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Kinematic differences among the players/repetitions and between the gender in regard to right (Dominant) Leg lunges exercise for lower extremities with 15 RM load

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Abstract
The aim of this study was to compare among players, repetitions and gender kinematically in regard to dominant leg lunges exercise (DLLE) for lower extremities with fifteen repetitions maximum (15 RM) load. The delimited variables were temporal variables and angle variables of DLLE. The study was conducted on ten subjects (five male and five female), weight of the subject was 68.1±14.98 kilogram and age ranged from 17 to 25 years. Each subject had performed DLLE with 15 RM load for 15 repetition. Data was collected using two dimensional digital video recording systems for 2D analysis (Kinovea 0.8.21). Collected data was computed with mean, standard deviation, coefficient of variance, 't' test and analysis of variance. The selected variables for the study were Maximum Knee Flexion Repetition Wise (MKFR), Maximum Knee Extension Repetition Wise (MKER), Time Taken for Downward Movement Repetition Wise (TTDMR), Time Taken for Upward Movement Repetition Wise (TTUMR) and Total Time Taken Repetition Wise (TTTR). The coefficient of variance (C.V.) that is comparison among the players of each repetitions independently reflected homogeneity in respect to variable namely MKER (C.V. ranged from 6.27% to 7.94% in 15 repetitions) but heterogeneity for the remaining variables namely MKFR (C.V. ranged from 11.53% to 17.31% in 15 repetitions), TTDMR (C.V. ranged from 13.68% to 55.15% in 15 repetitions), TTUMR (C.V. ranged from 18.07% to 37.5%in 15 repetitions), and TTTR (C.V. ranged from 17.24% to 35.81% in 15 repetitions). The comparison between male and female demonstrated significant difference in regard to MKFR ('t' = -4.719), MKER ('t' = -14.156), TTUMR ('t' = -2.386) and no difference in regard to TTDMR ('t' = -1.159) and TTTR ('t' = -1.943). Analysis of variance (i.e. comparison among the repetitions) of DLLE variables namely MKFRM (F=0.103), MKERM (F=0.568), TTDMRM (F=0.781), TTUMRM (F=0.554), TTTRM (F=0.842), MKFRF (F=0.108), MKERF (F=0.239), TTDMRF (F=0.458), TTUMRF (F=0.463) and TTTRF (F=0.358) were statistically insignificant at 0.05 level of significance. From the findings it is concluded that the comparison (C.V.) among the players demonstrated homogeneity in regard to angle variable namely MKER but heterogeneity for variables namely MKFR, TTDMR, TTUMR, and TTTR. There was gender difference in regard to selected angle and temporal variables namely MKFR, MKER and TTUMR and no difference in regard to temporal variables namely TTDMR and TTTR. From the analysis of variance it is concluded that DLLE are consistent for 15 repetitions in regard to all the selected variables.

Keywords: kinematic, lunges exercise, lower extremities, repetition maximum, 15 RM

1. Introduction
Lower extremity acts as base of support in walking, running and jumping. Only concentrating on upper extremity workout is a mistake. In human body the largest and longest muscles are located in lower extremity namely largest muscle is gluteus Maximus and longest muscle is Sartorius. Largest and longest muscles are essential in movements performed in day to day activities and in sports and games. Regular lower extremity exercise increase and develops strength in bones, improves balance, stamina, economy in movement and also decreases the risk of injuries. A strong lower extremity helps to slow the physical weakness that is the part of aging process and maintain stamina, balance and confidence [1].

1.1 Lunges
A lunge can refer to position where, one leg (right/left) is positioned forward with knee flexion and foot flat on the ground while the other leg is positioned behind. Lunges are used by athletes in cross training for sports and games by fitness trainers/ coaches as exercise and by yogis as part of asana regimen [2]. The lunge is a weight training exercise for build and strengthen the quadriceps muscles, glutes muscles and muscles comprising the hamstrings namely biceps femoris, semitendinosus and semimembranosus. It can be performed in several ways by using dumb bells, barbell, cables and even using smith machine [3]. There are numerous studies which included lunges exercise (Wing Kai Lam, [4] *et al*., 2016; Deborah King, [5] 2017; Florian Schellenberg, [6] *et al*., 2015; Rafael F. Escamilla, [7] *et al*., 2017; Matthew Zellmer [8] *et al*., 2017; Maryam Jalali [9] *et al*., 2014; Sanghoon Park [10] *et al*., 2016 and many more). However an analysis or kinematic of DLLE is missing in regard to

differences among the players, repetitions and between the gender.

