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عدد خاص ببحوث المؤتمر العلمي الثاني في البايوميكانيك المنعقد في
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Kinematics Analysis of Walking during load carriage for School children

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1. Introduction

God distinguishes man from other creatures in his beautiful shape. So we should keep this blessing and avoid any wrong action or unhealthful habit that change in body geometric figure. From these wrong actions are overweight of school bag and wrong carrying.

Last years, many educational institutions, increase the number of books in all subjects. This phenomenon leads to increasing of weight that should all school children carry during their walking way from home to school and comeback. This inevitably leads to the appearance of problems in the posture status of the student in growth phase that consider most critical phase from physical, mental, and emotional growth.

The researchers are seeking to benefit from the logic passage of biomechanics' role to keep children from stature deviations, through identify on the natural dynamic possibilities in human body generally and in children body especially, it requires to recognize mechanical of natural and typical of body motion. In particular during walking agree with anatomical and functional case, so overweight of school bag will affect on mechanical body and then deformities stature will occur in body children.

The Hong Kong Society for Child Health and Development reported that the mean ratio of school bag weight to body weight was 20.2%. They also found that 45 out of the 812 students examined had spinal deformities. And the mean weight of their school bags was ٤,٧٤kg, which was marginally higher than the ٤,٦١kg mean of the total sample. The Society believed that there was a causal relationship between the weight of school bags and spinal deformities.

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In a study in the USA, Pascoe et al reported that the mean weight of school bags was 17% of the student's mean body weight. They found that the most common symptoms associated with overweight backpacks were muscle soreness, back pain, numbness, and shoulder Pain (Pascoe et al,1997).

Both of Fazrolrozi & Rambely (2008) are to investigate the weight and content of school bags carried by primary school children in Malaysia. 175 school children (male and female) participated in the study. The subjects are divided into two groups, first year and second year groups. The weights of the children were noted with and without load. Results show that the first year group carries more than 25% of body weight (>25%BW) and the second year group carries (>15% BW). The decreasing percentage of body weight is not caused by a decreasing amount of load but it occurs because of the increment of body weight.

Were identified a study conducted by Hyun, Jongsang, Han, Youngho & Dohyung (2008) the biomechanical effects of weight variation for a sided load carriage upon walking. Our results showed that knee and hip did not resist the moment generated by gravity of carriage. But thoracic and lumbar kept the balance of the body and gait motion. These results could be very useful in analysis for delivery motion of daily life.

And the study that described by the Lei, Richard & David (2005) an investigation into the biomechanical effects of load carriage dynamics on human locomotion performance. A whole body, inverse dynamics gait model has been developed which uses only Kinematic input data to define the gait cycle. To provide input data, three-dimensional gait measurements have been conducted to capture whole body motion while carrying a backpack. A nonlinear suspension model is employed to describe the backpack dynamics. The model parameters for a particular backpack system can be identified using a dynamic load carriage test-rig. Biomechanical assessments have been conducted based on combined gait and pack simulations. It was found that the backpack suspension stiffness and damping have little effect on human locomotion energetic. However, decreasing suspension stiffness offers important biomechanical advantages. The peak values of vertical pack force, acting on the trunk, and lower limb joint loads are all moderated. This would reduce shoulder strap pressures and the risk of injury when heavy loads are carried.

The weight of schoolbags and the prevalence of musculoskeletal symptoms amongst 140 students (70 third form students comprising 35 females and 35

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males, and 70 sixth form students comprising 35 females and 35 males). From five New Zealand secondary schools was investigated. Schoolbag weight for third form students (mean age 13.6 years) was 13.2% of their body weight, while for sixth form students (mean age 17.1 years) it was 10.3% of their body weight. These weights may exceed the recommended guideline load limits for adult industrial workers. Musculoskeletal symptoms were reported by 77.1% of the students. Symptoms were most prevalent in the neck, shoulders, upper back and lower back. Although musculoskeletal symptoms are believed to be multifactorial in origin, the carriage of heavy schoolbags is a suspected contributory factor and may represent an overlooked daily physical stress for New Zealand secondary school students (Whittfield et al 2005).

