International Journal of Academic Research and Development
ISSN: 2455-4197
Impact Factor: RJIF 5.22
www.academicsjournal.com
Volume 3; Issue 1; January 2018; Page No. 167-173

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

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Abstract
Aim of the study, was to compare among players, repetitions, and gender kinematically the subordinate leg lunges exercise (SLLE) for lower extremities with fifteen repetitions maximum (15 RM) load. The delimited variables were angle and temporal variables of SLLE. 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 SLLE 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. 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 5.23% to 7.63% in 15 repetitions) but heterogeneity for the remaining variables namely MKFR (C.V. ranged from 11.11% to 16.07% in 15 repetitions), TTDMR (C.V. ranged from 18.95% to 39.67% in 15 repetitions), TTUMR (C.V. ranged from 13.25% to 28.26% in 15 repetitions) and TTTR (C.V. ranged from 15.34% to 27.8% in 15 repetitions).). Comparison between male, and female demonstrated significant differences in regards to MKFR ('t' = -5.706), MKER ('t' = -11.102), TTUMR ('t' = -0.659), TTTR ('t' = -4.630) and no difference in regard to TTDMR ('t' = -0.071). Analysis of variance (i.e. comparison among the repetitions) of SLLE variables namely MKFRM (F=0.045), MKERM (F=0.113), TTDMRM (F=0.487), TTUMRM (F=0.705), TTTRM (F=0.594), MKFRF (F=0.294), MKERF (F=0.511), TTDMRF (F=0.605), TTUMRF (F=0.263) and TTTRF (F=0.165) 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 the remaining angle and temporal variables namely MKFR, TTDMR, TTUMR and TTTR. There was gender difference in regard to angle and temporal variables namely MKFR, MKER, TTUMR, TTTR and no difference in regard to temporal variable namely TTDMR. From the analysis of variance it is concluded that SLLE are consistent for 15 repetitions in regard to all the selected variables.

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

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 Left Leg Lunges
A left leg lunge can refer to position where left leg is placed forward with slightly knee flexion and foot flat on the floor while the right leg is placed behind and only toe placed on the floor. Lunges are used by sportspersons in their fitness training programme by fitness trainers/ coaches as a strengthen exercise and by yogis, as the part of an asana [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

SLLE is missing in regard to differences among the players, repetitions and between the gender.
The main muscles of SLLE with barbell have been illustrated in fig. 1

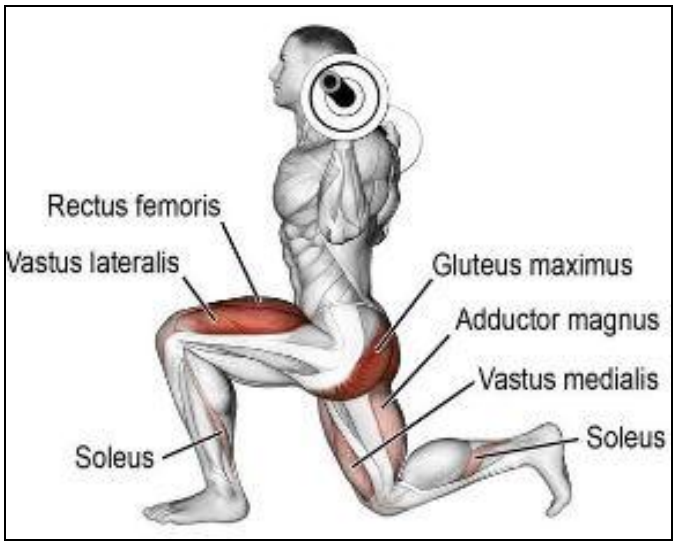

Fig 1: Muscles Involves in Lunges [11].

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

Caution: Keep back straight throughout the repetitions.

Fig 2: Subordinate Leg Lunges Exercise (SLLE)

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 in muscles and muscular endurance specifically power endurance. Importance of power endurance evident in athletes of tennis players, fencers, wrestlers, wushu players, taekwondo players, martial artists, judo players, 50 meters freestyle swimmers, sprinters, baseball pitchers and so on, these athletes must produce forceful movements with speed and rerun them again and again with no or very little pause. In order to carry on or maintain the same amount of speed with strength for that, certain level of power endurance is needed for each athlete. Power endurance, is generally characterized by the repetitions and intensity for a relatively short time period that is less than thirty 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 Subordinate 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 sample or subject for this study. The inclusion criteria for this study was sample with age ranged from 17 to 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 SLLE. The Subordinate leg of each subject was left leg. Each subject had performed SLLE 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 SLLE to be followed. 15 RM was determined by using trial and error method for each subject independently. The video data was analysed for selected variables using KINOVEA 0.8.21 software for 2D analysis. Ankle joint, knee joint and hip join were marked for measuring angles of extension and flexion of knee joint. 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 SLLE namely angle variables and temporal variables have been described in fig. 3.