The main muscles of DLLE with barbell have been illustrated in fig. 1.

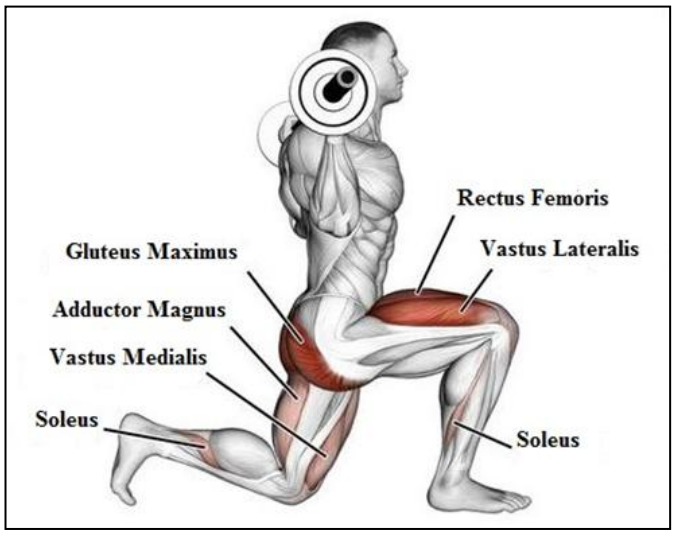

Fig 1: Muscles Involves in Lunges [11].

1.2 Steps to Perform Lunges Exercise (Fig. 2)

Step (1) Athlete, stand up and he is required to put or place barbell on the top of his shoulders behind his neck.

Step (2) He is required to take a wide step forward with dominant leg/ right leg so that, his knee shows flexion and slowly he bring himself back up in initial position after a short time or pause.

Caution: Keep back straight throughout the repetitions.

Fig 2: Dominant Leg Lunges Exercise (DLLE)

1.3 Fifteen Repetition Maximum (15 RM)

In this study, 15 repetition maximum (15 RM) was considered as this type of load develop both strength and endurance, hence appropriate for fitness region for most types of games and sports. 15 RM develops strength, hypertrophy of muscles and muscular endurance specifically power endurance. Importance of power endurance evident in athletes of tennis players, fencers, wrestlers, martial artists, judo, wushu players, 50 meter freestyle swimmers, sprinters, baseball pitchers and so on, these athletes must produce powerful movements and repeat them many times with little or no rest. In order to maintain, the same amount of power thus certain level of power endurance is required for each athlete. Power endurance is typically characterized by intense, repeated efforts for a relatively short period of time that is less than 30 seconds [12].

The results of this study was help primarily in further understanding the world's most renowned lower extremities exercise that is lunges and moreover this study was done on Indian intervarsity players so this will also serve as a foundation for further studies on Indians. The dual objective of this study is to provide kinematic description of dominant leg lunges exercise using temporal and angle variables in regard to individual differences, consistency/inconsistency among the repetitions and gender differences.

2. Methodology

Ten (10) healthy intervarsity sportsperson engaged in different sports were randomly selected as subjects for the study. The inclusion criteria for the study was subjects with age ranged from (17 – 25) years and with at least intervarsity level sports participation as their achievement. The sample consists of five male and five female. The weight of the subjects was 68.1±14.98 kilogram. The exclusion criterion for the subjects was those sportsperson who suffered a knee injury in past or showed symptoms of discomfort in knee during performance of DLLE. The dominant leg of each subject was right leg. Each subject had performed DLLE with 15 RM load for 15 repetition and was recorded with a digital video camera using two dimensional methods independently. Before participating in the study each participant was explained about the proper technique of DLLE to be followed. 15 RM was determined by using trial and error method for each subject independently. The video data was analyzed for selected variables using KINOVEA 0.8.21 software for 2D analysis. The hip joint, knee joint and ankle joint were marked for measuring angles of flexion and extension of knee. Total time taken to perform each repetition was taken in seconds, time for each repetition were recorded in different clocks. Angle of flexion and extension movement of knee joint of each repetition was measured and recorded. The measurements of the selected variable in DLLE namely angle variables and temporal variables have been described in fig. 3.

