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The Effect of Hip Joint Position and Velocity on Quadriceps Peak Torque in Children: An Analysis of Varying Knee Flexion Angles

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ABSTRACT

Background*:* The hip and knee joints are crucial for movement and are subjected to stress while walking, running, and jumping. The quadriceps muscles play an essential role in knee extension and peak torque production.

Objectives: This study aimed to investigate the relationship between the knee extension peak torque of the quadriceps muscle and the hip angle at different knee angles and different angular velocities while performing concentric knee extension.

Patients and methods: In this cross-sectional study, forty typically developed children of both genders with mean age, weight, and height of 10.22 ± 1.41 years, 40.12 ± 7.97 kg, and 140.65 ± 6.56 cm participated. The inclusion criteria for the study were children who could understand and follow instructions during the testing procedure. The study tested the knee extension peak torque at different knee angles, hip angles, and angular knee velocities.

Results: The results showed no significant difference in knee extensors' peak torque between supine and sitting positions at 180º/s but a significant increase in the sitting position at 60º/s. However, a significant increase was found in knee extensors' peak torque at 60º/s compared to 180º/s in both supine and sitting positions ($p<0.001$). In the supine position, the mean knee extensor peak torque was 36.45 ± 20.66 Nm at 60º/s and 40.1 ± 22.17 Nm at 60º/sitting position. Meanwhile, the mean knee extensor peak torque was 20.95 ± 14.09 Nm at 180º/s in the supine position and 22.05 ± 15.2 Nm at 180º/s in a sitting position. The hip angle, velocity, and knee angle all affected the muscle strength with a significant interaction between the hip angle and velocity. Also, there was a significant increase in knee extensors torque in supine and sitting positions with knee 30º, 50º and 70º at 60º/s ($p=0.001$) compared with that at 180º/s, while with knee 90º, there was increase in knee extensors torque in sitting position only at 60º/s compared with that at 180º/s ($p = 0.002$).

Results demonstrated that the knee extensor torque is higher in the slow speed rather than the high speed. Furthermore, at the slow speed (60°/s) across all the knee angles it was found that the extensor knee torque is higher at the sitting position compared to supine lying. Additionally, a significant increase was observed when the knee angle increases from 30° to 70° while it declines when the knee angle reaches 90° in both supine and sitting positions.

Moreover, across all the knee angles, the knee extensor torque is higher at slow speed compared to the fast speed regardless of the hip position.

Conclusion: The study provides insight into the impact of hip and knee position on the knee extensor peak torque production, which has an important effect on rehabilitation. The relationship between knee angle, velocity, and torque is an important area of study that can modify the development of rehabilitation and exercise programs to improve muscle performance.

Keywords: Peak torque; knee angles; concentric isokinetic strength; knee flexion

INTRODUCTION

Human knee joints endure significant loads during daily activities, with even greater stress during sports or sudden movements, making them susceptible to injuries [1–3]. Activities like walking and running strain both the hip and knee joints, which have degrees of freedom allowing various movements [1].

The quadriceps, particularly the rectus femoris (RF), function as primary knee extensors and hip flexors, playing a key role in physical activity [2]. Understanding how hip joint position affects knee extensor peak torque is essential for effective rehabilitation and injury prevention [1,2].

Peak torque refers to the maximum force produced in a single muscle contraction [1], and is influenced by muscle activation, movement velocity, and joint position [3]. Since the RF crosses both the hip and knee joints, its force-generating capacity is affected by changes in hip angle due to alterations in muscle length [3]. Research shows that hip joint position impacts knee torque, especially in isometric contractions [4], but findings on concentric contractions remain mixed [5]. Some studies report higher peak torque in flexed hip positions [3,5], and **Ema *et al.*** [6] suggest this may relate to the muscle's position on the force-length curve, influenced by sarcomere length.

The length-tension relationship explains that muscles generate maximum force at optimal lengths and less force when overstretched or overly shortened [7]. However, existing studies mostly focus on adults [6,8,9,10], leaving a gap in pediatric research.

