과

Abstract

The purpose of this study was to investigate (1) the relationship between muscle strength and muscle mass measured by traditional methods and the explosive strength of knee extensors (2) the acute effects of dynamic stretching (DS), DS combined antagonist muscle static stretching (AMSS), and DS combined RPM (DS - RPM) on isometric strength, isokinetic parameters, and explosive strength knee extensors. Twenty-nine participants were recruited for this study. Participants performed measurements of appendicular skeletal muscle mass (AMSS), handgrip strength, peak angular velocity (PAV) in knee extension, and isometric and isokinetic muscle function of the knee extensors. Explosive strength was determined by evaluating the rate of torque development (RTD) (0 - 50 ms and 100 - 200 ms) and the rate of velocity development (RVD). And the relationship between these variables was analyzed. In addition, participants visited the laboratory every 48 - 72 hours and performed three warm-up protocols: DS, DS - AMSS, and DS - RPM. To confirm the acute effect of the warm-up protocol, the muscle functions (isometric, isokinetic, and explosive strength) of the knee extensors measured before and after warm-up were compared. PAV accounts for 24.7% and 66.9% of the variance of RTD 0 - 50 and RVD, respectively (P < 0.05). The ASMI and isometric PT explains 49.2% of the RTD 100 - 200 (P < 0.05). DS - AMSS and DS - RPM significantly improved isometric peak torque (P < 0.05). However, the three warm-up protocols had no effect on isokinetic peak torque, RTD, and RVD (P > 0.05). In conclusion, early and late RTDs seem to be determined by different factors, respectively. Therefore, when evaluating explosive strength, these factors should be considered. It also suggests that performing warm-ups including DS may not induce explosive strength improvement.

1. Introduction

Skeletal muscles generate forces to maintain posture, produce movements that influence activity, and consequently maintain health and contribute to functional independence [1]. Various methods have been used to evaluate this muscle strength. It was possible to objectively measure muscle strength using the isometric contraction of muscles under static conditions, and then a method for measuring isokinetic muscle strength corresponding to dynamic muscle contraction was developed [2,3,4]. It is known that the reciprocal inhibitory (RI) function of spinal nerve circuits is important when performing fast and powerful muscle contractions as well as performing smooth joint movements and gait [5,6]. RI is defined as inhibition of antagonist motor neurons in parallel with activation of agonist motor neurons during movement [5]. Effective RI can play an important role in activities that require rapid and powerful activation of specific muscles, such as the sprint and long and high jump [7]. Accordingly, interest in RI enhancement strategies has recently increased [6]. Repetitive passive movement (RPM), which is currently widely used as a rehabilitation technique, not only enhances RI but also affects the proprioception and the cortical excitability (primary somatosensory cortex, the primary motor cortex) [8,9,10]. Consequently, RPM appears to contribute to neurological changes. However, few studies have used this RPM as part of a warm-up.

2. Method

2.1 Participant

Thirty-two young adults (Age 24.1 ± 2.7, height 168.29 ± 8.68 , weight 63.99 ± 10.43, BMI 22.48 ± 2.51) volunteered to participate in this study. Three participants were excluded due to the occurrence of knee pain (n=1) and loss of data (n=2). Finally, data from twenty-nine participants were used for analysis. The Institutional Review Board of Sunmoon University approved this study (SM-202109-065-2), which was performed in accordance with the principles of the Declaration of Helsinki.

2.2 Muscle function

To evaluate muscle performance of knee extensors, isometric (PT, RTD), isokinetic (PT, RVD), and isotonic (PAV) modes of an isokinetic dynamometer were used. In isometric testing, knee joints were flexed at 70°, and the arms were held on both sides of the bar [11,12]. After two practice trials, participants were asked to perform isometric knee extensions of the dominant limb for 3 s with verbal instructions to push as fast and as hard as possible [13,14].

2.3 Intervention

A: For DS of the knee extensors (quadriceps), in a standing position, the participants flexed the knee joint (hamstring contraction) so that the heel touched their buttock [15]. Stretching ranges were determined by the end of the range of motion reported by each participant.
B: Participants first completed the DS of knee extensors in the same way as the warm-up protocol consisting of only DS. After a rest of 20 seconds, SS of the hamstring corresponding to the antagonist muscle was performed.
C: Participants performed stretching of knee extensors in the same manner as in the DS warm-up protocol prior to RPM. After a rest of 20 seconds, RPM of the knee joint was executed using an isokinetic dynamometer to control the movement angular velocity and range of motion.