Fig 3: Measurement of Selected Variables of DLLE.

Table 1: Abbreviations of Selected Variables.

S. No.	Abbreviation	Variables
1.	MKFR (Degree)	Maximum Knee Flexion Repetition Wise
2.	MKER (Degree)	Maximum Knee Extension Repetition Wise
3.	TTDMR (Sec)	Time Taken For Downward Movement Repetition Wise
4.	TTUMR (Sec)	Time Taken For Upward Movement Repetition Wise
5.	TTTR (Sec)	Total Time Taken Repetition Wise

3. Statistical Analysis

For statistical analysis mean, standard deviation, coefficient of variance (in the conducted study the coefficient of variance (C.V.) equal to or more than ten percent considered as heterogeneous otherwise homogeneous), 't' test and one way analysis of variance were computed, hypothesis was tested at 0.05 level of significance.

4. Findings

Table 2: Kinematic Description of DLLE.

		Repetitions				
S. No	**Variables**	**1**	**2**	**3**	**4**	**5**
		m ± sd	**m ± sd**	**m ± sd**	**m ± sd**	**m ± sd**
1	MKFR	91.2±15.79	92.6±10.96	94.1±12.86	94.9±13.23	94.2±12.34
2	MKER	158±12.55	158.9±11.42	162.9±11.98	162.1±12.00	164.7±11.93
3	TTDMR	1.06±0.30	1.01±0.26	0.99±0.28	1.01±0.26	1.03±0.23
4	TTUMR	0.96±0.28	0.84±0.17	0.83±0.15	0.87±0.20	0.87±0.19
5	TTTR	2.02 ±0.48	1.85±0.36	1.81±0.38	1.88±0.41	1.90±0.38
		Repetitions				
S. No	**Variables**	**6**	**7**	**8**	**9**	**10**
		m ± sd	**m ± sd**	**m ± sd**	**m ± sd**	**m ± sd**
1	MKFR	94.5±11.83	96.5±11.88	93.4±10.87	95.6±12.52	95.4±11.70
2	MKER	164.5±11.34	164.3±11.59	161.1±12.65	161.6±12.21	161.9±12.42
3	TTDMR	0.99±0.23	0.99±0.18	1.14±0.26	1.08±0.29	1.08±0.26
4	TTUMR	0.89±0.23	0.84±0.18	0.88±0.19	0.93±0.25	0.93±0.31
5	TTTR	1.88±0.44	1.83±0.32	2.03±0.35	2.01±0.50	2.01±0.49
		Repetitions				
S. No	**Variables**	**11**	**12**	**13**	**14**	**15**
		m ± sd	**m ± sd**	**m ± sd**	**m ± sd**	**m ± sd**
1	MKFR	96.2±12.44	96.9±13.35	95.6±11.02	97.3±11.82	96.3±11.57
2	MKER	160.7±10.08	160.1±12.17	163.5±11.07	161.6±11.87	162.5±11.81
3	TTDMR	1.09±0.32	1.09±0.29	1.06±0.24	1.36±0.75	1.17±0.32
4	TTUMR	0.88±0.21	0.97±0.28	0.98±0.22	0.93±0.24	1.12±0.33
5	TTTR	1.97±0.48	2.06±0.54	2.03±0.44	2.29±0.82	2.29±0.53
S. No	**Variables**		**m**	**sd**	**cv**	
1	MKFR	∑∑	94.98	1.24	1.30	
2	MKER	∑∑	161.89	0.65	0.40	
3	TTDMR	∑∑	1.08	0.13	12.04	
4	TTUMR	∑∑	0.91	0.05	5.49	
5	TTTR	∑∑	1.99	0.12	6.03	

Note: N = 10, MKFR and MKER measurements in degree, TTDMR, TTUMR and TTTR measurements in seconds. MKFR = Maximum Knee Flexion Repetition Wise, MKER = Maximum Knee Extension Repetition Wise, TTDMR = Time Taken For Downward Movement Repetition Wise, TTUMR = Time Taken For Upward Movement Repetition Wise, TTTR = Total Time Taken Repetition Wise sd = Standard Deviation, m = Mean, cv = Coefficient of Variance and ∑∑ = Grand Mean, Standard Deviation and Coefficient of Variance.

