Biomechanical analysis of knee joint kinematics at different Gait speed of school going children

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Abstract -The main objective of this study was to describe the Biomechanical analysis of knee joint kinematics at three different walking speed of school going children. A total of 45 (forty five) male school-going children participated in this study. The ages of the participants were between 16-18 years. The data analysis included descriptive statistics, one-way analysis of variance (ANOVA), and post-hoc comparisons. The results of the study showed significant mean differences in Knee Flexion Loading Response, Knee Extension Terminal Stance, Knee Flexion Swing and Knee Extension Terminal Swing among slow, normal, and fast walking gait. The findings suggest that gait patterns are influenced by walking speed and highlight the importance of considering speed variations when assessing hip joint kinematics.

Keywords: Gait; Knee Flexion Swing; Speed variation of gait pattern; gait pattern of school-going children

INTRODUCTION

Human walking is an extremely complex biomechanical process. A large number of investigations have been carried out in the field of human walking (Elftman H 1939 and Alexsander R McN 1995). Because walking speed is known to affect kinematics, kinetics, spatiotemporal parameters and muscular activity (Schwartz et.al 2008).

Walking is the most popular form of prescribed exercise in special populations including obese individuals (Browning & Kram, 2007). Level walking gait consists of a continuous cycle of falling out of balance and regaining balance resulting in limb advancement (Deforche et al., 2009). There are two basic requirements of effective gait; to be able to support the body during movement, and to maintain balance to prevent falling (Sparrow & Tirosh, 2005). Adequate balance is a requirement to avoid falling for many 3 functional activities such as over ground walking, sitting and standing from a chair, and walking up and down stairs. However, obese individuals may be at a greater risk of falling due to impaired balance which likely limits activities such as treadmill or over ground walking. In an obese population, it is typical to see temporal modifications to gait. In 2008, Lai and colleagues, documented that obese adults typically walk with a shorter step length and an increased step width than their healthy weight counterparts, which caused a slower self-selected walking speed (Lai, Leung, Li, & Zhang, 2008). Browning et al. (2007), also concluded that obese adults walked at a slower self-selected speed (Browning & Kram, 2007; Browning et al., 2007). These adaptations are modifications to help increase double support time which directly improve balance. Browning et al. (2007), postulated that slower walking speeds may also potentially decrease ground reaction forces and knee moments when walking (Browning et al., 2007).

Kinematic factors

Kinematic factors are important because they reveal the significant effect of obesity on walking mechanics. During walking, obese adults have a more extended knee during early stance along with a greater pelvic obliquity during late stance (Lerner et al., 2014)

Kinetics

Kinetic factors are important because they reveal the significant effect of obesity walking. During walking, obese adults have a greater pelvic obliquity during late stance (Lai et al., 2008; Lerner et al., 2014), as well as increasing torque at the knee joint (Gilleard et al., 2008; Sibella et al., 2003). Leading ligament looseness and muscle strength reduction in ankle joints have been related to excess body weight. Excess body weight is also usually distinguished through lower strength (Hulens et al., 2001)

Stance time

Stance time is the period that passes during one extremity's stance phase during a gait cycle.

Single-support time

The amount of time that passes during a gait cycle with only one limb touching the ground is known as single-support time.

Double-support time

The duration of one gait cycle spent with both feet on the ground is known as the double-support time. For older adults and those with balance problems, double assistance may be required for longer. As the walking pace rises, the rate of time paid in double support drops.

METHODOLOGY

Forty (45) male school-going children (06 Overweight, 26 average weight, and 13 underweight) were randomly selected for the study from secondary schools in the Poonch district of Jammu and Kashmir, India. To maintain homogeneity, only 16–18-year-old students were selected. The entire group of students chosen readily agreed and volunteered to act as subjects for the study.

