The relationship between quadricep and hamstring muscle rate of velocity development and gait characteristics before and after total knee arthroplasty

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The relationship between quadricep and hamstring muscle rate of velocity development and gait characteristics before and after total knee arthroplasty

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Abstract

Introduction: Total knee arthroplasties (TKA) are commonly performed to alleviate pain and enhance the walking ability of patients with knee osteoarthritis (KOA). However, postoperative quadricep weakness and abnormal gait patterns persist after TKA. The rate of velocity development (RVD) is a measure of acceleration capacity during the initial phase of muscle contraction, and it has been suggested to be related to exercise performance. Yet, it remains unclear whether RVD is reduced after TKA, and whether it is associated with gait function. Therefore, our study aimed to assess changes in quadricep and hamstring maximal muscle strength and RVD before and after TKA, and to investigate the relationship between RVD and gait function.

Methods: Our study included twenty-eight patients who underwent TKA, and employed a comprehensive methodology to ensure validity. Evaluation was performed preoperatively and postoperatively (before discharge). Muscle strength was determined by taking the maximum value from three consecutive maximal isokinetic muscle strength tests (60 ° / s) of the quadriceps and hamstrings using a dynamometer. From the angular velocity-time curve obtained during muscle force measurements, RVD30 and RVD90 were calculated, corresponding to the time and angular velocity needed to reach 30% and 90% of 60° /s, respectively. Gait was analyzed using a three-dimensional motion analysis system, assessing walking speed, stride length, and cadence as temporal distance factors and joint angle and angular velocity as kinematic factors. Statistical analyses were performed using paired t-tests and Pearson's correlation coefficients, with significance at $p < 0.05$.

Results: No significant differences were observed in quadricep RVD30 and RVD90 or hamstring RVD90 before and after TKA. However, hamstring RVD30 levels increased significantly postoperatively. Postoperative quadricep and hamstring RVD30 and RVD90 were not significantly correlated with knee flexion-extension range of motion or maximum knee angular velocity during gait. However, a significant correlation was found between quadriceps RVD90 and cadence. Additionally, hamstring peak torque was significantly correlated with knee flexion-extension range of motion and maximum knee angular velocity during gait.

Conclusion: Postoperative quadricep strength was significantly lower, while postoperative hamstring RVD30 was considerably higher than preoperative levels, suggesting that muscle strength and RVD reflect contrasting functions and exhibit distinct postoperative trajectories approximately three weeks after TKA. Furthermore, while postoperative

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quadricep and hamstring RVD were not significantly correlated with peak knee angular velocity or knee flexion-extension range during gait, quadricep RVD90 was positively correlated with cadence, indicating a partial potential relationship with physical performance.

KEY WORDS

total knee arthroplasty, rate of velocity development, quadriceps, hamstrings

Introduction

Total knee arthroplasty (TKA) is a standard surgical procedure to reduce pain and improve the walking ability of patients with knee osteoarthritis (KOA). Previous studies have reported that quadriceps muscle strength decreases to approximately 60% of preoperative levels one month after TKA, leading to postoperative rehabilitation focusing on restoring quadriceps strength[1]. Despite the functional recovery in quadriceps strength, Timed Up and Go test, and stair climbing ability returning to preoperative levels within six months after TKA, these measures often remain inferior to healthy controls[2]. Additionally, a study has shown that one year after TKA, quadriceps strength, and walking speed are still reduced compared to healthy controls[3], suggesting persistent muscle weakness and long-term decreased functional performance after TKA.

Abnormal gait patterns, such as loss of double-knee action and reduced knee flexion angle[4], have been documented following TKA. A reduction in the knee flexion angle during walking, referred to as stiff-knee gait[5], increases the risk of tripping and decreases energy efficiency[6], potentially increasing the risk of contralateral TKA in the future[7]. Therefore, it is crucial to address abnormal gait patterns during TKA rehabilitation. Although the underlying factors contributing to stiff knee gait have not been fully elucidated, co-contraction of the quadriceps and hamstring muscles after TKA has been associated with reduced knee flexion angle during gait[8]. Moreover, previous simulation studies have shown that the knee flexion angle during the swing phase is most strongly influenced by knee flexion velocity at the toe off[9], suggesting a potential relationship between knee angular velocity and muscle function in improving stiff-knee gait.