According to the findings of table 2, the kinematic description (variables) of DLLE namely MKFR, MKER, TTDMR, TTUMR and TTTR demonstrated and irregular trends following the repetitions. The grand mean and standard deviation of 15 repetitions of the variables namely MKFR reported mean and standard deviation 94.98 ± 1.24 with C.V. 1.30, MKER reported mean and standard deviation 161.89 ± 0.65 with C.V. 0.40, TTDMR reported mean and standard deviation 1.08 ± 0.13 with C.V. 12.04, TTUMR reported mean and standard deviation 0.91 ± 0.05 with C.V. 5.49 and TTTR reported mean and standard deviation 1.99 ± 0.12 with C.V. 6.03 which suggest that repetitions are homogenous in regard to MKFR, MKER, TTUMR and TTTR variables and heterogeneous in regard to TTDMR variable. It has been observed that the C.V. ranged from 0.40 to 12.04, further highest was observed in the variable namely TTDMR followed by TTUMR, TTTR, MKFR, and the least was MKER.

Table 3: Coefficient of Variance (C.V.) of DLLE.

		Repetitions							
S. No	**Variables**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		CV	**CV**	**CV**	**CV**	**CV**	**CV**	**CV**	**CV**
1	MKFR	17.31	11.84	13.67	13.94	13.1	12.52	12.31	11.65
2	MKER	7.94	7.19	7.35	7.4	7.24	6.89	7.05	7.85
3	TTDMR	28.3	26	28.28	26	22.33	23.23	18.18	22.81
4	TTUMR	29.17	20.24	18.07	22.99	21.84	25.84	37.5	21.59
5	TTTR	23.76	19.46	20.99	21.81	20	23.4	17.49	17.24
		Repetitions							
S. No	**Variables**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
		CV	**CV**	**CV**	**CV**	**CV**	**CV**	**CV**	
1	MKFR	13.1	12.26	12.93	13.78	11.53	12.15	12.01	
2	MKER	7.56	7.67	6.27	7.6	6.77	7.35	7.27	
3	TTDMR	26.85	24.07	29.36	26.61	22.64	55.15	13.68	
4	TTUMR	26.88	33.33	23.86	28.87	22.45	25.81	29.46	
5	TTTR	24.88	24.38	24.37	26.21	21.67	35.81	23.14	

Note: N = 10, MKFR, MKER, TTDMR, TTUMR and TTTR measurements in percentage. MKFR = Maximum Knee Flexion Repetition Wise, MKER = Maximum Knee Extension Repetition Wise, TTDMR = Time Taken For Downward Movement Repetition Wise, TTUMR = Time Taken For Upward Movement Repetition Wise, TTTR = Total Time Taken Repetition Wise, CV = Coefficient of Variance.

According to the finding of table 3, the Coefficient of Variance of DLLE selected angle and temporal variables namely MKFR, MKER, TTDMR, TTUMR and TTTR demonstrated and irregular trends following the repetitions. It has been observed that in the variable namely MKFR the C.V. ranged from (11.53% to 17.31%), MKER the C.V. ranged from (6.27% to 7.94%), TTDMR the C.V. ranged from (13.68% to 55.15%), TTUMR the C.V. ranged from (18.07% to 37.5%) and TTTR the C.V. ranged from (17.24% to 35.81%). It is concluded that the comparison (C.V.) among the players demonstrated homogeneity in regard to angle variable namely MKER but heterogeneity for the remaining angle and temporal variables namely MKFR, TTDMR, TTUMR, and TTTR. The distributions of coefficient of variance of selected variables of DLLE have been shows in fig. 4.