Filming procedure

The data collection recording was conducted in sunny and clear weather on the playing ground of the concerned school. All the subjects were instructed to wear specified tight sports shorts to perform 05 meters of walking with a straight stride per the study's specifications. The researcher demonstrated different gait patterns with a proper explanation at three different speeds on the walking platform. Out of the three trials, the researcher chose the best trial for further study. For all participants, a wand with a height of 1.20 meters was employed as the calibration. Specific video fields were identified for the film analysis.

SPSS version 20.0 for Windows XP, statistical software for social sciences, was used to analyze the data. The data were analyzed using one-way ANOVA, post-hoc, statistical tests to see whether there were any differences. The center of mass, dispersion of scores, and normality of data in each group were also assessed using descriptive statistics such as mean, SD, and Z scores. 0.05 was used as the significant factor.

RESULTS AND DISCUSSION

Table 1. Description of the subjects

For this study, 45 school-age children were recruited as the subjects.

Table 1.Demographic information of the subjects

Subjects	No.	Age (y)		Weight (Kg.)		Height (cm)	
		Mean	S.D	Mean	S.D	Mean	S.D
	45	17.24	0.73	60.74	6.56	173.02	7.06

Table: 2. Descriptive statistics of knee joint kinematics at slow walking gait.

Subjects	No.	Mean	Descriptive						
			S.D	Skewness	Std. Error	z-score	Kurtosis	Std. Error	z-score
Knee Flexion Loading Response (º)	45	12.77	1.52	-0.12	0.35	-0.34	-1.25	0.69	-2.20
Knee Extension Terminal Stance(º)	45	4.40	0.83	0.36	0.35	1.03	-1.10	0.69	-1.59
Knee Flexion Swing(º)	45	70.47	5.58	0.28	0.35	0.80	-1.10	0.69	-1.59
Knee Extension Terminal Swing(º)	45	5.58	0.23	-0.04	0.35	-0.11	-1.00	0.69	-1.45
Knee Flexion Loading Response (º/s)	45	72.41	4.79	0.03	0.35	0.08	-1.20	0.69	-1.74
Knee Extension Terminal Stance º/s)	45	49.18	1.79	-0.20	0.35	-0.57	-0.97	0.69	-1.41
Knee Flexion Swing (º/s)	45	276.42	8.55	-0.00	0.35	0.00	-1.17	0.69	-1.69
Knee Extension Terminal Swing (º/s)	45	276.91	9.01	0.28	0.35	0.80	-0.79	0.69	-1.14

The 97.5 percentile point of the standard normal distribution, or 95% of the area under a normal curve, is approximately comparable to ± 1.96 in statistical analysis. Knee joint kinematics at slow walking gait have a determined Z score that ranges from -1.96 to 1.96, which suggests that the data is normally distributed

Table: 3. Descriptive statistics of knee joint kinematics at normal walking gait.

Subjects	No.	Mean	Descriptive						
			S.D	Skewness	Std. Error	z-score	Kurtosis	Std. Error	z-score
Knee Flexion Loading Response (º)	45	18.54	0.83	0.00	0.35	0.00	-0.91	0.69	-1.32
Knee Extension Terminal Stance (º)	45	5.45	0.81	0.28	0.35	0.8	-0.97	0.69	-1.40
Knee Flexion Swing (º)	45	68.10	3.11	-0.06	0.35	-0.17	-1.20	0.69	-1.74
Knee Extension Terminal Swing (º)	45	4.27	0.44	-0.15	0.35	-0.43	-1.32	0.69	-1.91
Knee Flexion Loading Response (º/s)	45	138.47	4.09	-0.12	0.35	-0.34	-1.21	0.69	-1.75
Knee Extension Terminal Stance (º/s)	45	84.79	3.25	0.04	0.35	0.11	-1.33	0.69	-1.93
Knee Flexion Swing (º/s)	45	316.75	3.41	-0.47	0.35	-1.34	-0.86	0.69	-1.25
Knee Extension Terminal Swing (º/s)	45	352.65	5.03	-0.17	0.35	-0.48	-1.42	0.69	-2.06

Table: 4. Descriptive statistics of knee joint kinematics at fast walking gait.

