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Evaluation of Potential Risk Factors for Osgood-Schlatter Disease

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Abstract

Osgood Schlatter Disease (OSD) is a condition of inflammation of the patellar tendon and tibial tuberosity that can lead to pain and discomfort. It is most common in adolescents aged 8-15 years who are physically active or participate in sports. Adolescents participating in sports and going through puberty struggle to handle the load put on their lower body. The few studies that have determined OSD risk factors have performed retrospective studies that consist of subjects who have already been diagnosed with OSD. Some of the commonly accepted risk factors are overuse, performing movements such as jumping or cutting, and an improper balance of strength and flexibility of the hamstring and quadriceps muscles. The quadriceps and hamstring muscles work in tandem to flex and extend the knee, which places stress on the patellar tendon. This study aims to evaluate the stress that certain soccer related movements place on the patellar tendon of children between ages 7 and 12 years old and if flexibility and muscle strength impacts that stress. Investigating how patellar tendon load is affected by certain soccer related movements and the flexibility and strength of the quadriceps and hamstrings will help to determine risk factors. Determining certain risk factors will inform pre-adolescents and adolescents of specific physical activity related precautions.

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Introduction

OSD Prevalence and Introduction

Osgood-Schlatter Disease (OSD) is an apophysitis occurring at the tibial tuberosity in adolescents (ages 8-15 years) that causes pain and discomfort in the knee. It affects approximately 10% of adolescents and is more common in children who are more physically active (Guldhammer et al. 2019). The knee and the patellar tendon can experience continuous loads of stress during sports participation, such as during soccer, football, volleyball, basketball, etc. This continuous stress could lead to overuse, which can increase the risk of damage to the still developing bone, such as the tibial tuberosity, in youth athletes. Youth athletes that are at the highest risk of sustaining overuse injuries on the knee are those who train year-round for one sport (Hall et al. 2015). If proper precautions, such as rest, stretching, and joint stabilization, are not taken after a diagnosis of OSD, then further and more severe damage can occur, such as avulsion fractures of the tibial tuberosity (Carius and Long, 2021).

Suggested OSD Risk Factors

Prospective research evidencing the exact risk factors of OSD among pre-adolescents is limited. Some of the commonly accepted risk factors based on retrospective research are repetitive movements, more intensive movements (jumping and cutting), and improper form when performing those movements (Halilbasic et al. 2019). One of the commonly proposed risk factors of children who develop OSD is reduced flexibility of the quadriceps muscles (Yanagisawa et al. 2014). The tightening of the quadriceps muscles can lead to increased stress being placed on the patellar tendon, which leads to irritation and swelling of the area of the tibial tuberosity. Another commonly proposed risk factor for OSD is increased muscle strength of the knee extensors and flexors (Nakase et al., 2015). During knee extension and flexion, the patellar tendon can experience repetitive stress from strong pulls of these muscles (Nakase et al. 2015). This form of stress is common in sports such as basketball, volleyball, and soccer that involve frequent jumping and cutting. Repeated stress to the patellar tendon during puberty can lead to morphologic alterations of the patella and patellar tendon and lead to a diagnosis of OSD (Lucena et al. 2011). These studies investigated subjects that were already diagnosed with OSD, which might confuse symptoms and risk factors. This study focused on subjects who have not been diagnosed with OSD or have shown signs or symptoms of OSD. Identifying the effect that muscular strength and flexibility have on patellar tendon loading during similar movements to the ones mentioned previously, e.g., jumping, cutting, and landing, will better differentiate between potential risk factors and symptoms.

Introduction of Directly Estimating Patellar Tendon Load

The stress placed on the patellar tendon causes repeated traction over the tibial tuberosity which leads to inflammation around the knee (Smith and Varacallo. 2017). Determining how much of a load is placed on the patellar tendon during different movements is important in establishing whether hamstring and quadriceps flexibility and strength are risk factors of OSD. However, the force experienced by the patellar tendon is an internal force, so it is difficult to directly measure. Indirectly, the patellar tendon load can be determined by finding the torque generated at the knee joint and diving it by the moment arm of the patellar tendon. Using data from cadavers, moment arm length for the patellar tendon can be estimated based on knee joint angle (Herzog and Read. 1993).