Shenoy *et al.* [9] showed that torque varies with knee angle, with peaks at 50°–70° of flexion, and reduced torque near full extension or deep flexion. These

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variations may result from both mechanical and neural factors. Clinicians must understand how hip position, speed, and knee angles affect quadriceps torque to guide rehabilitation.

The purpose of this study was to examine whether there is a relationship between the knee extension torque of the quadriceps muscle and the hip angle at different knee flexion angles and different angular velocities while performing concentric knee extension.

PATIENTS AND METHODS

This cross-sectional observational study included a total of 40 typically developed children of both genders, who referred to the Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, for testing the knee extension peak torque at different knee angles, hip angles, and angular knee velocities. This study was conducted between June 2022 to June 2023.

The mean age, weight, and height of the children were 10.22 ± 1.41 years, 40.12 ± 7.97 kg, and 140.65 ± 6.56 cm respectively. Body mass index, BMI (kg/m^2) was measured.

Inclusion criteria: children between the ages of 8 and 12 years who could understand and follow instructions during the testing procedure. Participants who had normal range of motion (ROM) for hips and knees bilaterally, free from any spinal or lower limb deformities (acquired or congenital), neurological, musculoskeletal, cardiopulmonary disease, cognitive disorders, or fractures or surgeries of lower extremities in the past six months were included in this study.

Exclusion criteria: Participants who did not meet the inclusion criteria were excluded from the study.

Study Design

The range of motion of both hip and knee joints was measured using universal digital plastic goniometer according to **Norkin *et al.*** [(12)]. The dominant leg was determined following procedures explained in the article by **Van Melick *et al.*** [(13)]. According to the instructions, participants were asked which lower limb they would use to shoot a ball at a target. The dominance in the study participants was determined based on the response.

Isokinetic Measurements

Assessment of knee extensor peak torque

Knee extensor peak torque was assessed from sitting and supine positions according to the work of **Ema *et al.*** [(7)] using Isokinetic Dynamometer (Computer sports medicine, Inc., model: (HUMAC NORM-502140), USA). The tool is valid for children with acceptable cronbach value (> 0.894) [(14)]. With the use of an isokinetic dynamometer, we determined the peak torque of the knee extension in children.

The Procedure

Participants sat or lay supine on the bench of an isokinetic dynamometer while being secured at the pelvis and torso to the bench with nonelastic straps. The centres of rotation of the dynamometer and the right knee joint were visually adjusted. Participants removed their shoes and socks prior to testing to prevent any unwanted noise while recording. After activating the software, each child's demographic information was entered, including their dominant limb, date of birth, name, sex, weight, and height. The researcher demonstrated each task in front of each participant alongside providing verbal encouragement during the trials. Each participant was required to go through two practice trials and three test trials. The time period for all five trials ranged from 15 to 20 minutes followed by a 1-minute break between each trial to minimize the potential impact of fatigue making it a total of 4-minute resting time; each trial consisted of 3 sets of concentric knee extension from both supine and sitting positions and at both speeds 60º/s and 180º/s.

Each set consisted of 5 repetitions at each angular velocity. The knee joint angle was set at 90° to 30° then performed 3 sets of 5 concentric knee extension trials with maximal effort at 180°/s and 80° hip joint angles in random order. The threshold torque of the concentric knee extension was set at 30 Nm to prevent the movement of the lever arm by the passive torque of the quadriceps femoris and the lower leg's mass. The torque was corrected for the mass of the leg, foot and lever arm of the dynamometer.

***Ethical Consideration*:**

This study was ethically approved by the Ethics Review Committee of the Faculty of Physical Therapy, Cairo University, Egypt (No: P.T. REC/ 012/002009). Written informed consent of all the participants' parents was obtained. The study protocol conformed to the Helsinki Declaration, the ethical norm of the World Medical Association for human testing.