2. Methods

The experimental research method used to analyzed walking for sample consist of 10 children (age 8.3 ± 2.66 years, height 129.16 ± 11.26 cm, body mass 26.72 ± 5.7 kg). The opinion of children's parents has taken for doing research experience on their children. The place and time has defined and ask the students to walk on the treadmill device carrying his school bag in weights (10%-20%-30%) of the weight of the child's body, was filmed walking movement by camera video in speed 25 p/sec, and using two-dimensional analysis for 13 variable kinematical (table1) then data have analyzed which collected by using Statistical Package for Social Sciences (SPSS).

Table 1 Variables Kinematic, unit of measure and acronyms.

S	Stage	Variable Kinematic	Unit of measure	Acronyms
1	Front Support	**neck angle**	Degree	**αnF**
2		**trunk angle**	Degree	**αtF**
3		**Knee angle**	Degree	**αkF**
4		**Foot angle**	Degree	**αfF**
5		**Distance of disability**	meter	**Dd**
6	Back Support	**neck angle**	Degree	**αnB**
7		**trunk angle**	Degree	**αtB**
8		**Knee angle**	Degree	**αkB**
9		**Foot angle**	Degree	**αfB**
10		**High heel before leave**	Centimeter	**Hh**
11	**Velocity of the hip joint**		**Centimeter per second**	V_h
12	**Stride length**		Centimeter	**ls**
13	**Time-weighted**		Seconds	**Tw**

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Figure1 shows dynamic sequence of one of research sample

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3. Results

Table 2 shows Mean, SD, Min and Max of Variables Kinematic of the three different loads 10%-20%-30% of child body weight.

Table 2 Descriptive Variables Kinematic of three different loads (N =10)

Variables	Loads	Mean	S.D	Min	Max
αnF	10%	53.70	7.903	39	65
	20%	56.20	9.496	36	67
	30%	57.30	7.804	42	66
αtF	10%	85.90	3.573	80	90
	20%	78.40	3.864	73	84
	30%	74.00	5.578	66	84
αkF	10%	174.00	4.761	167	180
	20%	166.50	7.807	157	180
	30%	165.90	8.266	150	176
αfF	10%	89.10	12.758	72	116
	20%	86.30	11.470	67	106
	30%	86.60	10.469	74	107
Dd	10%	25.059	3.9445	19.5	32.7
	20%	21.584	3.3333	18.6	29.3
	30%	19.318	2.2179	17.5	24.9

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αnB	**10%**	53.50	7.764	42	63
	20%	55.70	12.962	32	75
	30%	61.90	3.814	57	70
αtB	**10%**	86.10	5.896	77	97
	20%	79.50	5.104	71	88
	30%	77.70	4.373	71	84
αkB	**10%**	158.10	8.850	141	169
	20%	148.00	6.667	134	156
	30%	140.50	6.553	133	152
αfB	**10%**	111.70	7.243	106	128
	20%	109.40	6.168	103	120
	30%	110.30	8.152	98	124
Hh	**10%**	11.89	2.922	7	16
	20%	9.03	2.314	6	14
	30%	8.89	2.852	5	13
V_h	**10%**	33.973	9.1210	21.9	51.7
	20%	26.539	4.8885	18.8	33.8
	30%	22.631	6.6587	13.8	33.8
Is	**10%**	41.520	13.4971	17.3	55.2
	20%	34.702	12.0924	12.2	51.8
	30%	28.157	7.6199	14.7	40.8
Tw	**10%**	.2720	.05903	.20	.36
	20%	.2960	.04300	.20	.36
	30%	.2960	.08044	.16	.44

Table 3 shows One-way ANOVA of Variables Kinematic of the three different loads (N =10)