The rate of velocity development (RVD), derived from the time–velocity curve of isokinetic contraction, is an index of early acceleration capability during muscle contraction. Previous studies[10] reported that RVD increases with velocity-specific training even when knee extension strength does not change, indicating that RVD reflects a function distinct from that of muscle strength. Additionally, RVD has been shown to reflect age-related changes in muscle contraction acceleration in older adults and may be associated with daily performance[11]. RVD is related to physical performance and reflects aspects of neuromuscular function that differ from maximal strength. Given the demonstrated decrease in muscle strength following TKA, it remains unclear whether RVD also decreases and whether it is related to walking ability after TKA. Therefore, this study aimed to clarify the changes in quadriceps and hamstrings RVD before and after TKA, and to investigate the relationship between RVD and gait characteristics. In our study, we hypothesized that RVD would be decreased in the postoperative period compared with the preoperative period similar to muscle strength. Regarding the relationship between RVD and gait, we also hypothesized that RVD correlates with knee flexion-extension angle and peak angular velocity during gait.

Methods

This was a retrospective, observational study. The participants underwent total knee arthroplasty (TKA) for knee osteoarthritis at Fukui University Hospital between July 2012 and April 2016. The exclusion criteria were femoral necrosis, revision, rheumatoid arthritis, and pyogenic arthritis of the knee. Participants who were difficult to assess (muscle strength, RVD, gait analysis) for this study in the preoperative and postoperative periods were also excluded. The study was approved by the Ethics Committee of Fukui

University Faculty of Medicine (approval number: 20220174).

1. Muscle Strength and RVD Measurements

The following data were extracted from each participant's medical records as part of the rehabilitation evaluations conducted before and after surgery. Muscle strength and rate of velocity development (RVD) were assessed using a Biodex System 4 dynamometer (Biodex Medical Systems, Shirley, NY, USA). Participants were seated in a Biodex chair with their backs supported to ensure stabilization. The trunk, pelvis, thigh, and lower leg on the test side were secured with straps to prevent compensatory movements. The dynamometer axis was aligned with the knee joint axis, and the lower leg attachment was positioned at the distal end of the tibia. The knee joint range of motion was set from 110° flexion to 0° extension depending on the participant's available range of motion. The maximum isokinetic muscle strength of the quadriceps femoris and hamstrings was measured at 60°/s for three consecutive repetitions at the participant's maximum effort. The participants were instructed to extend their knees from maximum flexion to maximum extension as quickly as possible and then flex their knees as quickly as possible for three consecutive movements, with sufficient practice provided beforehand to ensure full effort. The peak torques (Nm) of the quadriceps and hamstrings were normalized to body weight, and the maximum isokinetic muscle strength (hereinafter referred to as muscle strength) was calculated.

Next, RVD was calculated from the angular velocity-time curve sampled at 100 Hz (RVD = Δ angular velocity / Δ time)[12] (Figure 1). The RVD30 for the quadriceps was calculated from the start of knee extension to 30% of 60°/s (angular velocity = 18°/s), and the RVD90 was calculated from the start of knee extension to 90% of 60°/s (angular velocity = 54°/s). Hamstrings RVD30 and RVD90 values were determined similarly during knee flexion contraction[13].