Subjects	No.	Mean	Descriptive						
			S.D	Skewness	Std. Error	z-score	Kurtosis	Std. Error	z-score
Knee Flexion Loading Response (º)	45	24.08	2.25	-0.12	0.35	0.34	-0.81	0.69	1.17
Knee Extension Terminal Stance(º)	45	3.55	0.27	-0.20	0.35	0.57	-0.79	0.69	1.14
Knee Flexion Swing(º)	45	70.51	3.11	-0.04	0.35	0.11	-1.21	0.69	1.75
Knee Extension Terminal Swing(º)	45	5.54	0.88	-0.10	0.35	0.29	-1.16	0.69	1.68
Knee Flexion Loading Response (º/s)	45	154.65	6.76	0.20	0.35	0.57	-1.26	0.69	1.83
Knee Extension Terminal Stance (º/s)	45	107.90	4.48	0.06	0.35	0.17	-1.43	0.69	2.07
Knee Flexion Swing (º/s)	45	340.33	3.34	-0.04	0.35	0.11	-0.80	0.69	1.16
Knee Extension Terminal Swing (º/s)	45	360.85	6.10	-0.45	0.35	1.29	-0.31	0.69	0.45

Table 5. One way analysis of variance (ANOVA) in knee flexion loading response at gait among the different speed variation

ANOVA							
		Sum of Squares	df	Mean Square	F	n^2	Sig
Knee Flexion Loading Response (º)	Between Groups	2876.15	2	1438.08	534.46*	0.89	0.00*
	Within Groups	355.17	132	2.70			
	Total	3231.33	134				

* The Mean difference is Significant at the 0.05 level

Table 5. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee flexion loading response (º) with F (2, 132)= 534.46, P=0.00, p<0.05.the value of n^2 was 0.89 (0.80>) which indicated large effect size.

Table 6. The Post-hoc (LSD) comparisons in knee flexion loading response between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Flexion Loading Response	Slow	Normal	-5.77*	0.34	0.00*
	Slow	Fast	-11.30 *	0.34	0.00*
	Normal	Fast	-5.53*	0.34	0.00*

Table 6. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

Table 7. One way analysis of variance (ANOVA) in knee extension terminal stance at gait among the different speed variation

ANOVA							
		Sum of Squares	Df	Mean Square	F	n^2	Sig
Knee Extension Terminal Stance (°)	Between Groups	81.96	2	40.98	87.01*	0.57	0.00*
	Within Groups	62.17	132	0.47			
	Total	144.13	134				

* The Mean difference is Significant at the 0.05 level

Table 7. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal stance (°) with F (2, 132)= 140.25, P=0.00, p<0.05.the value of n^2 was 0.57 (<0.80) which indicated medium effect size.

Table 8. The Post-hoc (LSD) comparisons in knee extension terminal stance between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Extension Terminal Stance	Slow	Normal	-1.06*	0.14	0.00*
	Slow	Fast	0.85*	0.14	0.00*
	Normal	Fast	1.90*	0.14	0.00*

Table 8. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

Table 9. One way analysis of variance (ANOVA) in knee flexion swing at gait among the different speed variation.

ANOVA							
		Sum of Squares	df	Mean Square	F	n^2	Sig
Knee Flexion Swing (°)	Between Groups	171.58	2	85.79	5.10*	0.07	0.00*
	Within Groups	2221.58	132	16.83			
	Total	2393.16	134				

Table 9. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee flexion swing (°) with F (2, 132)= 5.10, P=0.00, p<0.05.the value of n^2 was 0.07 (<0.20) which indicated no effect size.

Table 10. The Post-hoc (LSD) comparisons in knee flexion swing between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Flexion Swing	Slow	Normal	2.37*	0.86	0.00*
	Slow	Fast	-0.03	0.86	0.97
	Normal	Fast	-2.41*	0.86	0.00*

Table 10. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal and normal- fast walk. Therefore group of slow-fast walking shows insignificant differences.

