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Original Article

Assessment of kinematic characteristics of preschoolers' gait during the implementation of an intervention training program

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ABSTRACT

The purpose of this study was to assess the kinematic characteristics of the gait of preschoolers before and after the implementation of an intervention training program. A group of twenty preschoolers without motor disorders participating in the study were assigned to two groups: the experimental group - 10 preschoolers (mean age 4.9±0.2 years) - and the control group - 10 preschoolers (mean age 4.8±0.3 years). Participants were assessed using the same test before and after the implementation of the intervention training program: they had to walk in a straight line three times along a distance of 5 meters (m). Kinematic variables were analysed based on 3D video processing using APAS software. Repeated Measures ANOVA was used to examine the effectiveness of the intervention training program ($p<0.05$). Results indicated that there were statistically significant differences in the Displacement of the Center of Mass during the Right Foot Support phase. There is a need for intervention training programs to enhance motor skill levels and the quality of movement in all children. **Key words:** KINEMATIC CHARACTERISTICS; ASSESSMENT; MOTOR SKILL OF GAIT; PRESCHOOLERS; 3D KINEMATIC ANALYSIS; INTERVENTION TRAINING PROGRAM.

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INTRODUCTION

According to recent views on child development, movement is considered to be a primary means of development enhancement (Doherty & Bailey, 2003; Stodden et al., 2008; Pica, 2011). Indeed, in a framework of 'active learning' the child is considered to be the 'subject of his/her development' (Kautter, 1998; Clark& Metcalfe, 2002; Clark, 2007). Consequently, when aspiring to providing quality education, the compensatory role of Kindergarten promotes the creation of vital space on the basis of the needs, interests, and wishes of preschoolers (Zimmer, 2003; Breslin, Morton & Rudisill, 2008).

A necessary prerequisite condition for analyzing movement is its characteristic phases. Each one of them has a specific starting and ending point as well as a purpose (Gommez *et al*., 1995; Hausdorff *et al*., 1999). Gait includes alternating sequences, during which the first limb to come into contact with the ground is supported, followed by the other limb; in other words, there is a sequence of alternating single and double (limb) support. This comprises a complex process (Ounpuu, 1994; Cupp *et al*., 1999; Enoka, 2007). The support phase of gait seems to last longer than the swing phase (Seefeldt & Haubenstricker,1982).

In the initial stage the child is moving forward while being supported. One foot is used as a guide and the other follows behind the first. The gaze is turned to the feet and the body is rigid.

In the elementary stage, the child performs limited compensatory movements and is capable of moving in different directions (forward, sideways or backward); significant attention and effort are necessary.

At the mature stage, the child proceeds regularly with successive steps. It becomes capable of moving at a steady pace. The child's movements are characterized by continuity and they are controlled (Galahue, 2002).

Given that the preschool age is considered to be a critical stage for developing fundamental motor skills (Malina, 2004; Galahue, 2002; Galahue & Ozmun, 2006; Robinson & Goodway, 2009; Goldfield *et al*., 2012), and because only a small percentage of children at this age acquire basic motor skills to a satisfactory level (Malina, 2004), assessing the kinematic characteristics of basic motor skills and implementing an appropriate program to improve these specific skills is considered to be necessary.

The aim of this paper is to assess the kinematic characteristics of the basic motor skill of gait among preschoolers, before and after the implementation of an Intervention Program, adjusted to the developmental features of preschoolers and taking into account the aims of Physical Education for children of this age.

In accordance to our research hypothesis, the Intervention Program should bring about statistically significant differences in the mean values of the variables selected in relation to the kinematic characteristics of gait among children of preschool age.

METHOD

Participants and Procedure

This research study included 20 preschoolers without motor problems who participated voluntarily and attended a Kindergarten. The sample was randomly divided into two groups: The Experimental Group (EG) and the Control Group (CG). The EG participated only in the 10-week Intervention Program of motor activities, while the CG participated only in the school intra-curricular activity program.