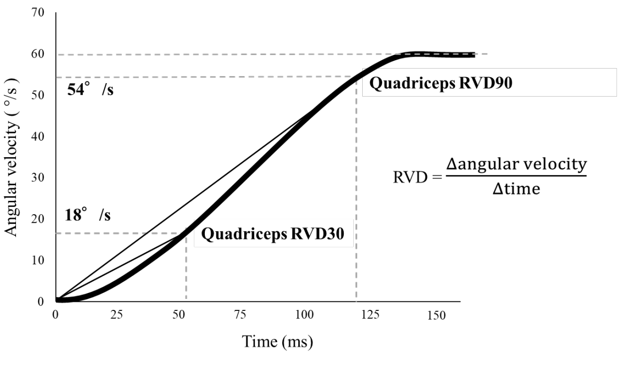

Figure 1: Rate of velocity development (RVD) calculated from angular velocity-time curve

2. Gait Analysis

Gait was assessed using a three-dimensional motion analysis system (VICON MX, Vicon Motion Systems, Oxford, UK), which included ten infrared cameras (T10, Vicon Motion Systems) and four force plates (AMTI, Watertown, MA, USA) with a sampling frequency of 100 Hz. Markers were applied based on the Plug-in-Gait lower limb model marker set, which included 14-mm infrared reflective markers placed on the bilateral anterior superior iliac spine, posterior superior iliac spine, thigh (on a line between the greater trochanter and lateral femoral epicondyle), lateral knee joint (midpoint of the anteroposterior diameter of the knee joint excluding patella thickness at the level of the median patella), lower leg (on a line between the fibular head and lateral malleolus), lateral malleolus, calcaneus, and second metatarsal head. We confirmed no difference between the actual lower-limb joint angles during standing and those measured by a three-dimensional motion analysis system during standing after the markers were affixed. The participants walked barefoot at a comfortable speed. The data were analyzed using Vicon NEXUS and Polygon 4 (Vicon Motion Systems, Oxford, UK). One gait cycle was normalized to 100%, and three trials were averaged. Walking speed (m/s), stride length (m), and cadence (steps/min) were used as temporal-spatial factors, and joint angle and angular velocity were calculated as kinematic factors, focusing on the sagittal plane angles and angular velocities of the knee joint (Figure 2). The knee joint angle was measured at four points: extension angle at the initial ground contact (A1), flexion angle

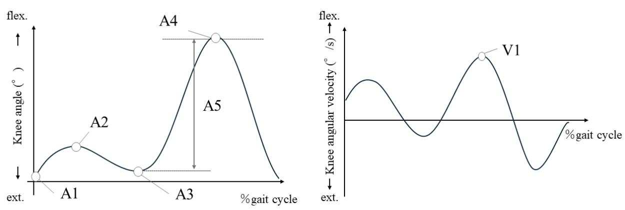

Figure 2: Kinematic parameters in sagittal plane during gait

during the loading response phase (A2), extension angle during the stance phase (A3), and flexion angle during the swing phase (A4). The knee joint angle range from the minimum to the maximum was also calculated (A5). In addition, peak angular velocity was calculated during the gait cycle (V1). The peak knee extension moment during the stance phase was calculated as kinematic data.

3. Statistical Analysis

The results of muscle strength, RVD, and gait analyses were extracted from only performed on the operated side. Statistical analyses were performed using IBM SPSS Statistics for Windows version 27 (IBM, Armonk, NY, USA). After confirming normality with the Shapiro-Wilk test, paired t-tests were used to compare the differences in each factor before and after TKA. Pearson's correlation coefficients were used to explore the associations among muscle strength, RVD, and gait analysis parameters. Statistical significance was set at 5%.