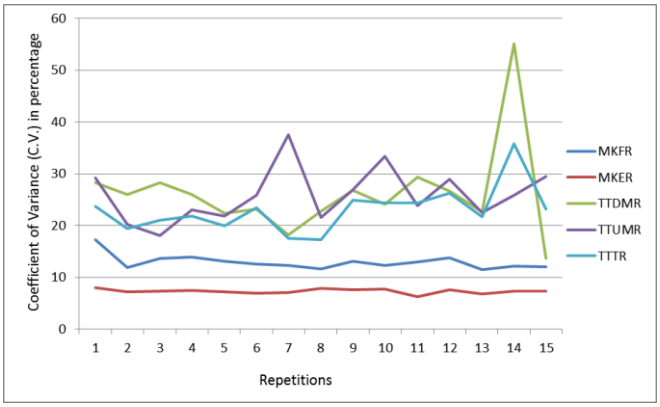

Fig 4: Line Diagram of Percentage Distribution of Coefficient of Variance of Selected Variables of DLLE.

Table 4: Descriptive Statistics of Selected Variables of DLLE of Male and Female Sportsperson

S. No.	Variable	Gender	N	Mean	Std. Deviation	Std. Error Mean
1	MKFR	Male	75	90.7067	9.50217	1.09722
		Female	75	99.2533	12.47927	1.44098
2	MKER	Male	75	153.4000	6.83789	.78957
		Female	75	170.6667	8.05108	.92966
3	TTDMR	Male	75	1.0549	.37885	.04375
		Female	75	1.1189	.29200	.03372
4	TTUMR	Male	75	.8775	.20861	.02409
		Female	75	.9680	.25385	.02931
5	TTTR	Male	75	1.9324	.47787	.05518
		Female	75	2.0869	.49626	.05730

N=75 (Male = 5, Female = 5), Repetitions = 15.

In the table 4, the mean and standard deviation in regard to selected angle and temporal variables namely MKFR, MKER, TTDMR, TTUMR and TTTR have been documented.

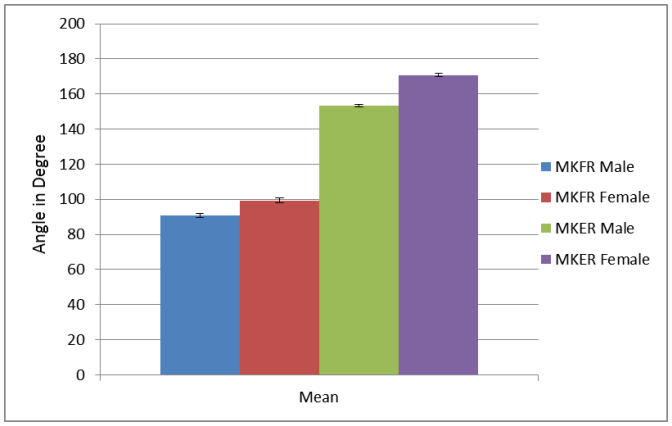

Fig 5: Comparison between Male and Female Sportsperson in regard to Means of MKFR and MKER of DLLE.

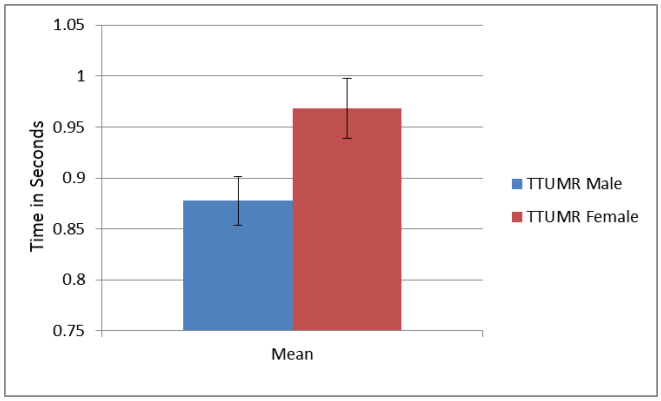

Fig 6: Comparison between Male and Female Sportsperson in regard to Means of TTUMR of DLLE.