Table 1: Anthropometric characteristics of the two groups

	EXPERIMENTAL GROUP (EG)		CONTROL GROUP (CG)	
NUMBER (n)	10 (5 boys-5 girls)		10 (5 boys-5 girls)	
	M	SD	M	SD
AGE (years)	4.9	0.2	4.8	0.3
HEIGHT (cm)	113.8	4.5	111	5.2
WEIGHT (kgr)	19.5	3.9	19.4	4.2

Note: M: Mean; MS: Standard Deviation; EG: Experimental Group; CG: Control Group

The majority of the children did not participate in other regular extra-curricular sports activities. The research study was undertaken in compliance with the principles of the Ethics Code of Aristotle University of Thessaloniki, following written consent by the children's parents and official approval by the Ministry of Education, Research and Religions.

For the purposes of this study healthy preschoolers were voluntarily assessed following their parents' written consent. The Intervention Program and the assessing tests were performed at the premises of Gym in the vicinity of the Kindergarten. The children were dressed in appropriate comfortable clothes and wore sports shoes. Digitization of children's joints and implementation of the Intervention Program were performed by the same examiner.

The procedure of measurement took place twice, before the Intervention Program and after the relevant program was concluded. In fact, the initial measurement lasted one day and was performed in the beginning of October. Then followed the 10-week Intervention Program and the new measurement was performed between the 10th and 20th of December. Both children groups, namely the Experimental (EG) and the Control (CG) groups, participated in the measurement procedure. Before every test performance, clear instructions were given as follows 'Walk in a straight line, along 5 meters (m), specifying 'as fast as you can'.

Measuring Instruments

Kinematic Recording and Analysis

The kinematic analysis of gait was performed using the three-dimensional (3D) video-analysis, of the APAS (Ariel Performance Analysis System) software. The 3d movement analysis includes three phases: 1) movement recording; 2) digitization and 3) data calculation.

Tests were videotaped using two JVC 9800 cameras (NCS 120 fr/sec) placed on a fixed tripod. Simultaneous camera operation allowed the recording of the position of body parts at different points in time and in different spatial positions (Winter, 1990).

To ensure ideal lighting conditions, a spot light was used. To calibrate the space where the tests were performed, eight reference points were used on the calibration 'cube' (1.10mx2m in size) (Ladin, 1995).

An electronic computer with a special software program (Ariel Performance Analysis System, APAS) was also used to record and assess the relevant variables (Ariel, 1990).

Variables

Eighteen kinematic variables were analysed and assessed based on 3D video processing using APAS software.

Table 2: Gait Variables

Kinematic Characteristics	Variable	Measuring Unit
Shifting the Body Mass Center X-axis Gait in the phase of right foot support (gait cycle)	VatDKMSx	cm
Shifting the Body Mass Center Y-axis Gait in the phase of right foot support (gait cycle)	VatDKMSy	cm
Shifting the Body Mass Center 3d Gait in the phase of right foot support (gait cycle)	VatDKMS3d	cm
Velocity of the Body Mass Center X-axis Gait in the phase of right foot support (gait cycle)	VatVKMSx	cm/sec
Velocity of the Body Mass Center Y-axis Gait in the phase of right foot support (gait cycle)	VatVKMSy	cm/sec
Velocity of the Body Mass Center 3d Gait in the phase of right foot support (gait cycle)	VatVKMS3d	cm/sec
Angular Velocity of the Right Foot Gait in the phase of right foot support (gait cycle)	VatWDPodiou	deg/sec
Angle of the Right /Foot Gait in the phase of right foot support (gait cycle)	VatGDPodiou	deg
Angular Velocity of the Right Knee Gait in the phase of right foot/ support (gait cycle)	VatWDGonatou	deg/sec
Angle of the Right Knee Gait in the phase of right foot support (gait cycle)	VatGDGonatou	deg
Angular Velocity of the Right Hip Gait in the phase of right foot support (gait cycle)	VatWDIsxiou	deg/sec
Angle of the Right Hip Gait in the phase of right foot support (gait cycle)	VatGDIsxiou	deg
Angular Velocity of the Left Foot Gait in the phase of right foot support (gait cycle)	VatWAPodiou	deg/sec
Angle of the Left Foot Gait in the phase of right foot support (gait cycle)	VatGAPodiou	deg
Angular Velocity of the Left Knee Gait in the phase of right foot support (gait cycle)	VatWAGonatou	deg/sec
Angle of the Left Knee Gait in the phase of right foot support (gait cycle)	VatGAGonatou	deg
Angular Velocity of the Left Hip Gait in the phase of right foot support (gait cycle)	VatWAIsxiou	deg/sec
Angle of the Left Hip Gait in the phase of right foot support (gait cycle)	VatGAIsxiou	deg