Estimating the force through the patellar tendon might provide better evidence for hamstring and quadriceps flexibility and strength as risk factors for OSD.

This study aimed to identify sports-related movements that lead to an increased risk of developing OSD and how strength and flexibility affect those movements. Based on the data from previous studies, we hypothesized that reduced hamstring and quadriceps flexibility would lead to an increase in the force generated through the patellar tendon and an increased patellar tendon loading rate. We also hypothesized that increased muscle strength of both flexors and extensors would also lead to an increase in the force generated through the patellar tendon and an increased patellar tendon loading rate.

Materials and Methods:

Participants

This study is a cross-sectional study of 12 pre-adolescents ranging from 7 to 12 years old. Only participants who have not been diagnosed with Osgood-Schlatter Disease nor show any of the symptoms and who have yet to reach peak height velocity were included. The tests were performed at the Motion Analysis lab at the University of Dayton with a parent or guardian present. The subjects were instructed on how each test would be conducted.

Table 1: Subject anthropometrics.

Subject	Age	Sex	Height (cm)	Mass (kg)
TD01	9	M	152.7	21.8
TD02	9	F	150	33.6
TD03	7	F	138.2	27.11
TD04	10	F	147.6	45.46
TD05	7	F	124.6	24.46
TD06	11	F	151.5	43.3
TD07	7	F	128.3	32.8

TD08	11	M	164.7	61.16
TD09	11	M	167.5	64.62
TD10	7	F	134.1	27.12
TD11	8	F	135.8	24.64
TD12	10	F	148.3	41.8

Table 2: Subject Strength and Flexibility Results.

Subject	EccExt 60	EccExt 120	ConExt 60	ConExt 120	EccFlex 60	EccFlex 120	ConFlex 60	ConFlex 120	Quad Flex	Ham Flex
TD01	34.6	30.6	27.7	25.4	37.2	40	28.9	29.3	50	74
TD02	72.8	72.3	34.2	28.7	50.2	35.4	69	66	55	85
TD03	25.9	43.4	38.6	29	60.7	53.4	35.4	21.8	64	85
TD04	50.3	54	40.5	27.9	82.4	90.4	50.2	53.7	59	85
TD05	26.8	37	17.2	11.8	39.9	23.3	25.1	29.2	54	79
TD06	68.7	66.9	27	33.2	31.3	46.1	63.2	62	39	76
TD07	18.8	29.2	20.6	24.7	43.7	33.6	22.2	20.2	45	77
TD08	90.3	99.8	90.9	62.2	73.1	91.8	93.6	98.4	56	47
TD09	84.2	100.5	53.4	46.2	74.7	63.1	82.7	100.6	54	55
TD10	38.6	44.6	16.6	27.8	51.3	67.8	36.1	42.4	39	55
TD11	42.2	49.4	43.7	30.1	47.9	45.2	39.2	46.6	45	76
TD12	61	68.9	50.6	52.5	67.4	66.9	47.1	70.4	36	74

Protocols

Subjects wore tight-fitting clothes and were provided with laboratory shoes. All tests were completed on the non-dominant leg, which was determined as the opposite leg from what was used by the subject to kick a soccer ball. Reflective, anatomical markers were placed on the iliac crest, greater trochanter, medial and lateral femoral condyles, medial and lateral tibial plateaus, medial and lateral malleoli, the first and fifth metatarsal head, and the distal aspect of the non-dominant foot. There were also reflective markers placed over the anterior superior iliac spines, the L5-S1 interspinous space, and over the rearfoot.

Subjects were instructed to complete six different soccer related movements. The subjects were instructed about one movement at a time and then were given some time to practice that task. Once the subject felt comfortable about completing the task, they completed five trials of that task. This was repeated for each of the six tasks. The subject was encouraged to take as much rest as necessary in between each rep. The instruction for each movement is listed in Table 3.