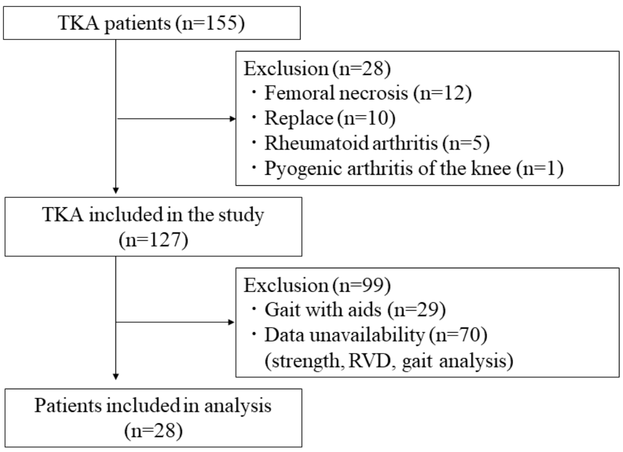

Figure 3: Flow diagram of this study

Results

Figure 3 shows a flow diagram of the subjects. During the study period, 155 subjects were included and twenty-eight were excluded because of their primary disease. Additionally, ninety-nine subjects were excluded due to gait with aids or data unavailability, leaving twenty-eight subjects (eight males and twenty females) for study. Fourteen participants had a preoperative Kellgren-Lawrence (K-L) grade 3 classification, while the remaining fourteen had a grade 4 classification. The mean time from TKA to the measurement of physical functions at discharge was 18.5 ± 3.7 days (Table 1).

Table 1: Participant Characteristics

Age (years old)	74.5 ± 5.2
Male / Female (n)	8 / 20
Height (cm)	150.1 ± 8.2
Body weight (kg)	60.4 ± 13.3
BMI (kg/m^2)	26.6 ± 3.8
Days from TKA to measurement of physical functions at discharge (days)	18.5 ± 3.7
K-L classification (n)	
Grade 3	14
Grade 4	14

avg. ± SD

Quadriceps muscle strength significantly decreased postoperatively, from 0.64 ± 0.29 Nm/kg preoperatively to 0.50 ± 0.16 Nm/kg (p < 0.01), and hamstrings muscle strength no significant difference, with values of 0.39 ± 0.18 Nm/kg preoperatively and 0.35 ± 0.09 Nm/kg postoperatively (Figure 4). On the other hand, the RVD for the quadriceps did not show significant changes postoperatively: RVD30 was 358.2 ± 267.6°/s^2 preoperatively and 350.0 ± 203.5°/s^2 postoperatively, while RVD90 was 470.4 ± 298.5°/s^2 preoperatively and 431.4 ± 216.7°/s^2 postoperatively. However, there was a significant increase in hamstring RVD30, from 297.1 ± 190.8°/s^2 preoperatively to 366.3 ± 234.9°/s^2 postoperatively (p = 0.04). Hamstring RVD90 did not show a significant difference, with values of 405.0 ± 257.0°/s^2 preoperatively and 449.1 ± 254.5°/s^2

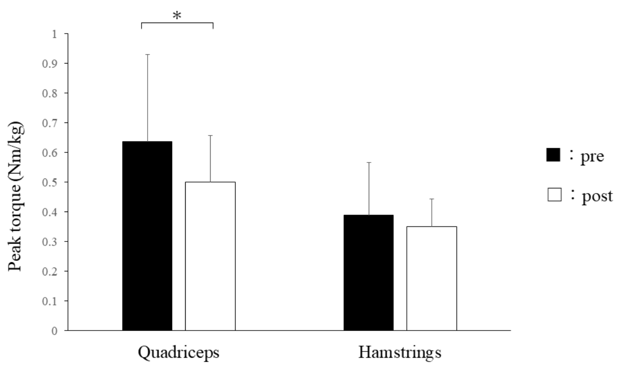

Figure 4: Comparison of maximum knee muscle strength before and after surgery
*: p < 0.05

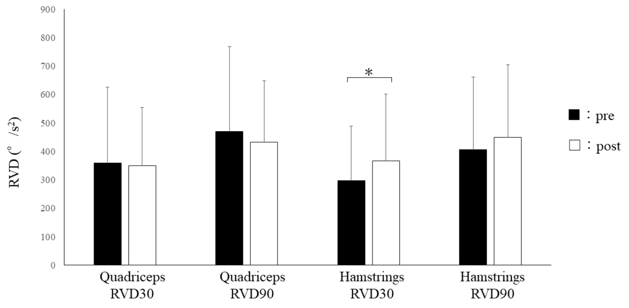

Figure 5: Comparison of RVD before and after surgery
*: $p < 0.05$

postoperatively (Figure 5).