Fig 3: Measurement of Selected Variables of SLLE.

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 ANOVA were computed, hypothesis was tested at 0.05 level of significance.

4. Findings

Table 2: Kinematic Description of SLLE.

		Repetitions				
S. No	**Variables**	**1**	**2**	**3**	**4**	**5**
		M±SD	M±SD	M±SD	M±SD	M±SD
1	MKFR	92.1±14.80	94.3±12.75	93.8±11.95	95.8±12.79	95.3±11.45
2	MKER	159.3±10.91	163.2±8.53	162±10.01	164.1±10.98	163.4±10.12
3	TTDMR	0.98±0.22	0.95±0.18	1.01±0.26	0.99±0.23	0.99±0.24
4	TTUMR	0.85±0.17	0.81±0.11	0.83±0.11	0.91±0.17	0.89±0.17
5	TTTR	1.83±0.33	1.76±0.27	1.84±0.35	1.9±0.37	1.88±0.35
		Repetitions				
S. No	Variables	6	7	8	9	10
		M±SD	M±SD	M±SD	M±SD	M±SD
1	MKFR	96±12.17	97.4±12.33	96.2±11.11	97.4±13.17	98.5±11.26
2	MKER	162.8±10.12	164±10.20	161.3±10.12	161.9±11.26	161.1±9.06
3	TTDMR	102±0.33	0.99±0.23	1.06±0.25	1.09±0.25	1.07±0.33
4	TTUMR	0.88±0.15	1.91±0.16	0.87±0.18	0.91±0.19	1.92±0.26
5	TTTR	1.90±0.41	1.90±0.36	1.94±0.38	2.01±0.40	1.99±0.53
		Repetitions				
S. No	Variables	11	12	13	14	15
		M±SD	M±SD	M±SD	M±SD	M±SD
1	MKFR	96.8±11.43	97.5±12.74	97.3±12.05	97.6±11.03	97.1±11.43
2	MKER	161.8±8.87	163.6±11.50	163±10.54	161.8±10.75	164.3±12.53
3	TTDMR	1.17±0.33	1.15±0.39	1.14±0.35	1.26±0.48	1.21±0.48
4	TTUMR	0.92±0.18	0.91±0.25	0.93±0.19	0.96±0.16	1.05±1.27
5	TTTR	2.09±0.49	2.05±0.57	2.07±0.44	2.22±0.59	2.26±0.53
S. No	Variables		M	S.D	C.V	
1	MKFR	∑∑	96.21	1.00	1.04	
2	MKER	∑∑	162.51	1.04	0.64	
3	TTDMR	∑∑	1.07	0.09	8.41	
4	TTUMR	∑∑	0.90	0.04	4.44	
5	TTTR	∑∑	1.98	0.09	4.55	

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 S.D. = Standard Deviation, M = Mean, C.V. = Coefficient of Variance and ∑∑ = Grand Mean, standard Deviation and Coefficient of Variance.

According to the findings of table 2, the kinematic description (variables) of SLLE 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 96.21 ± 1.00 with C.V. 1.04, MKER reported mean and standard deviation 162.51 ± 1.04 with C.V. 0.64, TTDMR reported mean and standard deviation 1.07 ± 0.09 with C.V. 8.41, TTUMR reported mean and standard deviation 0.90 ± 0.04 with C.V. 4.44 and TTTR reported mean and standard deviation 1.98 ± 0.09 with C.V. 4.55 which suggest that repetitions are homogenous in regard to MKFR, MKER, TTDMR, TTUMR and TTTR variables. It has been observed that the C.V. ranged from 0.64 to 8.41, further highest was observed in the variable namely TTDMR followed by TTTR, TTUMR, MKFR, and the least was MKER.