Intervention Program

The Intervention Program included the group of activities to study the basic motor skill of gait:

Exploration Activities
When engaged in this group of activities, children have the opportunity to experiment and accumulate sufficient experiences related to effort (force, time, flow), space (level, direction, field), relationships (objects, human beings). Children are, therefore, facilitate, whatever their developmental stage (initial, elementary), to acquire valuable knowledge about their physical movements (Buchanan *et al*., 2004).

Activities of guided discovery
What prevails in this group of activities is the method of problem solving, so that children may discover appropriate motor movements of their upper and lower arms, their torso and their entire body in general (Breslin *et al*., 2008).

Play
This is the predominant form of children's activities. Not only do the children fine-tune their conduct, but they also perform significant developmental functions. Motor games give children the opportunity to deepen into an activity motor experience. They are given the opportunity to repeatedly perform the movements of a skill without any influence from their environment (Zimmer, 2007).

The aims of the Intervention Program for motor were the following:

- To support the motor, social, cognitive and emotional development of children;
- To satisfy the children's need for movement, physical and appropriate play activities;
- To give children the opportunity to get to know their own body and personal potential;
- To expand and improve their motor skills and competencies;
- To acquire a sense of joy for physical activity and life-long exercise.

This program took place within a gym. It was part of the children's regular weekly schedule, as it was implemented twice a week for a period of ten weeks. The Experimental Group (EG) participated in 25΄- 30΄ activities under the supervision of the kindergarten teacher and researcher of this paper. The Control Group (CG) participated only within intra-curricular activities. The Intervention Program was flexible in structure and related to the interests, needs, wishes and experiences of the children.

Statistical Analysis
The statistical analysis of data was performed using SPSS 15 (Statistical Package for the Social Sciences). To be precise, the normality of distribution of the dependent variables was examined in both groups before and after the Intervention Program using the Kolmogorov-Smirnov test ($p > 0.05$). Variance analysis (ANOVA) was performed using REPEATED MEASURES so that interaction could be analyzed. Then t-tests and paired t-tests analyses of independent samples ensued.

The differences between the two groups before the intervention were examined with t-testing independent samples (independent t-test). The average values of dependent variables between the two groups, namely the Control Group and the Experimental Group were examined before and after the Intervention Program. A paired t-test between the two repeated measurements ensued, for both the Experimental Group and the Control Group to investigate whether there were statistically significant differences in dependent variables (Bonferroni adaptation).

The statistical significance level was set at $p<0.05$.

Table 3: Intervention Program

Week	Teaching session	Duration	Activities	Aims
1st	1st 2nd			• To experiment and accumulate sufficient experiences related to effort (force, time, flow), space (level, direction. Field), relationships (objects, human beings).
2nd 3rd	3rd 4th 5th 6th	25´	Exploration Activities	• To acquire a sense of joy for physical activity and life-long exercise.
4th	7th 8th			• To discover appropriate motor movements of their upper and lower arms.
5th	9th 10th	25´	Guided Discovery Activities	• To support the motor, social, cognitive and emotional development of children.
6th	11th 12th			
7th 8th	13th 14th 15th 16th			• To deepen into an activity motor experience.
9th	17th 18th	25´	Play	• To satisfy the children's need for movement, physical and appropriate play activities.
10th	19th 20th			

RESULTS

Interaction between the groups and repeated measurements in the Experimental Group and the Control Group, as well as their change in time was found to be statistically significant for variables VatDKMSx, $F_{(1,18)}$=16.048 p=.001 and VatDKMS3d, $F_{(1,18)}$ = 10.099, p= .005.