Regarding correlations with gait parameters, postoperative quadriceps RVD30 and RVD90 showed no significant correlation with postoperative flexion range angle (r = 0.20, p = 0.32 and r = 0.24, p = 0.22, respectively) or peak knee angular velocity (r = 0.34, p = 0.06 and r = 0.36, p = 0.06, respectively). Similarly, postoperative hamstrings RVD30 and RVD90 showed no significant correlation with postoperative flexion range angle (r = 0.07, p = 0.72 and r = 0.16, p = 0.42, respectively) or peak knee angular velocity (r = 0.12, p = 0.55 and r = 0.24, p = 0.22, respectively) (Table 2). No significant correlation was found between quadriceps RVD30 and cadence (r = 0.35, p = 0.07); however, a significant correlation was found between quadriceps RVD90 and cadence (r = 0.41, p = 0.03). Additionally, maximum hamstring muscle strength was significantly correlated with knee flexion range angle (r = 0.49, $p < 0.01$) and peak knee angular velocity (r = 0.50, $p < 0.01$).

Discussion

This is the first study to examine the changes in RVD before and after TKA and the relationship postoperative RVD with postoperative gait parameters. We found that hamstring RVD30 significantly increased postoperatively compared to preoperative levels. Additionally, cadence was associated with the quadriceps RVD90 after TKA.

The recovery of muscle strength after TKA remains a significant challenge. The results of this study demonstrated a significant decrease in quadriceps strength approximately three weeks after surgery compared with preoperative levels, while hamstring strength remained unchanged. Quadriceps strength decreases in the early postoperative period due to surgical invasion, pain, and arthrogenic muscle inhibition following TKA[14]. Although hamstring muscle strength also decreases after TKA[15], the reduction is smaller than that observed in quadriceps [16] strength owing to the lack of direct surgical invasion. In our study, as in previous studies, quadriceps strength significantly decreased at three weeks postoperatively compared with preoperative values, while hamstring muscle strength did not show a significant difference.
Regarding RVD, our findings indicated no significant difference in quadriceps RVD30 and RVD90 postoperatively compared with preoperative values. Given the lack of research on RVD before and after TKA, we turned to studies on RTD (rate of torque development) and RFD (rate of force development) to inform our discussion. While RTD and RFD are

Table 2: Results of Correlation coefficient between muscle strength or RVD and gait parameters (post TKA)

Gait parameters	Quadriceps peak torque		Hamstrings peak torque		Quadriceps RVD30		Quadriceps RVD90		Hamstrings RVD30		Hamstrings RVD90	
	r	p	r	p	r	p	r	p	r	p	r	p
Walking speed (m/s)	0.38	0.048*	0.29	0.13	0.30	0.12	0.33	0.09	0.09	0.65	0.28	0.16
Cadence (steps/min)	0.14	0.47	0.22	0.27	0.35	0.07	0.41	0.03*	0.08	0.68	0.25	0.20
Stride length (m)	0.42	0.03*	0.25	0.20	0.18	0.37	0.17	0.39	0.08	0.68	0.20	0.30
A1: IC extension angle (°)	- 0.23	0.24	- 0.07	0.73	0.14	0.49	0.12	0.55	0.03	0.87	- 0.02	0.92
A2: St flexion angle (°)	- 0.17	0.39	< 0.01	0.96	0.22	0.26	0.20	0.31	0.11	0.57	0.07	0.73
A3: Mst. extension angle (°)	- 0.22	0.27	- 0.09	0.65	0.09	0.66	0.13	0.52	- 0.04	0.84	- 0.10	0.63
A4: Sw. flexion angle (°)	0.04	0.85	0.30	0.12	0.22	0.27	0.26	0.18	0.03	0.90	0.06	0.76
A5: flexion range angle (°)	0.25	0.19	0.49	< 0.01*	0.20	0.32	0.24	0.22	0.07	0.73	0.16	0.42
Peak knee angular velocity (°/s)	0.29	0.13	0.50	< 0.01*	0.34	0.08	0.36	0.06	0.12	0.55	0.24	0.22
Peak knee extension moment (Nm/kg)	- 0.17	0.39	0.11	0.78	0.11	0.58	0.11	0.59	- 0.19	0.35	- 0.17	0.40