Statistical analysis

We used the Shapiro-Wilk test to check if all data were normally distributed, all data were normally distributed ($p>0.005$). Descriptive statistics were presented as mean ± standard deviation (Mean ±SD). The two-way analysis of variance (2-way ANOVA) was used to examine the relationship between knee extensors peak torque at different angular velocities (60º/s and 180º/s), concentric knee extension peak torques measured for two hip angles (supine and sitting), and different knee angles (30º, 50º, 70º, and 90º). Torque produced during concentric knee extensions was investigated as a function of hip joint angle, angular velocity, and knee angles using multiple analyses of variance (MANOVA). Post hoc Bonferroni multiple comparisons were run, and partial eta squared was computed to serve as an effect size measure for paired comparisons. All the values in the test were presented as (Mean ± SD) at a 0.05 alpha value. IBM-SPSS version 20 (IBM, Armonk, NY, United States of America) was used to process the statistical analysis.

RESULTS

Forty typically developed children participated in this study group, with mean age, weight, and height were 10.22 ± 1.41 years, 40.12 ± 7.97 kg, and 140.65 ± 6.56 cm, respectively. The gender distribution were 20 (50%) girls and 20 (50%) boys. The dominant leg distribution of the study group showed that 29 (72.5%) children had the right leg dominant, and 11 (27.5%) children had the left side dominant.

Descriptive Statistics of the knee extensor peak torque from different hip positions (sitting, and supine position), different angular velocities (60º/s and 180º/s), and different knee extensor angles (30º, 50º, 70º, and 90º)

The researcher averaged data from three trials in each test condition for data analyses.

Table 1 shows that the mean ± SD of the knee extensors peak torque at a speed of 60º/s in the supine position with knee 30º, 50º,70º, and 90º were 9.27 ± 8.29 Nm, 26.17 ± 17 Nm, 31.37 ± 20.75 Nm, 13.02 ± 9.27 Nm respectively. The knee extensor torque in the supine position at a speed of 180°/s with knee angles of 30°, 50°, 70°, and 90° were 1.2 ± 2.83 Nm, 13.8 ± 11.68 Nm, 17.55 ± 13.94 Nm, and 12.05 ± 8.62 Nm respectively. Furthermore, the knee extensor torque in the sitting position at a speed of 60°/s with knee angles of 30°, 50°, 70°, and 90° were 13.52 ± 9.28 Nm, 31.3 ± 19.59 Nm, 34.75 ± 21.26 Nm, and 17.1 ± 12.09 Nm respectively. The knee extensor torque in the sitting position at a speed of 180°/s with knee angles of 30°, 50°, 70°, and 90° were 0.73 ± 1.76 Nm, 16.25 ± 13.68 Nm, 19.4 ± 14.86 Nm, and 11.42 ± 6.35 Nm respectively

The knee extensor peak torque was higher in the sitting position compared with the supine position. In addition, it was also greater during the slow speed (60°/s), compared to the fast speed (180°/s) movement of the knee extension. Moreover, there was an increase in the knee extensor peak torque when the knee angle increased from 30° to 70°, and it declined when the knee angle reached 90° in both the supine and sitting positions, regardless of the speed of motion.

Table 1: Mean values of the knee extension peak torque (Nm)

Knee extension torque (Nm)				
	Supine		**Sitting**	
	60º/s	**180º/s**	**60º/s**	**180º/s**
Knee Angle	**$\bar{X}$± SD**	**$\bar{X}$± SD**	**$\bar{X}$± SD**	**$\bar{X}$± SD**
30º	9.27 ± 8.29	1.2 ± 2.83	13.52 ± 9.28	0.73 ± 1.76
50º	26.17 ± 17	13.8 ± 11.68	31.3 ± 19.59	16.25 ± 13.68
70º	31.37 ± 20.75	17.55 ± 13.94	34.75 ± 21.26	19.4 ± 14.86
90º	13.02 ± 9.27	12.05 ± 8.62	17.1 ± 12.09	11.42 ± 6.35

$\bar{X}$, Mean; SD, Standard deviation.