Table 5: Comparison Among the Selected Variables of DLLE between Male and Female Sportspersons (Independent samples test)

Varibles		Levene's Test for Equality of Variances		t-Test for Equality of Means	
		F	Sig.	t	df
MKFR	Equal variance assumed	20.745	.000	-4.719	148
	Equal variances not assumed			-4.719*	138.220
MKER	Equal variances assumed	4.785	.030	-14.156	148
	Equal variances not assumed			-14.156*	144.220
TTDMR	Equal variances assumed	.721	.397	-1.159 (NS)	148
	Equal variances not assumed			-1.159	138.988
TTUMR	Equal variances assumed	4.036	.046	-2.386	148
	Equal variances not assumed			-2.386*	142.644
TTTR	Equal variances assumed	.438	.509	-1.943 (NS)	148
	Equal variances not assumed			-1.943	147.790

N=75 (Male = 5, Female = 5), Repetitions = 15, NS = Not significant and *= Significant at 0.05 level of significance

According to table 5, the selected variable namely MKFR (t = -4.719), MKER (t = -14.156) and TTUMR (t = -2.386) have been found to be statistically different at 0.05 level whereas the remaining temporal variables namely TTDMR (t = -1.159), and TTTR (t = -1.943) found to be statistically not different at 0.05 level of significance. The findings have been graphically illustrated vide fig. number 5 and 6 in regard to significant variable namely MKFR, MKER and TTUMR.

Table 6: Analysis of Variance among the Repetitions of DLLE.

Variables		Sum of Squares	df	Mean Square	F	Sig
MKFRM	Between Groups	156.747	14	11.196	.103(NS)	1.000
	Within Groups	6524.800	60	108.747		
	Total	6681.547	74			
MKERM	Between Groups	405.200	14	28.943	.568(NS)	.879
	Within Groups	3054.800	60	50.913		
	Total	3460.000	74			
TTDMRM	Between Groups	1.637	14	.117	.781(NS)	.685
	Within Groups	8.984	60	.150		
	Total	10.621	74			
TTUMRM	Between Groups	.368	14	.026	.554(NS)	.890
	Within Groups	2.852	60	.048		
	Total	3.220	74			
TTTRM	Between Groups	2.775	14	.198	.842(NS)	.622
	Within Groups	14.124	60	.235		
	Total	16.899	74			
MKFRF	Between Groups	283.387	14	20.242	.108(NS)	1.000
	Within Groups	11240.800	60	187.347		
	Total	11524.187	74			
MKERF	Between Groups	253.467	14	18.105	.239(NS)	.998
	Within Groups	4543.200	60	75.720		
	Total	4796.667	74			
TTDMRF	Between Groups	.609	14	.043	.458(NS)	.946

	Within Groups	5.701	60	.095		
	Total	6.310	74			
TTUMRF	Between Groups	.465	14	.033	.463(NS)	.944
	Within Groups	4.304	60	.072		
	Total	4.768	74			
TTTRF	Between Groups	1.403	14	.100	.358(NS)	.982
	Within Groups	16.821	60	.280		
	Total	18.224	74			

Note: N = 10, MKFRM/F = Maximum Knee Flexion Repetition Wise Male/Female, MKERM/F = Maximum Knee Extension Repetition Wise Male/Female, TTDMRM/F = Time Taken For Downward Movement Repetition Wise Male/Female, TTUMRM/F = Time Taken For Upward Movement Repetition Wise Male/Female, TTTRM/F = Total Time Taken Repetition Wise Male/Female. MKFRM, MKERM, MKFRF and MKERF measurements in degree, TTDMRM, TTUMRM, TTTRM, TTDMRF, TTUMRF and TTTRF measurements in seconds, NS = Not significant at 0.05 level.

From the analysis of table 3, it was found that selected variables of DLLE are insignificant at 0.05 level, while compared among the repetitions.

5. Conclusions

- The comparisons among the players of each repetition demonstrated heterogeneity in regard to angle and temporal variables namely maximum knee flexion repetition wise (MKFR), time taken for downward movement repetition wise (TTDMR), time taken for upward movement repetition wise (TTUMR) and total time taken repetition wise (TTTR) of DLLE.
- The comparison among the players of each repetition demonstrated homogeneity in the angle variable namely maximum knee extension repetition wise (MKER) of DLLE.
- The Comparison between male and female sportspersons reveals significant difference in regard to angle and temporal variable namely MKFR, MKER and TTUMR of DLLE.
- The Comparison between male and female sportspersons reveals insignificant difference in regard to temporal variables namely TTDMR and TTTR of DLLE.
- The comparisons among the repetitions reveals insignificant difference (i.e. movement constancy) in regard to variables namely MKFR, MKER, TTUMR, TTDMR, and TTTR of DLLE.

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