Variables		Sum of Squares	df	Mean Square	F	Sig.
αnF	Between Groups	68.067	2	34.033	.478	.625
	Within Groups	1921.800	27	71.178		
	Total	1989.867	29			
αtF	Between Groups	724.067	2	362.033	18.468	**.000**
	Within Groups	529.300	27	19.604		
	Total	1253.367	29			
αkF	Between Groups	407.400	2	203.700	4.022	**.030**
	Within Groups	1367.400	27	50.644		
	Total	1774.800	29			

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αfF	Between Groups	47.267	2	23.633	.176	.840
	Within Groups	3635.400	27	134.644		
	Total	3682.667	29			
Dd	Between Groups	167.232	2	83.616	7.941	**.002**
	Within Groups	284.298	27	10.530		
	Total	451.530	29			
αnB	Between Groups	379.467	2	189.733	2.344	.115
	Within Groups	2185.500	27	80.944		
	Total	2564.967	29			
αtB	Between Groups	391.200	2	195.600	7.340	**.003**
	Within Groups	719.500	27	26.648		
	Total	1110.700	29			
αkB	Between Groups	1560.067	2	780.033	14.122	**.000**
	Within Groups	1491.400	27	55.237		
	Total	3051.467	29			
αfB	Between Groups	26.867	2	13.433	.257	.775
	Within Groups	1412.600	27	52.319		
	Total	1439.467	29			
Hh	Between Groups	57.607	2	28.804	3.923	**.032**
	Within Groups	198.256	27	7.343		
	Total	255.863	29			
V_h	Between Groups	663.995	2	331.998	6.577	**.005**
	Within Groups	1362.859	27	50.476		
	Total	2026.855	29			
ls	Between Groups	892.973	2	446.487	3.466	**.046**
	Within Groups	3478.132	27	128.820		
	Total	4371.105	29			
Tw	Between Groups	.004	2	.002	.488	.619
	Within Groups	.106	27	.004		
	Total	.110	29			

Table 3 shows One-way ANOVA of Variables Kinematic of the three different loads 10%-20%-30% of child body weight.

To know the effect of three different loads 10%-20%-30% of child body weight. The researchers has used ONE_WAY ANOVA on Kinematic variables during walking on the treadmill and become clear that there is significant difference between three different loads in follow Kinematic variables: **αtF**, **αkF**, **Dd**, **αtB**, **αkB**, **Hh**, **Vh**, **ls** & **Tw** because (P<0.05) to these variables.

For more details on the moral differences described Table 3 test was used least significant difference LSD results as shown in table 4.

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Table 4 Shows the Mean Difference for three different loads for some kinematical variables.

Dependent Variable	(I) load	(J) load	Mean Difference (I-J)	Sig.
αtF	10%	20%	7.50(*)	**.001**
		30%	11.90(*)	**.000**
	20%	30%	4.40(*)	**.035**
αkF	10%	20%	7.50(*)	**.026**
		30%	8.10(*)	**.017**
	20%	30%	.60	.852
Dd	10%	20%	3.475(*)	**.024**
		30%	5.741(*)	**.000**
	20%	30%	2.266	.130
αtB	10%	20%	6.60(*)	**.008**
		30%	8.40(*)	**.001**
	20%	30%	1.80	.442
αkB	10%	20%	10.10(*)	**.005**
		30%	17.60(*)	**.000**
	20%	30%	7.50(*)	**.032**
Hh	10%	20%	2.87(*)	**.025**
		30%	3.01(*)	**.020**
	20%	30%	.14	.908
Vh	10%	20%	7.434(*)	**.027**
		30%	11.343(*)	**.001**
	20%	30%	3.909	.229
Is	10%	20%	6.818	.190
		30%	13.363(*)	**.014**
	20%	30%	6.545	.208

* The mean difference is significant at the .05 level.