The difference between the groups before the intervention was checked using the t-test of independent samples (independent t-test). Average values of dependent variables between the groups (Control Group, Experimental Group) before the program did not present any statistically significant difference (p>.05). Average values of dependent variable after the program in the Experimental Group showed statistically significant differences (p<.05), namely for variables VatDKMSx, $t_{(18)}$= 0.685, p= .001 and VatDKMS3d, $t_{(18)}$=2.424 p= .005, while no such statistically significant difference was noted for the Control Group (p>.05).

A paired t-test (between the two repeated measurements ensued both for the Experimental Group and the Control Group to investigate whether there were statistically significant differences in the dependent variables (Bonferroni adaptation was performed). Results showed that for the Experimental Group there were statistically significant differences in the following variables: VatDKMSx2, $t_{(9)}$= -4.205, p= .001, VatDKMS3d2, $t_{(9)}$= -3.260, p= .044, while there were no such differences for the Control Group.

Table 4: Means and standard deviations before and after the Intervention Program

Variable	Group	Before		After	
		M	SD	M	SD
VatDKMSx[cm]	EG	45,56	17,51	74 ↑	19,71
	CG	62,22	43,86	63,57	43,86
VatDKMSy[cm]	EG	62,52	18,63	58,58	5,6
	CG	62,64	4,6	63,99	4,6
VatDKMS3d[cm]	EG	124,75	32,57	177,95 ↑	47,96
	CG	133,03	30,49	134,37	30,49
VatVKMSx[cm/sec]	EG	150,5	93,51	187,11	42,52
	CG	124,13	40,77	125,47	40,77
VatVKMSy[cm/sec]	EG	34,33	16,3	25,19	25,77
	CG	26,07	19,38	27,42	19,38
VatVKMS3d[cm/sec]	EG	195,12	110,66	213,78	40,75

	CG	159,59	39,51	160,93	39,51
VatWDPodiou[deg/sec]	EG	532,67	386,47	380,52	249,23
	CG	445,12	161,08	446,47	161,08
VatGPodiou[deg]	EG	98,08	17,84	87,58	6,17
	CG	88,96	12,65	90,3	12,65
VatWDGonatou[deg/sec]	EG	478,08	304,63	539,76	231,74
	CG	526,41	344,04	527,76	344,04
VatGDGonatou[deg]	EG	132,87	17,08	146,18	18,91
	CG	127,13	24,91	128,48	24,91
VatWDIsxiou[deg/sec]	EG	364,94	181,64	537,7	363,03
	CG	611,16	262,8	612,5	262,8
VatGDIsxiou[deg]	EG	154,71	11,05	156,61	8,75
	CG	146,26	16,04	147,61	16,04
VatWAPodiou[deg/sec]	EG	447,27	176,86	497,01	247,4
	CG	521,31	289,07	522,65	289,07
VatGAPodiou[deg]	EG	78,15	8,37	88,81	11,02
	CG	91,83	22,13	93,18	22,13
VatWAGonatou[deg/sec]	EG	546,87	177,58	470,13	261,74
	CG	586,88	288,99	588,22	288,99
VatGAGonatou[deg]	EG	129,45	14,7	134,17	22,81
	CG	139,3	17,73	140,65	17,73
VatWAIsxiou[deg/sec]	EG	414,56	135,83	466,55	311,99
	CG	493,73	224,31	495,08	224,32