Effect of hip joint angle on concentric knee extension Peak torque

Table 2 shows that there was a significant increase in the knee extensors peak torque at 60º/s with the knee in 30º, 50º, 90º in sitting position compared with that in supine (p = 0.01), (p = 0.02), and (p = 0.01) respectively while there was no significant difference in knee extensors torque at 180º/s with the knee in 30º, 50º, 70º, and 90º between supine and sitting positions (p = 0.28), (p = 0.09), (p = 0.17), and (p = 0.52) respectively.

Table 2: Effect of hip joint angle on the concentric knee extensor peak torque

Knee extension torque (Nm)				
	60º/s		**180º/s**	
	Supine	**Sitting**	**Supine**	**Sitting**
	± SD	**± SD**	**± SD**	**± SD**
Knee 30	9.27 ± 8.29	13.52 ± 9.28	1.2 ± 2.83	0.73 ± 1.76
Knee 50	26.17 ± 17	31.3 ± 19.59	13.8 ± 11.68	16.25 ± 13.68
Knee 70	31.37 ± 20.75	34.75 ± 21.26	17.55 ± 13.94	19.4 ± 14.86
Knee 90	13.02 ± 9.27	17.1 ± 12.09	12.05 ± 8.62	11.42 ± 6.35
Position effect (supine vs sitting)				
		Mean Difference	**p-value**	
60º/s	Knee 30	-4.25	0.01*	
	Knee 50	-5.13	0.02*	
	Knee 70	-3.38	0.2	
	Knee 90	-4.08	0.01*	
1800º/s	Knee 30	0.47	0.28	
	Knee 50	-2.45	0.09	
	Knee 70	-1.85	0.17	
	Knee 90	0.63	0.52	

The level of significance was set at 0.05. * $p < 0.05$.

Table 3 and figure 1 show a significant increase in knee extensor peak torque in the supine position at 60º/s compared with 180º/s for all knee angles (30º, 50º, 70º). The mean difference in peak torque was highest at the 70º knee angle, with a value of 13.82 Nm. However, there was no significant difference in knee extensor peak torque in the supine position with knee 90º between 60º/s and 180º/s. The knee extensor torque results in the sitting position were similar to those in the supine position. At the knee angle of 30º, the mean torque was 13.52 ± 9.28 Nm at 60º/s and 0.73 ± 1.76 Nm at 180º/s. When the knee angle was increased to 50º, the mean torque was 31.3 ± 19.59 Nm at 60º/s and 16.25 ± 13.68 Nm at 180º/s. The mean torque was higher at 60º/s compared to 180º/s when the knee angle was 70º and 90º, respectively (Table 2).

These results indicate that knee extensor torque is generally higher at 60º/s than 180º/s, regardless of whether sitting or supine position.

The study's results on knee extensor peak torque in different hip angles and with varying knee angles show a consistent pattern. The mean torque was consistently higher at 60º/s compared to 180º/s, regardless of the hip angle and knee angle. For example, in the supine position, the knee extensor torque was 9.27 ± 8.29 Nm at 60º/s and 1.2 ± 2.83 Nm at 180º/s with a knee angle of 30º. With a knee angle of 50º, the mean torque was 26.17 ± 17 Nm at 60º/s and 13.8 ± 11.68 Nm at 180º/s. Similarly, with a knee angle of 70º, the mean torque was 31.37 ± 20.75 Nm at 60º/s and 17.55 ± 13.94 Nm at 180º/s. The only exception was in the supine position with a knee angle of 90º, with no significant difference between 60º/s and 180º/s (Table 3).