Mst.: Mid stance phase, Sw.: Swing phase, *: p<0.05

well-established measures used to evaluate the rapid generation of force or torque during muscle contraction, RVD (rate of velocity development) focuses specifically on the speed at which muscles can accelerate during the initial phase of contraction. For example, Winters et al. [17] reported a decrease in knee extension RTD one month after TKA compared with preoperative levels, and Rice et al. [18] found that experimental pain in knee joint reduced knee extension RFD. These studies led us to anticipate a decrease in quadriceps RVD during the early postoperative period when pain and surgical stress are prevalent. However, our findings did not confirm this expectation, possibly due to the different contraction modalities used in the evaluations. RVD was measured using isokinetic contraction, which assess the velocity of muscle contraction at a constant speed, in contrast to RTD and RFD, which are typically assessed using isometric contractions that focus on force generation without joint movement. The distinction in what each measure evaluates may explain the differing results. Nonetheless, the absence of direct comparisons between RVD and RTD or RFD in TKA patients highlights the need for further studies to better understand these relationships.

Our results showed a significant increase in hamstring RVD30 after TKA. This improvement in RVD may be attributed to the fact that the factors contributing to this improvement in RVD are unknown, but it is possible that the hamstrings are not directly affected by the surgical invasion and thus benefit from joint reconstruction and postoperative physical therapy, resulting in increased RVD postoperatively. Neurogenic changes, such as increased motor unit recruitment, are known to occur during the early phase of muscle strengthening exercises[19]. Since RVD is thought to reflect the firing rate of motor units[20], it is possible that such neurogenic adaptations may have contributed to the increase in hamstring RVD30.

Regarding gait parameters, none of the RVD measures showed significant correlations with knee flexion range or peak knee joint angular velocity after TKA. Stiff knee gait, a common gait pattern in patients with knee osteoarthritis (KOA) and TKA, is characterized by a reduced knee flexion range angle and angular velocity[9), 21)]. Although RVD has been shown to reflect early contraction ability and is strongly associated with physical performance[11)] , this study did not find a significant association between RVD and the characteristic parameters of stiff knee gait. However, it remains unclear whether the subjects in this study exhibited a stiff knee gait, and future subgroup analyses are needed to clarify the relationship between gait parameters and RVD in patients with stiff knee gait.

In contrast, when considering time-distance parameters, postoperative quadriceps RVD90 was positively correlated with cadence. From a biomechanical perspective, increasing cadence typically requires a higher rotational speed of joint motion during gait and smooth transitions between movements. The ability to quickly accelerate knee extension, as indicated by a higher RVD, may facilitate more rapid and efficient limb movement, allowing for a smoother and faster gait cycle. This could explain why patients with higher quadriceps RVD90 were able to achieve increased cadence following TKA, as the enhanced muscle contraction speed likely contributed to maintaining a comfortable and consistent gait rhythm during the postoperative recovery period. These findings suggest that improving quadriceps RVD may play a critical role in optimizing gait mechanics and overall walking performance specifically after TKA.