VatGAIsxiou[deg]	EG	153,08	8,9	150,52	8,04
	CG	155,57	9,08	153,71	8,97

Notes: M: Mean; MS: Standard Deviation; EG: Experimental Group; CG: Control Group; Before: Before the intervention program; After: After the intervention program; VatDKMSx[cm]: Shifting the Body Mass Center x-axis Gait in the phase of right foot support (gait cycle);VatDKMSy[cm]: Shifting the Body Mass Center y-axis Gait in the phase of right foot support (gait cycle);VatDKMS3d[cm]: Shifting the Body Mass Center 3d Gait in the phase of right foot support (gait cycle);VatVKMSx[cm/sec]: Velocity of the Body Mass Center x-axis Gait in the phase of right foot support (gait cycle);VatVKMSy[cm/sec]: Velocity of the Body Mass Center y-axis Gait in the phase of right foot support (gait cycle);VatVKMS3d[cm/sec]: Velocity of the Body Mass Center 3d Gait in the phase of right foot support (gait cycle);VatWDPodiou[deg/sec]: Angular Velocity of the Right Foot Gait in the phase of right foot support (gait cycle);VatGPodiou[deg]: Angle of the Right Foot Gait in the phase of right foot support (gait cycle);VatWDGonatou[deg/sec]: Angular Velocity of the Right Knee Gait in the phase of right foot support (gait cycle);VatGDGonatou[deg]: Angle of the Right Knee Gait in the phase of right foot support (gait cycle);VatWDIsxiou[deg/sec]: Angular Velocity of the Right Hip Gait in the phase of right foot support (gait cycle);VatGDIsxiou[deg]: Angle of the Right Hip Gait in the phase of right foot support (gait cycle);VatWAPodiou[deg/sec]: Angular Velocity of the Left Foot Gait in the phase of right foot support (gait cycle);VatGAPodiou[deg]: Angle of the Left Foot Gait in the phase of right foot support (gait cycle);VatWAGonatou[deg/sec]: Angular Velocity of the Left Knee Gait in the phase of right foot support (gait cycle);VatGAGonatou[deg]: Angle of the Left Knee Gait in the phase of right foot support (gait cycle);VatWAIsxiou[deg/sec]: Angular Velocity of the Left Hip Gait in the phase of right foot support (gait cycle);VatGAIsxiou[deg]: Angle of the Left Hip Gait in the phase of right foot support (gait cycle).

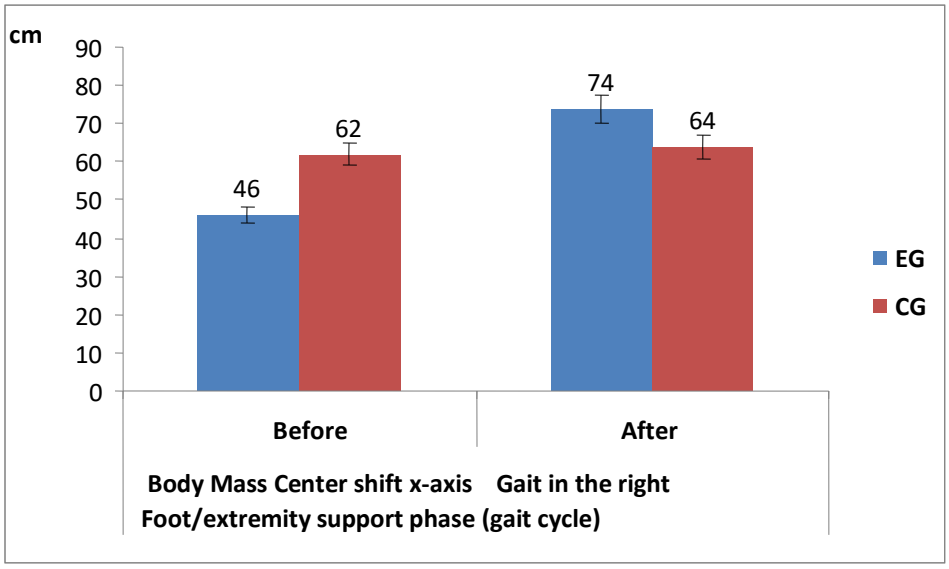

Figure 1. Graph presenting the Body Mass Center Shift X-axis Gait in the phase of right foot support (gait cycle)-VatDKMSx before and after the Intervention Program.