Table 3: Effect of the change of the velocity on the concentric knee extensor peak torque

Knee extension torque (nm)								
Angle at the knee joint	**Supine**				**Sitting**			
	60º/s (Mean ± SD)	180º/s (Mean ± SD)	MD	p-value	60º/s (Mean ± SD)	180º/s (Mean ± SD)	MD	p-value
Angle at the knee joint, 30 degrees	9.27 ± 8.29	1.2 ± 2.83	8.07	0.001	13.52 ±9.28	0.73 ±1.76	12.79	0.001
Angle at the knee joint, 50 degrees	26.17 ± 17.00	13.8 ± 11.68	12.37	0.001	31.3 ± 19.59	16.25 ± 13.68	15.05	0.001
Angle at the knee joint, 70 degrees	31.37 ± 20.75	17.55 ± 13.94	13.82	0.001	34.75 ± 21.26	19.4 ± 14.86	15.35	0.001
Angle at the knee joint, 90 degrees	13.02 ± 9.27	12.05 ± 8.62	0.97	0.310	17.1 ± 12.09	11.42 ± 5.35	5.68	0.002

Values are presented as mean ± standard deviation; MD, mean difference, *p < 0.05

Effect of the change of knee angle on the concentric knee extension peak torque from supine and sitting position at 60º/s and 180º/s

There was a significant increase of the knee extensor peak torque when the knee angle increased from 30 to 70 degrees in both supine and sitting positions regardless of the speed of the movement. However, there was a significant decrease of the knee extensor peak torque at the knee angle of 90 degrees compared with the previous angles in both supine and sitting positions regardless of the speed of the movement.