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

		Repetitions							
S. No	**Variable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		C.V.	C.V.	C.V.	C.V.	C.V.	C.V.	C.V.	C.V.
1	MKFR	16.07	13.52	12.74	13.35	12.01	12.17	12.33	11.11
2	MKER	6.85	5.23	6.18	6.68	6.19	6.22	6.22	6.27
3	TTDMR	22.45	18.95	26	23.23	24.24	32.35	23.23	23.58
4	TTUMR	20	13.58	13.25	18.68	19.1	17.05	17.58	20.69
5	TTTR	18.03	15.34	19.02	19.47	18.62	21.58	18.95	19.59
		Repetitions							
S. No	Variable	9	10	11	12	13	14	15	
		C.V.	C.V.	C.V.	C.V.	C.V.	C.V.	C.V.	
1	MKFR	13.17	11.26	11.81	13.07	12.38	11.3	11.77	
2	MKER	6.98	5.6	5.48	7.03	6.47	6.64	7.63	
3	TTDMR	22.94	30.84	28.21	33.91	30.7	38.1	39.67	
4	TTUMR	20.88	28.26	19.57	27.47	20.43	16.67	18	
5	TTTR	19.9	26.63	23.44	27.8	21.26	26.58	23.45	

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, C.V. = Coefficient of Variance.

According to the finding of table 3, the Coefficient of Variance of SLLE 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 (11.11% to 16.07%), MKER the C.V. ranged from (5.23% to 7.63%), TTDMR the C.V. ranged from (18.95% to 39.67%), TTUMR the C.V. ranged from (13.25% to 28.26%) and TTTR the C.V. ranged from (15.34% to 27.8%). 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 SLLE have been shows in fig. 4.

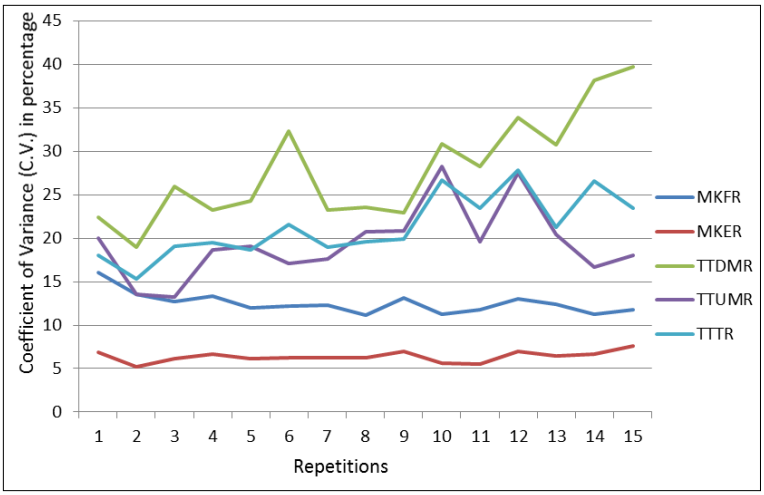

Fig 4: Line Diagram of Percentage Distribution of Coefficient of Variance of Selected Variables of SLLE.

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

S. No.	Variable	Gender	N	Mean	Std. Deviation	Std. Error Mean
1	MKFR	Male	75	91.2400	8.59264	.99219
		Female	75	101.1733	12.38828	1.43048
2	MKER	Male	75	155.8133	8.58927	.99180
		Female	75	169.2133	5.95772	.68794
3	TTDMR	Male	75	1.0817	.33718	.03893
		Female	75	1.0856	.32696	.03775
4	TTUMR	Male	75	1.4827	.54947	.06345
		Female	75	1.5512	.71420	.08247
5	TTTR	Male	75	2.2852	.63902	.07379
		Female	75	2.9923	1.15795	.13371

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

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

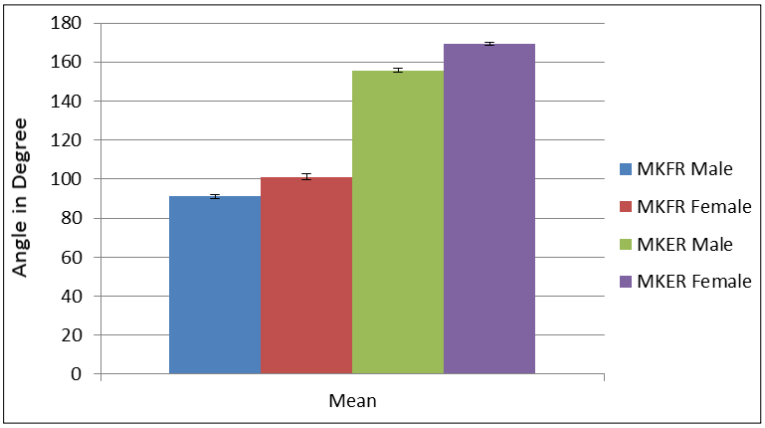

Fig 5: Comparison Between Male and Female Sportsperson in regard to Means of MKFR and MKER of SLLE.