This study had several limitations. We did not evaluate pain or conduct electromyography (EMG) measurements, making it unclear whether RVD was influenced by pain after TKA. Additionally, the timing of contraction and relaxation of the quadriceps and hamstrings could not be assessed using EMG; therefore, it is uncertain whether the delayed increases in joint angular velocity were due to impaired agonist muscle contraction or impaired antagonist muscle relaxation. Another limitation is the small sample size, which prevented a comparison with healthy elderly participants. Furthermore, all subjects were able to walk without assistive devices both preoperatively and at the time of discharge. They also achieved an angular velocity of 60°/ s in all muscle strength measurements, which may have introduced subject bias. Data regarding outdoor walking and stair climbing prior to surgery and at discharge were difficult to obtain from medical records, limiting the detailed characterization of subjects' physical activity. Therefore, further studies involving a larger and more diverse population are necessary to enhance the generalizability of these findings.

Conclusion

After TKA, quadriceps strength significantly decreased, while hamstring RVD30 increased notably compared with preoperative levels. These findings suggest that muscle strength and RVD reflect different aspects of muscle function and recovery, with quadriceps being more susceptible to early postoperative decline due to surgical trauma, whereas hamstring RVD may benefit from the lack of direct surgical invasion and postoperative rehabilitation. Additionally, while postoperative quadriceps and hamstring RVD showed no significant correlations with peak knee angular velocity or knee flexion range, the positive correlation between quadriceps RVD90 and cadence highlights a potential link to improved physical performance. This study highlights the importance of considering both muscle strength and RVD in assessing postoperative recovery and gait function.

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References

1) Ryan L Mizner, Stephanie C Petterson, Jennifer E Stevens, et al.(2005): Early quadriceps strength loss after total knee arthroplasty, J Bone Joint Surg Am, 87, 1047-1053.
2) Michael J Bade, Wendy M Kohrt, Jennifer E Stevens-Lapsley(2010): Outcomes before and after total knee arthroplasty compared to healthy adults, J Orthop Sports Phys Ther, 40, 559–567.
3) M Walsh, L J Woodhouse, S G Thomas, et al.(1998): Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects, Phys Ther, 78, 248-258.
4) Jodie A McClelland, Kate E Webster, Julian A Fellar(2007): Gait analysis of patients following total knee replacement: a systematic review, Knee, 14, 253-263.
5) Saryn R Goldberg, Sylvia Ounpuu, Scott L Delp(2003): The importance of swing-phase initial conditions in stiff-knee gait, J Biomech, 36, 1111-1116.
6) Michael D Lewek, Abigail J Osborn, Clinton J Wutzke(2012): The Influence of Mechanically and Physiologically Imposed Stiff-Knee Gait Patterns on the Energy Cost of Walking, Arch Phys Med Rehabil, 93, 123-128.
7) Joseph A Zeni Jr, Portia Flowers, Michael Bade, et al.(2019): Stiff Knee Gait May Increase Risk of Second Total Knee Arthroplasty, Journal of Orthopaedic Research, 37, 397-402.
8) M G Benedetti, F Cateni, T W Bilotta, et al.(2003): Muscle activation pattern and gait biomechanics after total knee replacement, Clin Biomech (Bristol, Avon), 18, 871-876.
9) Frank C Anderson, Saryn R Goldberg, Marcus G Pandy, et al.(2004): Contributions of muscle forces and toe-off kinematics to peak knee flexion during the swing phase of normal gait: an induced position analysis, J Biomech, 37, 731-737.
10) Lee E Brown, Michael Whitehurst(2003): The Effect of Short-Term Isokinetic Training on Force and Rate of Velocity Development, J Strength Cond Res, 17, 88-94.
11) Brennan J Thompson, Eric C Conchola, Ty B Palmer, et al.(2014): Effects of aging on maximal and rapid velocity capacities of the leg extensors, Exp Gerontol, 58, 128-131.
12) Yusuke Osawa , Stephanie A Stedenski, Luigi Ferrucci(2018): Knee extension rate of velocity development affects walking performance differently in men and women, Exp Gerontol, 112, 63-67.
13) Massimo Angelozzi, Marco Madama, Cristiana Corsica, et al.(2012): Rate of force development as an adjunctive outcome measure for return-to-sport decisions after anterior cruciate ligament reconstruction, J Orthop Sports Phys Ther, 42, 772-780.
14) Jennifer E Stevens, Ryan L Mizner, Lynn Snyder-Mackler(2003): Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis, J Orthop Res, 21, 775-779.
15) Sanda Yutaro, Ohsawa Suguru, Shiiki Takayuki, et al. (2017): Variations in the Isometric Quadriceps and Hamstrings Strength at Different Knee Joint Angles and Points of Time after Total Knee Arthroplasty. Rigakuryoho Kagaku, 32, 553-557.In Japanese.
16) Young-Wan Moon, Hyun-Jung Kim, Hyeong-Sik