Table 3: Task Instructions

Task	Instructions
Standing Vertical Jump	The subject will start by standing with only their non-dominant foot on the force plate. They will then jump straight up in the air and land with only their non-dominant foot on the force plate.
Running Vertical Jump	The subject will take five running steps towards the force plate before performing a vertical jump. The subject will not aim for the force plate. They will go through their natural motion. We will change the starting position to ensure that the subject lands on the force plate.
Soccer Kick	The subject will take five running steps towards the force plate. A soccer ball will be placed to the side of the force. The subject will run up to the soccer ball and kick it into a net that will be set up. The subject will not aim for the force plate. They will kick the soccer ball in the same way that they normally do in practice and games. We will make the necessary adjustments to make sure that the subject lands on the force plate during their kick.
Lateral Cut	The subject will start by standing off to the side of the force plate. They will then step to the side landing only on the foot that started closest to the force plate. They will then immediately push off the force plate and sprint through a designated marker.
Forward Cut	The subject will start by standing behind the force plate. They will then step forward with their non-dominant foot onto the force plate. They will then immediately push off the force plate laterally with their non-dominant leg and sprint through a designated marker.

Running Start	The subject will start by standing behind the force plate. They will then step forward with their non-dominant foot and immediately push off the force plate and sprint forward toward a designated marker.

Both kinematic and kinetic data were collected from the tasks performed by the subjects. To collect kinematic data, the three-dimensional position of the reflective markers placed on the anatomical landmarks were tracked using eight infrared cameras and a motion capture system (Vicon, Oxford, UK). For collecting the kinetic data, ground reaction force was measured under the subject's foot using two floor embedded force plates (Bertec, OH, USA).

Strength and flexibility measurements were taken for the hamstring and quadriceps muscle groups. Strength measurements were taken using a Biodex machine. The Biodex measures muscular strength of the hamstrings and quadriceps by applying constant resistance to the subject's lower leg. The muscle strength was tested isokinetically at an angular velocity of both 60° and 120°/sec from 90° to 0° of flexion of the knee joint. Subjects completed a test trial at 60°/sec to acclimate to the movement and cadence of the Biodex machine before completing 12 trials on the Biodex. The trials consisted of 3 trials of flexion at both 60° and 120°/sec and 3 trials of extension at both 60° and 120°/sec. Each trial consisted of 5 maximal efforts and the subjects were given a minute rest in between each of the trials. Both the flexion and extension trials measured concentric strength, when the subject was pushing with the machine, and eccentric strength, when the subject was pushing against the machine. The use of 60° and 120°/sec isokinetic testing was chosen to provide two separate speeds to measure torque and 180°/sec tests were found to provide inconsistent results for children younger than 10 years old (Wiggin et al. 2006). Flexibility was measured for the quadriceps muscle group using a heel to butt test. In this test, the subject would lay on their stomach on a table and attempt to touch their heel to their butt without using their hands (Sekiguchi et al. 2020). The angle of the subject's knee during the test was measured for three separate trials using a goniometer. Flexibility of the hamstring muscle group was measured using a straight leg raise test. In this test, subjects would lay on their back on a table and raise their non-dominant leg as high in the air as possible without bending their knee (Sekiguchi et al. 2020). The angle of the subject's leg with respect to the table was measured for three separate trials using a goniometer.

Data Analysis

The vertical jump, run jump, forward cut, lateral cut, and run start were evaluated during the period of time when the non-dominant foot was in contact with force plate. For the vertical jump, the trials were evaluated from downward movement of the L5S1 marker until the subject left the force plate. The kick trials were assessed from when the subject's non-dominant foot first made contact with the force plate until the foot left the force plate or when the subject visually ended their kicking motion. An inverse dynamics approach was used to estimate the knee joint moment using Visual 3D software (C-Motion, Boyds, MD, USA). The moment arm of the patellar tendon was determined using data from cadavers (Herzog and Read. 1993). The peak patellar tendon force is calculated by dividing the knee joint moment by the moment arm of the patellar tendon. Patellar tendon loading rate is then calculated by dividing the peak patellar tendon force by the time it takes to reach the peak force. Both of these variables were normalized based on the subject's bodyweight.