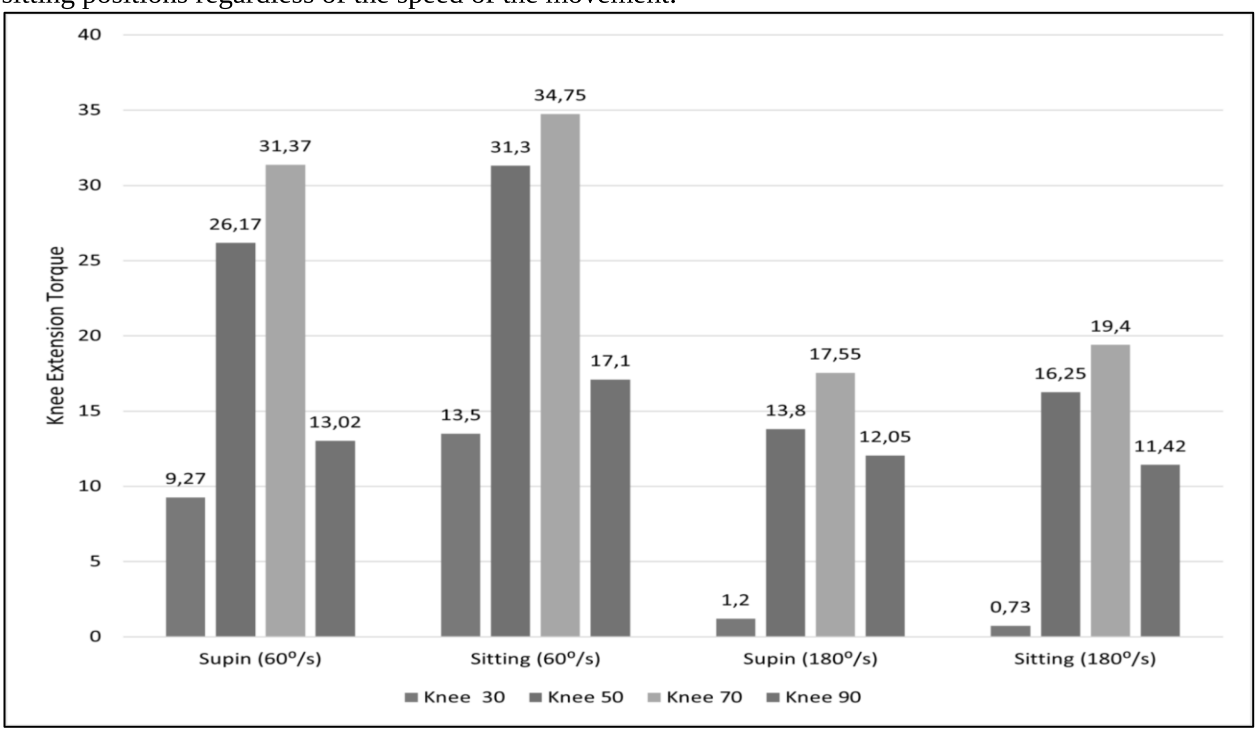

Figure 1: Knee extension torque in supine and sitting positions at 60º/s (P<0.05) and 180º/s (P>0.05).

Effect of hip joint angle, angular velocity, and knee angle's variation on knee extension peak torque

The results of knee extensor peak torque at different joint angles and angular velocities were analyzed to determine the effect of hip joint angle, angular velocity, and knee angle on the knee extensors peak torque. There is no significant interaction effect between all the variables (Hip joint angle x Angular Velocity x Knee angle; Hip joint angle x Knee angle) except for hip joint angle with angular velocity (P<0.010), and angular velocity with knee angles (p<0.001). Whereas there is a significant main effect of all the variables (p<0.001) (Table 4).

The effect of hip joint angles, angular velocity, and knee angle on the knee extension peak torque is explained in table 5. Accordingly, the knee extensor torque was measured at 60º/s for four different knee angles (30º, 50º, 70º, and 90º) in both supine and sitting positions.

For the interaction between the hip angles and the angular velocity; at the slow speed (60°/s) across all the knee angles, the knee extensor peak torque is higher in sitting position compared to the supine position. However, at the fast speed (180°/s), across all the knee angles, there was no significant difference in the knee extensor peak torque between the sitting and supine position.

For the interaction between the knee angles and the angular velocity; across all the knee angles the knee extensor torque is higher is slow speed compared to the fast speed regardless of the hip angle.

The results showed that for all knee angles except 70º, there was a significant increase in knee extensor torque in the sitting position compared to the supine position. The mean difference in knee extensor torque was -4.25 Nm for knee 30º, -5.13 Nm for knee 50º, -3.38 Nm for knee 70º, and -4.08 Nm for knee 90º.

The significance level was p < 0.010 for knee 30º, knee 50º, and knee 90º, while p = 0.2 for knee 70º. These findings suggest that the knee extensor torque increased in the sitting position compared to the supine position for different knee angles, except for 70º, where no significant difference was observed. The mean knee extensors torque at 180°/s with knee 30° in a supine position was 1.2 ± 2.83 Nm, and that in a sitting position was 0.73 ± 1.76 Nm, with a mean difference of 0.47 Nm. No significant difference was found between the supine and sitting positions (p = 0.28). At knee 50°, the mean knee extensor torque was 13.8 ± 11.68 Nm in the supine position and 16.25 ± 13.68 Nm in the sitting position, with a mean difference of -2.45 Nm. However, the two positions had no significant difference (p = 0.09).

At knee 70°, the mean knee extensor torque was 17.55 ± 13.94 Nm in the supine position and 19.4 ± 14.86 Nm in the sitting position, with a mean difference of -1.85 Nm. Again, the two positions had no significant difference (p = 0.17). Finally, at knee 90°, the mean knee extensor torque was 12.05 ± 8.62 Nm in the supine position and 11.42 ± 6.35 Nm in the sitting position, with a mean difference of 0.63 Nm. No differences in the knee torque at any angle at the two different positions in the fast speed (p = 0.52) (Table 5).