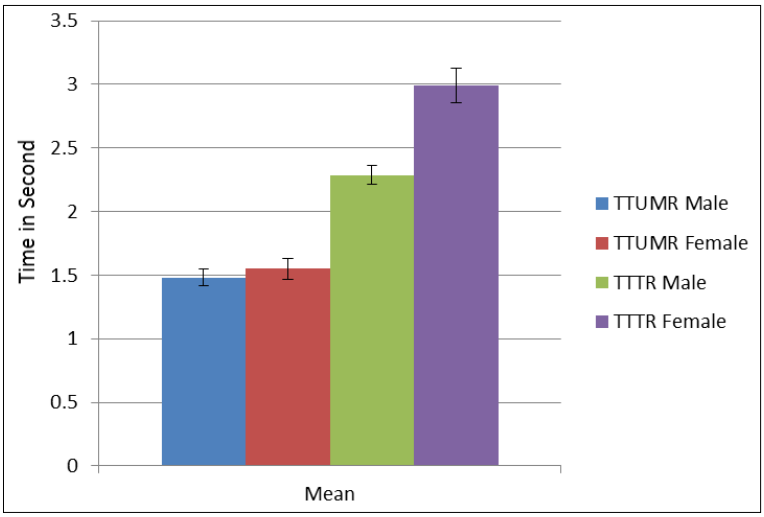

Fig 6: Comparison Between Male and Female Sportsperson in regard to Means of TTUMR and TTTR of SLLE.

Table 5: Comparison Among the Selected Variables of SLLE Between Male and Female Sportspersons (Independent Samples Test)

Variables		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
MKFR	Equal variances assumed	23.322	.000	-5.706	148
	Equal variances not assumed			-5.706*	131.820
MKER	Equal variances assumed	7.898	.006	-11.102	148
	Equal variances not assumed			-11.102*	131.821
TTDMR	Equal variances assumed	1.424	.235	-.071(NS)	148
	Equal variances not assumed			-.071	147.860
TTUMR	Equal variances assumed	3.943	.049	-.659	148
	Equal variances not assumed			-.659*	138.873
TTTR	Equal variances assumed	18.874	.000	-4.630	148
	Equal variances not assumed			-4.630*	115.247

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 = -5.706), MKER (t = -11.102), TTUMR (t = -0.659) and TTTR (t = -4.630) have been found to be statistically different at 0.05 level whereas the remaining temporal variable namely TTDMR (t = -0.071) 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, TTUMR and TTTR.

Table 6: Analysis of variance among the repetitions of SLLE.

Variables		Sum of Squares	df	Mean Square	F	Sig.
MKFRM	Between Groups	57.280	14	4.091	.045(NS)	1.000
	Within Groups	5406.400	60	90.107		
	Total	5463.680	74			
MKERM	Between Groups	139.787	14	9.985	.113(NS)	1.000
	Within Groups	5319.600	60	88.660		
	Total	5459.387	74			
TTDMRM	Between Groups	.858	14	.061	.487(NS)	.931
	Within Groups	7.555	60	.126		
	Total	8.413	74			
TTUMRM	Between Groups	3.158	14	.226	.705(NS)	.760
	Within Groups	19.184	60	.320		
	Total	22.342	74			
TTTRM	Between Groups	3.679	14	.263	.594(NS)	.859
	Within Groups	26.539	60	.442		
	Total	30.218	74			
MKFRF	Between Groups	729.147	14	52.082	.294(NS)	.993
	Within Groups	10627.600	60	177.127		
	Total	11356.747	74			
MKERF	Between Groups	279.787	14	19.985	.511(NS)	.918
	Within Groups	2346.800	60	39.113		
	Total	2626.587	74			
TTDMRF	Between Groups	.978	14	.070	.605(NS)	.851
	Within Groups	6.933	60	.116		
	Total	7.911	74			
TTUMRF	Between Groups	2.181	14	.156	.263(NS)	.996
	Within Groups	35.566	60	.593		
	Total	37.746	74			
TTTRF	Between Groups	3.674	14	.262	.165(NS)	1.000
	Within Groups	95.549	60	1.592		
	Total	99.223	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 of significance.

From the analysis of table 3, it was found that selected variables of SLLE 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 SLLE.
- The comparison among the players of each repetition demonstrated homogeneity in the angle variable namely maximum knee extension repetition wise (MKER) of SLLE.
- The Comparison between male and female sportspersons reveals significant difference in regard to angle and temporal variable namely MKFR, MKER, TTUMR and TTTR of SLLE.
- The Comparison between male and female sportspersons reveal insignificant difference in regard to temporal variable namely TTDMR of SLLE.
- The comparison among the repetitions reveals insignificant difference (i.e. movement constancy) in regard to variables namely MKFR, MKER, TTUMR, TTDMR, and TTTR of SLLE.

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