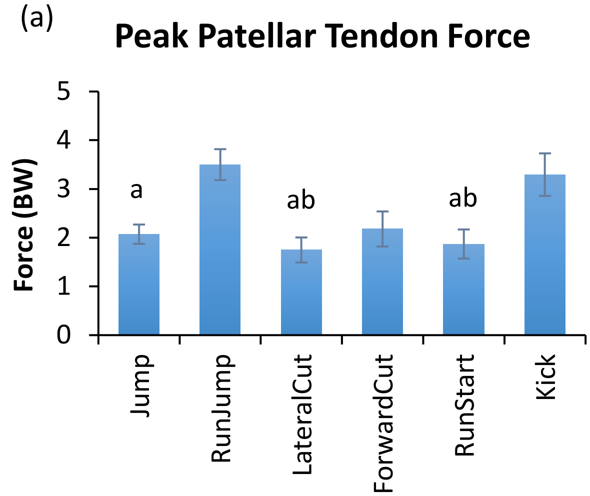
Statistical Analysis

The dependent variables analyzed were peak patellar tendon force and patellar tendon loading rate. We conducted a one-way ANOVA (6 tasks) with repeated measures to compare all six movements, standing vertical jump, running vertical jump, kick, lateral cut, forward cut, and run start. Post-hoc pairwise comparisons with Bonferroni adjustments were completed when appropriate. Three multiple linear regression models were conducted for both the kick and run jump movements to determine if muscle flexibility, extensor muscle strength, and flexor muscle strength were predictors of peak patellar tendon force or patellar tendon loading rate, separately. Statistical analysis was conducted using JASP software (Amsterdam, The Netherlands). Significant differences were set at $\alpha=0.05$.

Results

Peak patellar tendon force was greater for the kick and run jump movements (Fig. 1a). There was a task main effect ($F(5,54)=5.562$, $p<0.001$), where run jump was significantly greater than jump, lateral cut, and run start. In addition, kick was significantly greater than lateral cut and run start. The kick and run jump movements also had the greatest peak patellar tendon loading rate (Fig. 1b). There was a task main effect ($F(5,54)=4.340$, $p=0.002$), where run jump was significantly greater than jump and lateral cut. Meanwhile, kick was significantly greater than jump.

(a)



(b)

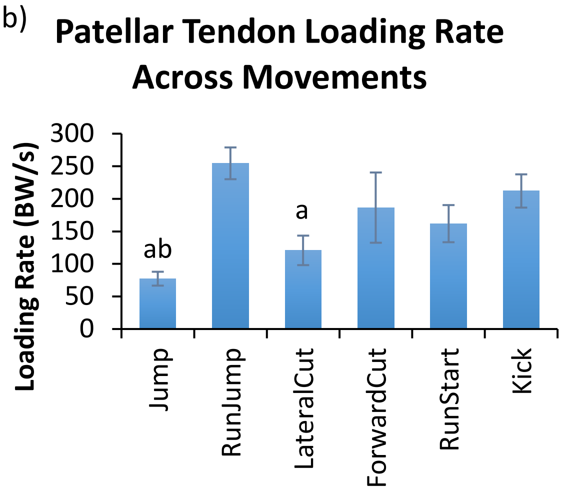


Figure 1: Mean and standard deviation of peak patellar tendon force (a) and patellar tendon loading rate (b). a indicates a statistical difference from run jump and b indicates statistical difference from kick.

Multiple linear regression models of muscle flexibility, extensor muscle strength, and flexor muscle strength did not significantly predict the peak patellar tendon force during the run jump task. Similarly, these models did not significantly predict peak patellar tendon force during the kick task. Multiple linear regression models of muscle flexibility, extensor muscle strength, and flexor muscle strength were also conducted with patellar tendon loading rate for run jump and kick. Only, the multiple linear regression model for extensor muscle strength indicated that as both concentric and eccentric extension strength measurement at 60°/sec increased, so did the patellar tendon loading rate during the run jump task. The model also indicated that as both concentric and eccentric extension strength measurement at 120°/sec increased, then the patellar loading rate decreased during the run jump task. The same models did not significantly predict patellar tendon loading rate during the kick task.