Table 4: MANOVA with repeated measures for the effect of hip joint angle, angular velocity, and knee angle on the knee extension peak torque

	Variables	**F**	**p-value**	**Partial Eta Squared**
Interaction effect	(Hip joint angle x Angular Velocity x Knee angle)	F (3,37) = 0.6	0.62	0.04
	(Hip joint angle x angular Velocity)	F (1,39) = 6.63	0.010*	0.14
	(Hip joint angle x Knee angle)	F (3, 37) = 0.92	0.43	0.07
	(Angular Velocity x Knee angle)	F (3,37) = 20.63	0.001*	0.62
Main effect	Hip joint angle	F (1,39) = 7.89	0.008*	0.16
	Angular Velocity	F (1,39) = 127.19	0.001*	0.76
	Knee angle	F (3,37) = 31.24	0.001*	0.71

The level of significance was set at 0.05. * p < 0.05

Table 5: The effect of hip joint angle, angular velocity, and knee angle on the knee extension peak torque

Knee extension torque (nm)								
Angle at the knee joint	Speed difference-60º/s				Speed difference-180º/s			
	Supine (Mean ± SD)	Sitting (Mean ± SD)	MD	p-value	Supine (Mean ± SD)	Sitting (Mean ± SD)	MD	p-value
Angle at the knee joint, 30 degrees	9.27 ± 8.29	13.52 ± 9.28	-4.24	0.010 *	1.2 ±2.83	0.73 ±1.76	0.47	0.28
Angle at the knee joint, 50 degrees	26.17 ± 17	31.3 ± 19.59	-5.13	0.020 *	13.8 ± 11.68	16.25 ± 13.68	-2.45	0.09
Angle at the knee joint, 70 degrees	31.37 ± 20.75	34.75 ± 21.26	-3.38	0.200	17.55 ±13.94	19.4 ± 14.86	-1.85	0.17
Angle at the knee joint, 90 degrees	13.02 ± 9.27	17.1 ± 12.09	-4.08	0.010 *	12.05 ± 8.62	11.42 ± 5.35	0.63	0.52

The level of significance was set at 0.05. * p < 0.05, Values are presented as mean ± standard deviation; MD, mean difference.

Effect of hip joint angle and angular velocity on knee extensors peak torque

There was no significant interaction effect between the hip joint angle and angular velocity (p = 0.44) and no significant main effect of the hip joint angle (p = 0.15). However, there was a significant main effect of the angular velocity (p < 0.001) (Table 6). The results showed no significant difference in knee extensors peak torque between supine and sitting positions at both 60º/s and 180º/s speeds (p = 0.09 and p = 0.36, respectively).

However, a significant increase was found in knee extensors' peak torque at 60º/s compared to 180º/s in both supine and sitting positions (p<0.001). The mean knee extensor peak torque was 36.45 ± 20.66 Nm at 60º/s in the supine position and 40.1 ± 22.17 Nm at 60º/s in the sitting position. Meanwhile, the mean knee extensor peak torque was 20.95 ± 14.09 Nm at 180º/s in the supine position and 22.05 ± 15.2 Nm a at 180º\s in a sitting position.

Table 6: Two-way MANOVA with repeated measures for the effect of hip joint angle and angular velocity on knee extensors peak torque and knee ROM

MANOVA with repeated measures	**F (2, 38)**	**p-value**	**Partial Eta Squared**
Interaction effect (Hip joint x Angular velocity)	0.82	0.44	0.04
Hip angle effect	1.96	0.15	0.09
Velocity effect	62.52	0.001*	0.76

The level of significance was set at 0.05. * p < 0.05.

Table 7: Effect of hip joint angle and angular velocity on knee extensors peak torque and knee

		Supine (Mean ± SD)	**Sitting** (Mean ± SD)	**Mean Difference**	**P value**
KEPT (nm)	**60º/s**	36.45 ± 20.66	40.1 ± 22.17	-3.65	0.09
	80º/s	20.95 ± 14.09	22.05 ± 15.2	-1.1	0.36
	MD	15.5	18.05		
Knee ROM (Degree)	**60º/s**	11.15 ± 2.41	11.05 ± 2.75	0.1	0.86
	80º/s	11.05 ± 2.51	10.4 ± 1.01	0.65	0.12
	D	0.1	0.65		
		p = 0.86	*p*= 0.12		

The level of significance was set at 0.05, Values are presented as mean ± standard deviation; MD, mean difference, *p < 0.05, KEPT= knee extensor peak torque, ROM= range of motion.