Table 11. One way analysis of variance (ANOVA) in knee extension terminal swing at gait among the different speed variation.

ANOVA							
		Sum of Squares	df	Mean Square	F	n^2	Sig
Knee Extension Terminal Swing (°)	Between Groups	49.80	2	24.90	73.18*	0.52	0.00*
	Within Groups	44.92	132	0.34			
	Total	94.72	134				

Table 11. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal swing (°) with F (2, 132)= 73.18, P=0.00, p<0.05.the value of n^2 was 0.52 (<0.80) which indicated medium effect size.

Table 12. The Post-hoc (LSD) comparisons in knee extension terminal swing between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Extension Terminal Swing	Slow	Normal	1.31* *	0. .12	0.00*
	Slow	Fast	0.04	0.12	0.72
	Normal	Fast	-1.26*	0.12	0.00*

Table 12. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal and normal- fast walk. Therefore group of slow-fast walking shows insignificant differences.

Table 13. One way analysis of variance (ANOVA) in knee flexion loading response at gait among the different speed variation.

ANOVA							
		Sum of Squares	Df	Mean Square	F	n^2	Sig
Knee Flexion Loading Response (°/s)	Between Groups	170856.51	2	85428.25	3.00*	0.98	0.00*
	Within Groups	3755.80	132	28.45			
	Total	174612.30	134				

Table 13. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee flexion loading response (°/s) with F (2, 132)= 3.00, P=0.00, p<0.05.the value of n^2 was 0.98 (0.80>) which indicated large effect size.

Table 14. The Post-hoc (LSD) comparisons in knee flexion loading response between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Flexion Loading Response	Slow	Normal	-66.07 *	1.12	0.00*
	Slow	Fast	-82.24 *	1.12	0.00*
	Normal	Fast	-16.17 *	1.12	0.00*

Table 14. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

Table 15. One way analysis of variance (ANOVA) in knee extension terminal stance at gait among the different speed variation.

ANOVA							
		Sum of Squares	df	Mean Square	F	n^2	Sig
Knee Extension Terminal Stance (°/s)	Between Groups	78745.02	2	39372.51	3.49*	0.98	0.00*
	Within Groups	1487.58	132	11.27			
	Total	80232.60	134				

Table 15. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal stance (°/s) with F (2, 132)= 3.49, P=0.00, p<0.05.the value of n^2 was 0.98 (<0.80) which indicated large effect size.

Table 16. The Post-hoc (LSD) comparisons in knee extension terminal stance between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Extension Terminal Stance	Slow	Normal	-35.61 *	0.71	0.00*
	Slow	Fast	-58.72 *	0.71	0.00*
	Normal	Fast	-23.11 *	0.71	0.00*

Table 16. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

Table 17. One way analysis of variance (ANOVA) in knee flexion swing at gait among the different speed variation.

ANOVA							
		Sum of Squares	Df	Mean Square	F	n^2	Sig
Knee Flexion Swing (°/s)	Between Groups	93995.66	2	46997.83	1.47*	0.96	0.00*
	Within Groups	4221.33	132	31.98			
	Total	98216.99	134				

Table 17. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee flexion swing (°/s) with F (2, 132)= 1.47, P=0.00, p<0.05.the value of n^2 was 0.96 (<0.80) which indicated large effect size.

Table 18. The Post-hoc (LSD) comparisons in knee flexion swing between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Flexion Swing	Slow	Normal	-40.32 *	1.19	0.00*
	Slow	Fast	-63.91 *	1.19	0.00*
	Normal	Fast	-23.58 *	1.19	0.00*

Table 18. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

Table 19. One way analysis of variance (ANOVA) in knee extension terminal swing at gait among the different speed variation.