Ahn, et al.(2016): Serial changes of quadriceps and hamstring muscle strength following total knee arthroplasty: a meta-analysis, PLoS One, 11(2), 1-10.

17) Joshua D Winters, Cory L Christiansen, Jennifer E Steven-Lapsley(2014): Preliminary investigation of rate of torque development deficits following total knee arthroplasty, Knee, 21, 382-386.

18) David A Rice, Jamie Mannion, Gwyn N Lewis, et al.(2019): Experimental knee pain impairs joint torque and rate of force development in isometric and isokinetic muscle activation, Eur J Appl Physiol, 119, 2065-2073.

19) Akima H, Takahashi H, Kuno S Y, et al.(1999): Early phase adaptations of muscle use and strength to isokinetic training, Med Sci Sports Exerc, 31, 588-594.

20) Nathaniel D.M. Jenkins, Ty B. Palmer, Joel T. Cramer(2013): Comparisons of voluntary and evoked rate of torque development and rate of velocity development during isokinetic muscle actions, Isokinet Exerc Sci, 21, 253-261.

21) Saryn R Goldberg, Frank C Anderson, Marcus G Pandy, et al.(2004): Muscles that influence knee flexion velocity in double support: implications for stiff-knee gait, J Biomech, 37, 1189-1196.

人工膝関節全置換術前後における大腿四頭筋とハムストリングスの速度発揮率と歩行特性との関連性

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要　旨

［はじめに］人工膝関節全置換術（TKA）は，変形性膝関節症患者の疼痛軽減や歩行能力向上を目的として行われる一般的な手術であるが，筋力低下や異常な歩行パターンは TKA 後も残存する。筋収縮の加速能力の指標である RVD（Rate of Velocity Development）は運動パフォーマンスとの関連性が示唆されているが，RVD が TKA 術後に低下するか，また術後の歩行機能と関連するかどうか明らかではない。そこで，TKA 術前後における大腿四頭筋とハムストリングスの筋力及び RVD の変化と，術後の RVD と歩行機能との関連性を調査することとした。
［方法］筋力は，大腿四頭筋とハムストリングスの等速性筋力測定（60° /s）の最大値とし，RVD は角速度 - 時間曲線から，RVD30 と RVD90 を算出した。歩行は 3 次元動作解析装置を用いて，歩行速度，歩幅，ケイデンス，膝関節角度，膝関節角速度を算出した。統計解析は対応のある t 検定とピアソンの相関係数を用いて行い，有意水準は 5 %とした。
［結果］術前と比較し術後では，大腿四頭筋筋力は有意に低下し，ハムストリングス RVD30 は有意に増加した。術後において大腿四頭筋とハムストリングスの RVD30，RVD90 は，膝関節角度や膝関節角速度と有意な相関関係を認めなかったが，大腿四頭筋 RVD90 とケイデンスは有意な相関関係を認めた。
［結語］TKA 術後約 3 週では筋力と RVD は異なる術後経過を示しており、術後の回復は筋の機能によって異なることが考えられた。また，大腿四頭筋 RVD90 はケイデンスと有意な相関関係を認め，歩行機能と部分的に関連する可能性が示唆された。