Table 4: Multiple linear regression analyses of peak patellar tendon force for the run jump movement.

	Unstandardized	Standard Error	t	p-value
Peak Force and Flexibility Model				
Intercept	3.911	2.883	1.357	0.217
Quadriceps	-0.016	0.054	-0.302	0.771
Hamstrings Flexibility	0.006	0.028	0.215	0.836
Peak Force and Extensor Strength Model				
Intercept	2.860	1.207	2.369	0.064
Eccentric 60°/s	-0.024	0.066	-0.361	0.7333
Eccentric 120°/s	0.018	0.071	0.259	0.806
Concentric 60°/s	-0.016	0.053	-0.310	0.769
Concentric 120°/s	0.045	0.095	0.468	0.659
Peak Force and Flexor Strength Model				

Intercept	2.621	1.769	1.482	0.199
Eccentric 60°/s	0.016	0.061	0.261	0.805
Eccentric 120°/s	0.003	0.037	0.072	0.946
Concentric 60°/s	0.011	0.071	0.152	0.885
Concentric 120°/s	-0.013	0.059	-0.230	0.827

Table 5: Multiple linear regression analyses of patellar tendon loading rate for the run jump movement.

	Unstandardized	Standard Error	t	p-value
Loading Rate and Flexibility Model				
Intercept	175.400	218.406	0.803	0.448
Quadriceps	2.148	4.091	0.525	0.616
Hamstrings Flexibility	-0.457	2.147	-0.213	0.838
Loading Rate and Extensor Strength Model				
Intercept	269.132	33.712	7.983	< 0.001
Eccentric 60°/s	5.050	1.850	2.730	0.041
Eccentric 120°/s	-7.290	1.977	-3.688	0.014
Concentric 60°/s	6.077	1.471	4.132	0.009
Concentric 120°/s	-2.660	2.656	-1.002	0.362
Loading Rate and Flexor Strength Model				
Intercept	273.113	115.851	2.357	0.065
Eccentric 60°/s	-4.211	4.020	-1.048	0.343

Eccentric 120°/s	3.079	2.402	1.282	0.256
Concentric 60°/s	3.649	4.647	0.785	0.468
Concentric 120°/s	-2.476	3.837	-0.645	0.547

Table 6: Multiple linear regression analyses of peak patellar tendon force for the kick movement

	Unstandardized	Standard Error	t	p-value
Peak Force and Flexibility Model				
Intercept	2.904	3.942	0.737	0.485
Quadriceps	-0.014	0.074	-0.185	0.858
Hamstrings Flexibility	0.015	0.039	0.396	0.704
Peak Force and Extensor Strength Model				
Intercept	2.537	1.557	1.629	0.164
Eccentric 60°/s	-0.059	0.085	-0.696	0.517
Eccentric 120°/s	0.066	0.091	0.721	0.503
Concentric 60°/s	-0.055	0.068	-0.811	0.454
Concentric 120°/s	0.066	0.123	0.535	0.615
Peak Force and Flexor Strength Model				
Intercept	1.392	2.128	0.654	0.542
Eccentric 60°/s	0.098	0.074	1.323	0.243
Eccentric 120°/s	-0.046	0.044	-1.047	0.343
Concentric 60°/s	-0.063	0.085	-0.741	0.492

Concentric 120°/s	0.039	0.071	0.553	0.604

Table 7: Multiple linear regression analyses of patellar tendon loading rate for the kick movement.