ANOVA						
Sum of Squares	df	Mean Square	F	n^2	Sig

KneeExtension Terminal Swing (°/s)	Between Groups	192776.29	2	96388.15	2.01*	0.97	0.00*
	Within Groups	6326.58	132	47.93			
	Total	199102.88	134				

Table 19. shows that the significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal swing (°/s) with F (2, 132)= 2.01, P=0.00, p<0.05.the value of n^2 was 0.97 (<0.80) which indicated large effect size.

Table 20. The Post-hoc (LSD) comparisons in knee extension terminal swing between speed variations.

Multiple Comparisons					
LSD					
Dependent Variable	(I) VAR00002	(J) VAR00002	Mean Difference (I-J)	Std. Error	Sig.
Knee Extension Terminal Swing	Slow	Normal	-75.75 *	1.16	0.00*
	Slow	Fast	-83.94 *	1.46	0.00*
	Normal	Fast	-8.20*	1.46	0.00*

Table 20. shows that the Post-hoc comparisons indicated significant mean differences between slow- normal, slow – fast and normal- fast walk.

CONCLUSION

Table 2, 3 and 4 presents descriptive statistics for Knee Flexion Loading Response, Knee Extension Terminal Swing, Knee Flexion Swing and Knee Extension Terminal Stance. The data for hip joint kinematics during slow, normal and fast walking gait is normally distributed, as indicated by the Z scores falling within the range of -1.96 to 1.96.

Table 5 displays one-way analysis of variance (ANOVA) in knee flexion loading response at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking gait of school going children on knee flexion loading response, with a large effect size ($n^2 = 0.89$).

Table 6 shows that the post-hoc comparisons indicated significant mean differences between slow- normal, slow –fast and normal- fast walk.

Table 7 one-way analysis of variance (ANOVA) in knee extension terminal stance at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking gait of school going children on knee extension terminal stance, with medium effect size ($n^2 = 0.57$).

Table 8 shows that the post-hoc comparisons indicated significant mean differences between slow- normal, slow –fast and normal- fast walk.

Table 9 one-way analysis of variance (ANOVA) in knee flexion swing at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking gait of school going children on knee flexion swing, with no effect size ($n^2=0.07$).

Table 10 shows that the post-hoc comparisons indicated significant mean differences between slow-normal and normal- fast walk. Therefore group of slow-fast walking shows insignificant differences.

Table 11 one-way analysis of variance (ANOVA) in knee extension terminal swing at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking gait of school going children on knee extension terminal swing with medium effect size ($n^2 = 0.52$).

Table 12 shows that the post-hoc comparisons indicated significant mean differences between slow-normal and normal- fast walk. Therefore group of slow-fast walking shows insignificant differences.

Table 13 one-way analysis of variance (ANOVA) in knee flexion loading response at gait among the different speed variation The analysis reveals significant mean differences among slow, normal and fast walking gait of school going children on knee flexion loading response, with large effect size ($n^2 =0.98$).

Table 14 shows that the post-hoc comparisons indicated significant mean differences between slow-normal, slow –fast and normal- fast walk.

Table 15 one-way analysis of variance (ANOVA) in knee extension terminal stance at gait among the

different speed variation The analysis reveals significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal stance, with large effect size (n^2 =0.98).

Table 16 shows that the post-hoc comparisons indicated significant mean differences between slow-normal, slow –fast and normal- fast walk.

Table 17 one-way analysis of variance (ANOVA) in knee flexion swing at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking GAIT of school going children on knee flexion swing, with large effect size (n^2 =0.96) which indicated.

Table 18 shows that the post-hoc comparisons indicated significant mean differences between slow-normal, slow –fast and normal- fast walk.

Table 19 one-way analysis of variance (ANOVA) in knee extension terminal swing at gait among the different speed variation. The analysis reveals significant mean differences among slow, normal and fast walking GAIT of school going children on knee extension terminal swing, with large effect size (n^2 =0.97).

Table 20 shows that the post-hoc comparisons indicated significant mean differences between slow-normal, slow –fast and normal- fast walk.

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