2.4 Statistical analysis

All measured values are expressed as mean and standard deviation. The Shapiro–Wilk test was used to test the normality of the data. . Pearson's product-moment correlation was used to analyze the correlation of RTD and RVD with BMI, ASMI, knee extensor muscle performance, and HGS. Pearson correlation coefficients were interpreted as weak (< 0.40), moderate (0.40 - 0.59), strong (0.60 - 0.79), and very strong (> 0.80) (Sovtic, Minic, Markovic-Sovtic, & Trajkovic, 2018). A two-way repeated measures analysis of variances (ANOVA) was used to compare the changes in isometric and isokinetic muscle function according to the warm-up (DS, DS - AMSS, and DS - RPM) x time (pre- and post-test). Bonferroni post hoc pairwise comparisons were conducted in case of significant main effects or interactions. All procedures were performed using SPSS software (SPSS 22.0, Armonk, New York, USA).

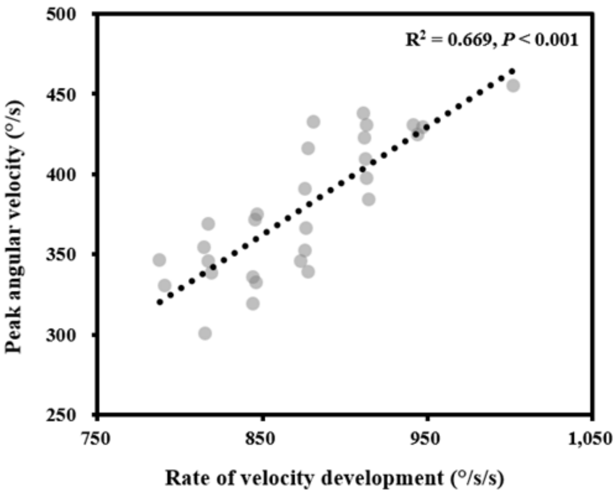
3. Result

Table 1 presents the correlation of RTD and RVD with BMI, ASMI, knee extensor muscle performance, and HGS. RTD 0 - 50 showed a weak positive correlation with BMI (r = 0.374, P = 0.046) and AMSI (r = 0.391, P = 0.036) and a moderate positive correlation with isometric PT (r = 0.439, P = 0.017) and PAV (r = 0.497, P = 0.006). Multiple linear regression models were calculated only for variables (BMI, ASMI, isometric PT, PAV) that showed significant correlations in the Pearson correlation test. [Figure 1] present the results of multiple linear regression analysis for RVD (dependent variable). In Model 1 (enter strategy), all independent variables (BMI, ASMI, absolute HGS, HGS, isokinetic PT, PAV) did not influence RVD (P > 0.05). In the stepwise multiple regression model (model 2), 66.9% of the variance in the RVD was predicted by PAV (y = 0.993x + 497.914, P < 0.001).

[Table 1] Pearson product-moment correlation coefficients of RTD 0 - 50 with BMI, ASMI, knee extensor muscle performance, and HGS

Variables (n = 29)		BMI (kg/m2)	ASMI (kg/m2)	Absolute HGS (kg)	HGS (kg/kg)	Isometric PT (Nm/kg)	Isokinetic PT(Nm/kg)	PAV(°/s)
RTD 0-50(Nm/s)	r	0.374	0.391	0.343	0.113	0.439	0.330	0.497
	p	0.046*	0.036*	0.068	0.560	0.017**	0.081	0.006**

Significant differences are presented in bold. * Weak, ** Moderate correlation
RTD: rate of torque development, BMI: body mass index, ASMI: appendicular skeletal muscle index, HGS: handgrip strength, PT: peak torque, PAV: peak angular velocity.



[Fig. 1] Relationship between rate of velocity development and peak angular velocity during knee extension(regression equation:y = 0.993x+497.914

4. Discussion

Early RTD is mainly affected by PAV, which is thought to be a result of muscle fiber type. Therefore, PAV presents the possibility of an alternative method to evaluate explosive performance. Late RTD seems to be related to AMSS or isometric PT. It is predicted that this is mainly because the time point at which PT occurs is closer to the late phase in the RTD time interval. Although DS-AMSS and DS-RPM improve isometric PT, the three warm-up protocols (DS, DS-AMSS, DS-RPM) do not appear to influence explosive strength and isokinetic strength at fast angular velocity. Considering the high volume of DS used in this study, it is thought to be the effect of muscle fatigue. A warm-up protocol to improve explosive strength should be investigated in the future.

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