	Unstandardized	Standard Error	t	p-value
Loading Rate and Flexibility Model				
Intercept	228.065	232.309	0.982	0.359
Quadriceps	-0.880	4.351	-0.202	0.845
Hamstrings Flexibility	0.415	2.284	0.182	0.861
Loading Rate and Extensor Strength Model				
Intercept	156.967	90.692	1.731	0.144
Eccentric 60°/s	-3193	4.976	-0.642	0.549
Eccentric 120°/s	2.529	5.318	0.475	0.654
Concentric 60°/s	-3.177	3.957	-0.803	0.458
Concentric 120°/s	6.048	7.145	0.846	0.436
Loading Rate and Flexor Strength Model				
Intercept	202.390	137.683	1.470	0.202
Eccentric 60°/s	2.220	4.778	0.465	0.662
Eccentric 120°/s	-2.279	2.855	-0.798	0.461
Concentric 60°/s	0.278	5.523	0.050	0.962
Concentric 120°/s	-0.085	4.561	-0.019	0.986

Discussion:

This study investigated the effects of hamstring and quadriceps strength and flexibility on patellar tendon loading during different soccer-related movements. Our results did not support our hypothesis that patellar tendon force would increase as flexibility decreased and muscle strength increased. Our second hypothesis was partially supported as increased extensor strength during the 60°/sec movement corresponded to a higher patellar tendon loading rate.

Peak patellar tendon force and loading rates were greatest during the kick and run jump movements. The run jump movement is a common movement in most sports while the kick movement is mostly prevalent in soccer. These results support the conclusion from another study that knee extension moment in the support leg is increased during a soccer kick (Watanabe et al., 2018). Soccer players tend to kick with their trunk inclined backward leading to a shift in the center of gravity posteriorly and placing greater force on the support leg (Watanabe et al., 2018).Pre-adolescents should be cautious about how often they are performing these movements due to the potential elevated stress placed on their developing tibial tuberosity.

The multiple linear regression models of muscle flexibility, extensor muscle strength, and flexor muscle strength determined that none of these dependent variables were a significant predictor of peak patellar tendon force in either the kick or run jump movements. A previous study identified that quadriceps muscle tightness was significantly greater in subjects with OSD than in subjects without OSD (Nakase et al., 2015). That study also determined that the quadriceps strength of knee extension was greater in those with OSD than those without OSD. This brings into question whether a decrease in flexibility of the hamstring and quadriceps muscles as well as an increase in muscle strength are risk factors for OSD or occur after the fact as symptoms. Decreased flexibility of the quadriceps muscles could occur in adolescents right before OSD diagnosis due to growth spurts in which tendons and bones grow at different rates. Another possibility for a decrease in flexibility as a result of OSD is the swelling that occurs at the tibial tuberosity. The swelling can cause the patellar tendon to stretch and the quadriceps muscles to tighten. The swelling and discomfort can also lead to decrease in physical activity and subsequently a decrease in flexibility. OSD is more common in adolescents who regularly perform physical activity, which may explain why increased muscle strength is common in patients with OSD. Those adolescents are improving muscle strength due to the increased physical activity.

The multiple linear regression models of extensor muscle strength for patellar tendon loading rate found that it was a significant predictor for loading rate during the run jump movement. The results showed that as the extensor muscle strength increased so did the patellar tendon loading rate, but only during the 60°/sec movement. The previous study that had found that strength of knee extension was higher in subjects with OSD (Nakase et al., 2015) supports these results. For the 120°/sec movement it was the opposite with a higher extensor strength corresponding to a lower patellar tendon loading rate. A previous study determined that peak torque decreases during faster isokinetic testing, which could be the case during this study (Gillen et al., 2020). Subjects who are able to generate larger torques at faster velocities may be better at controlling the forces on their body during dynamic movements, but it is still unclear exactly what caused the negative correlation between extensor strength during the 120°/sec movement and patellar tendon loading rate.

Limitations

A limitation of our study is the use of only soccer players and soccer related movements used to gather data. However, most of the studied movements transfer across other sports. Another limitation of our study is the relatively small sample size. Despite the small sample size, the data comparison across movements demonstrated a large effect size which indicates that the data has practical significance.

Conclusion

The present study suggests that flexibility and muscle strength of the hamstring and quadriceps muscles are not predictive of greater amounts of force experienced by the patellar tendon during dynamic movements. However, patellar tendon loading rate was predicted by extensor muscle strength, with increased strength demonstrating both protective and increased effects dependent on the strength test. Based on these results it is possible that flexibility and flexor strength are symptoms of OSD rather than risk factors.

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