DISCUSSION

This study explored the influence of hip joint angle, knee angle, and angular velocity on quadriceps peak torque during concentric knee extension. Results support all study hypotheses, showing significant variation in torque based on these biomechanical variables.

I. Effect of hip joint angle on concentric knee extension Peak torque

Knee extensor peak torque was significantly higher in the flexed hip position (90°) than in the extended (0°) position at both angular velocities, supporting Hypothesis I. This is explained by the length-tension relationship, where the rectus femoris (RF) operate at an optimal sarcomere length in the flexed hip (sitting) position, enhancing cross-bridge formation and torque generation. This aligns with findings by Herzog et al. [(15)] who found that the Rectus Femoris (RF)'s capacity for generating force based on its length is greater in the sitting position (flexed hip position) compared to the supine position (extended hip position) among health adults

II. Effect of the change of the velocity on the concentric knee extensor peak

Across all knee angles, torque was greater at 60°/s than at 180°/s, regardless of hip position, confirming Hypothesis II. This supports the force-velocity relationship, where increased velocity reduces muscle force due to less action-myosin binding [(16, 18, 19)]. The importance of fast-twitch (FT) fibers in high-speed contractions was also noted [(16)].

III. Effect of knee angle on concentric knee extension peak torque

Torque increased significantly from 30° to 70°, then declined at 90°, consistent across hip positions and speeds. This pattern reflects the force-length relationship of RF, where 70° corresponds to optimal overlap of contractile filaments [(15)]. Beyond 70°, muscle over-lengthening reduces torque output.

IV. Effect of hip joint angle, angular velocity, and knee angle's variation on knee extension peak torque

At 60°/s, the sitting position showed higher torque at all knee angles except 70°, where no significant difference between sitting and supine was observed. At 180°/s, no significant differences in torque were found across hip positions. This supports Herzog's [(15)] model: RF operates on the ascending limb in hip flexion and descending limb in extension. At 70°, the RF may be at an optimal functional length, making hip position less influential. Additionally, torque, knee angle, and velocity interact mechanically: as knee angle increases, velocity decreases, requiring more torque to move the joint [(17, 18, 19)].

Implications for Practice and Future Research

Findings emphasize that knee angle, speed, and hip position all affect torque generation [(20–22)]. In rehabilitation, starting at lower velocities and moderate angles (30°–70°) may enhance strength gains [(23, 24)]. As supine position reduces torque, this should be considered in training and evaluation [(17)]. Despite promising insights, more research is needed to clarify the biomechanical complexities of joint torque production.

LIMITATION

One potential limitation of the study was that it did not estimate the individual contributions of each muscle to the total quadriceps muscle force, nor did it calculate the stiffness of the tendon-aponeurosis complex for each quadriceps muscle component. Due to the lack of these comparisons between the constituents, our values may be useful as a snapshot. Besides, this study was limited to the healthy children, so further research is necessary to determine these properties in clinical populations. However, knowing this information will be valuable for future research to accurately characterize healthy populations and gain a deeper understanding of their unique characteristics.

Another limitation faced was the evaluation measures. Electromyography wasn't implemented to provide electrodiagnostic results. Thus, we recommend that future studies test such findings through electromyography (EMG).

CONCLUSION

The study provides insight into the impact of hip and knee position on the knee extensor peak torque production, which has an important effect on rehabilitation. The relationship between knee angle, velocity, and torque is an important area of study that can modify the development of rehabilitation and exercise programs to improve muscle performance.

Further investigations are required to enhance the current knowledge of the biomechanical processes related to the knee joint and to develop effective interventions for individuals with knee joint injuries including EMG.

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Conflict of Interest

The authors with this declare that they don't have any financial or personal conflicts of interest.

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