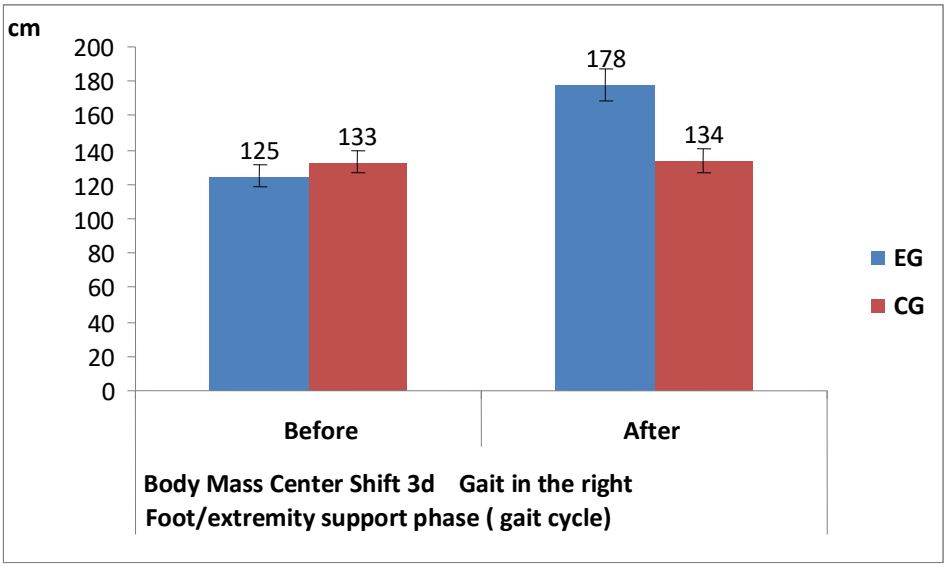

Figure 2. Graph of the differences in the Body Mass Center Shift 3d-VatDKMS3d Gait in the phase of right foot support (gait cycle) before and after the Intervention Program.

DISCUSSION AND CONCLUSIONS

This study is an initial attempt at assessing selected kinematic characteristics of the basic motor skill of gait among healthy preschoolers following the implementation of an Intervention Program.

In this research study a total of 18 variables were assessed. The 3D recording and analysis of joint movement in the upper and lower extremities along all axes facilitate drawing the most reliable results possible, as this is a measurement procedure par excellence, which allows an objective recording of movement.

The findings of the study seem to be confirming the research hypothesis, i.e., that the Intervention Program would bring about statistically significant differences in the mean values of selected variables concerning kinematic characteristics of the basic motor skill of gait among children of preschool age.

According to the hypothesis in question, the Intervention Program would result in statistically significant differences in the averages of selected variables concerning the kinematic characteristics of gate among preschoolers. In fact, statistically significant differences were noted in the Body Mass Center Shift in the phase of right foot support, (i.e. at the end of the gait cycle), following the Intervention Program. The 3D recording and analysis of the movement facilitated drawing the most reliable results possible in relation to the complex gait procedure (Ounpuu, 1994; Enoka, 2007). The Body Mass Center Shift is an important indication of the improvement of the motor skill of gait among the children who participated in the Intervention Program, providing stability to their movement (Sutherland, 1997). We cannot, however, support that they have fully adopted the adult gait pattern, as claimed by Ganley & Powers (2005). In their research, they assessed kinematic, dynamic and anthropometric data of the gait skill, the joint angles, the torque values, and the power in 15 seven-year old children against the same variables of 15 adults. The only differences observed were in the dynamic characteristics of the children's ankles. The immaturity of the children's neuromuscular system seems to be presented as a possible explanation, as underlined in an older paper by Cupp *et al* (1999).

Contrary to the researchers above, Chester *et al*. (2006), as well as Ounpuu (1994), support that a similar gait pattern with that of adults is achieved by children by the age of five. This conclusion was drawn by Chester *et al*. (2006) when comparing gait kinetic patterns of children between the ages of three and thirteen and by Ounpuu (1994) when comparing children aged five to sixteen years old. In conclusion, according to the results of this research study, children of a preschool age are capable not only of developing but also of improving and altering their gait techniques, actively participating in an appropriate intervention program.

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