Become clear that there is significant difference to all Kinematic variables in table 4 except one variable **Is** (P> 0.05). Between first load 10% and second load 20%.

It was also become clear that there is significant difference to all Kinematic variables in table 4 between first load 10% and third load 30% (P <0.05).

The difference between the second load 20% and the third load 30% did not show significant differences for the kinematical variables table 4 of (P> 0.05) except for variables **αtF** & **αkB** where differences were significant (P <0.05).

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4. Discussion

In this study, according to table 2 & 3, there is clear effect on children abilities because of overweight school bag and this affect on mechanical condition for body children in walking. So it will be haste the strain and fatigued as well as stature deformities and deviations will occur in future. This agrees with what he referred to (Erica, 2002) load carriage is an abnormal condition in human walking. The recommended 'Backpack Safety America/International' backpack safety is a critical issue for the long-term health of our children, proper posture and healthy ergonomics for future generations. This is why it's important to maintain the proper status of mechanical body.

Through table 4, Which Shows the Mean Difference for three different loads for some kinematical variables.

The reason for significance differences in variables **αtF**, **αtB** is over stress on children because of overweight schoolbag. This affect on trunk angel with horizontal pivot in forward and backward support, in case of carry school bag in load 20%-30%, the rate of the angel is decreasing. Trunk mass evaluated by 43% from body mass. Trunk is most important to achieve balance and stability for human body to determine the body’s center of gravity, this is agree with practicing activity, weight load, and its loading way. Also agree with many studies results whether adults or children. Martin & Nelson (1986), Carvalho & Rodacki (2008), Hong & Brueggemann (2000), Sharifah et al (2009). The researchers conclude that increasing school bag load about 20% of child body weight. The trunk should be turn in walking foreword.

According to researchers the differences in variables **αkF**, **αkB** refers to the research sample is trying to decrease body’s center of gravity. In walking by carrying school bag in load 20%-30% to keep body balance. Whenever body’s center of gravity decreased to earth, more stability achieved. body’s center of gravity is linked closely associated with angles of lower limbs joints for body, especially knee joint. So that the knee joint has most important role to keep body stability and this agree with what he referred to both Cheung & Hong (2000) When walking while using a backpack, the body’s center of gravity is raised, making walking unstable in order to maintain balance.

The researchers ascribed the significance difference in variable **Dd** to associate it with variable **αtF-ls** and they setting out the horizontal distance between the base of the front support and body’s center of gravity. When bending frontal of

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trunk and shorting stride length after carrying schoolbag has weight 20%-30% of weight child. This in turn make **Dd** will affected clearly because whenever loads were increasing on child during his carrying schoolbag, **Dd** will decrease in walking. Children are trying to make body center of gravity located on support base as well as shorting step length to keep balance and stability. It was also found that there are no significant differences between second load 20% and third 30% in this variable. This concludes that variable **Dd** will begin influenced by clearly in load 20% or more.

Researchers attributed the differences in variable **Hh** to sample research during carry schoolbag weight 10% in good sequence mechanical walk through agreement in body parts as well as dynamic control on the contrary when load increase over 20%. This result agree with a lot of studies that show mechanical of child walk is effecting by carry his school bag that weight 20% of child weight (Hong and Brueggemann,2000)(Hyun et al,2008).

As well as they increased the loading about 20%-30% of research sample, did not follow the correct mechanical way in last pushing process in walking, So the insteps are not last part that have left earth. The researchers notice that there is large part of their feet touch earth before leave moment, while the instep should be last part touch earth in order to increase of height heel before leave.

Also researchers attributed the differences in variable **Vh** to effecting sample research by increase load on child. It becomes clear when load increased 20% of child weight. We concluded that back pack weight should not exceed 10% of body weight and this is advice by Arabic Site Spinal Column Injuries (2008) and Hong, Brueggemann (2000).

Speed will be decreased when schoolbag weight increased which child carry in walking. So it normal result when child was trying to lessen necessary energy in work that is economical. This result agrees with LaFiandra et al (2000) and Sutherland et al (1994).

And the differences in variable **ls**, the researchers attributed it to effect of overweight of schoolbag and the child was trying to decrease step length to keep his stability. Indeed that effect is not clear when carrying schoolbag in weight 20% of child weight, while he show in load 30% of his weight. the results show there is not significance differences between second load 20% and

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30% of body weight, In other words the beginning of influence on step length was in 30% load. Although that, this result is not agree with Pascoe et al (1997) results study, they found that there were significant decreases in stride length with respect to normal walking when children walked with a backpack weight of 20% of the weight of the child but it agree with other results studies when they concluded that most of the load carriage studies using backpacks weight of 20% of the weight of the child have not yielded significant changes in stride length and cadence. (Hong and Brueggemann,2000) (Charteris and Comparison,1998) (GOh,1998).

5. Conclusion

In this study there is considerable influence on mechanical of child walk during their carry schoolbag in weight 20% or more than their body weight .significance difference is found to Angles trunk and knee of front and back support, Distance of disability, High heel before leave, Velocity of the hip joint, and stride length between three different loads 10%-20%-30% of child body weight, While did not show significant differences for the other kinematical variables.

Caution should be raised when children carry backpack loads weighing up to 20% or more body weight for their daily schooling. it should be awareness workshop for parents and teachers in particular overweight schoolbag harms and reduction mechanism for schoolbag and homework.

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ملخص البحث:

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في السنين الماضية العديد من المؤسسات العلمية قامت بزيادة عدد الكتب في جميع المواد الدراسية، هذه الظاهرة أدت إلى زيادة الوزن الذي يجب على جميع أطفال المدارس إن يحملوه عند طريقهم من المدرسة إلى البيت وبالعكس. وهذا يؤدي حتما إلى ظهور مشاكل في الحالة القوامية لدى الطالب في مرحلة النمو و التي تعتبر أهم مرحلة من ناحية النمو العقلي والانفعالي والبدني.

تم استخدام الأسلوب التجريبي لتحليل حركة المشي لعينة مكونة من ١٠ أطفال (العمر بوسط حسابي ٨.٣ وبانحراف معياري ±٢.٦٦ سنة، الطول بوسط حسابي ١٢٩.١٦ وبانحراف معياري ±١١.٢٦سم، كتلة الجسم بوسط حسابي ٢٦.٧٢ وبانحراف معياري ±٥.٧ كغم)، طلب من كل طالب بالمشي العادي مع حمل حقيبته المدرسية على جهاز السير المتحرك بأوزان ١٠%، ٢٠%، ٣٠% من وزن جسم الطفل، وتم تصوير حركة المشي بكاميرا فيديو ذات سرعة ٢٥ صورة بالثانية وتم استخدام التحليل الثنائي الأبعاد لـ١٣ متغير كينماتيكي، بعدها تم تحليل البيانات التي تم جمعها باستخدام البرنامج الإحصائي للعلوم الاجتماعية(SPSS).

وقد وجد ان هناك تأثير كبير على ميكانيكية مشي الأطفال أثناء حملهم للحقائب المدرسية التي تزن ٢٠% أو أكثر من وزن أجسامهم، ووجد ان هناك فروق معنوية لـ٨ متغيرات كينماتيكية مقاسة بين الأحمال الثلاث المختلفة ١٠%-٢٠%-٣٠% من وزن أجسام الأطفال، بينما لم تظهر فروق معنوية بالمتغيرات الكينماتيكية الأخرى. وينبغي زيادة الحذر عند الأطفال أثناء حمل حقيبة الظهر بوزن يصل إلى ٢٠% أو أكثر من وزن الجسم من واجباتهم اليومية.

الكلمات المفتاحية : الميكانيكا الحيوية، الأطفال، حمل الحقيبة، المشي.