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身體狀態限制對兒童靜態平衡動作之發展效應

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THE DEVELOPMENTAL EFFECTS OF STANDING CONTROL IN CHILDREN UNDER INDIVIDUAL CONSTRAINT

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中文摘要

動作發展的動態系統觀點強調動作的發展是由環境、工作及個體三個次系統交互影響所產生。本研究的主要目的即是透過短時期強度高的全身性疲勞運動，產生身體疲勞狀態的個體限制，以了解身體疲勞狀態對於不同年齡之中晚期兒童（8 歲、10 歲及 12 歲）平衡控制型態的影響。實驗參加者在 Kistler 垂直跳躍反應板上接受連續原地垂直跳躍的無氧運動處理，直到無力再跳為止。疲勞運動處理前後分別透過 Catsys 2000 平衡穩定測量系統、Biovision 多通道多功能訊號處理系統（包含電子關節角度計及傾斜計），記錄實驗參加者完成 1 分鐘開眼單足靜態站立平衡動作時的生物力學參數變化特徵。結果發現不同年齡兒童在疲勞狀態下，軀幹矢狀面及額狀面角速度變異性、壓力中心擺動速度及矢狀軸擺動距離，均比疲勞前大（ $p < .05$ ）。各關節平衡控制的工作特徵方面，疲勞前不同年齡兒童在各關節角速度變異性並無顯著差異（ $p > .05$ ）；但是在疲勞狀態下，8 歲組兒童髖關節矢狀面角速度變異性（ $9.17 \pm 1.49 \text{deg/s}$ ）顯著高於 10 歲組兒童（ $6.08 \pm 0.33 \text{deg/s}$ ）（ $p < .05$ ）；而 10 歲組兒童的踝關節額狀面角速度變異性（ $14.57 \pm 4.70 \text{deg/s}$ ）則顯著高於 8 歲組（ $9.38 \pm 2.12 \text{deg/s}$ ）及 12 歲組兒童（ $9.60 \pm 1.54 \text{deg/s}$ ）（ $p < .05$ ）。此一結果說明，兒童靜態平衡控制表現受個體疲勞狀態限制的影響，不同年齡的兒童在疲勞狀態下，均產生較大的身體擺動情形。雖然不同年齡兒童在疲勞狀態前之平衡控制型態並沒有不同，然而在疲勞狀態的個體條件限制下，不同年齡兒童顯現出不同的平衡控制型態，而其中更出現平衡控制發展的階段性改變現象。

關鍵詞：生物力學、動作發展、平衡控制、年齡差異、個體限制、疲勞

ABSTRACT

From the aspect of the dynamic systems theory, the development of motor control is affected by the interaction of three subsystems, namely, task, environment, and individual. The purpose of this study was to investigate the age difference of the strategies of balance control in middle/late children under individual constraint of fatigue through instant and intense exercise for the whole body. Five volunteer boys for each age group (8-, 10-, and 12-year-old) served as participants in this study. Every participant was asked to perform continuous counter movement jump on a Kistler Quattro Jump Platform monitoring the fatigue index until no more jump could be performed. Before and after the fatigue treatment, the biomechanical characteristics were recorded by a Catsys 2000 Sway Force

Plate system and a Biovision system with electrogoniometers and inclinometers during the one minute period in which each participant performed one foot standing balance movement with eyes open. Mixed-design two-way ANOVA and Duncan's test were adopted to analyze the statistical differences for developmental effects and before/after fatigue treatment with an alpha level of .05. The results showed that the variability of angular velocity (VAV) for trunk inclination, the centre of pressure (COP) sway velocity, and the COP anteroposterior sway displacements significantly increased ($p < .05$) under the post-fatigue condition. For the balance control characteristics of lower extremity, there were no significant age differences for VAV at the hip, knee, and ankle joints under the pre-fatigue condition ($p > .05$). Nevertheless, under the post-fatigue condition, the VAV at the hip in the sagittal plane for the 8-year-old children ($9.17 \pm 1.49 \text{ deg/s}$) was observed to be significantly greater than that for the 10-year-old children ($6.08 \pm 0.33 \text{ deg/s}$) ($p < .05$). It is further noted that under the same post-fatigue condition, the 10-year-old group exhibited a prominent increase in the activity at the ankle over the other 2 groups, as seen in the highest VAV at the ankle in the frontal plane ($14.57 \pm 4.70 \text{ deg/s}$) compared to that of the 8-year-old group ($9.38 \pm 2.12 \text{ deg/s}$) and the 12-year-old group ($9.60 \pm 1.54 \text{ deg/s}$) ($p < .05$). The findings indicated that middle/late children were affected by the fatigue constraint to exhibit an increase in body sway. With regard to the balance control characteristics at different joints, however, though under the pre-fatigue condition it seemed of no obvious difference among the three age groups, there did exist age differences in the balance control patterns under the fatigue constraint. This study demonstrated that fatigue, an individual constraint, could induce phase shift in the development of standing control.

Keywords: biomechanics, motor development, balance control, age difference, individual constraint, fatigue

INTRODUCTION

As the aspect of dynamic systems theory, the development of motor control is affected by the interaction of several subsystems from task, environment, and individual. The word dynamic conveys the concept that developmental change is nonlinear and discontinuous. And the word systems convey the concept that the human organism is self-organizing and composed of several subsystems. The instability behavioral patterns or the phase transition from one stable state of behavioral pattern to another that the human organism is self-organizing of several systems would be occurred within the task constraint, the environment constraint, or the individual constraint (Magill, 1998). Lepers, Bigrad, Diard, Gouteyron and Guezennec (1997) indicated that the sensibilities of vision, vestibule, or perceptual-motor will decay to adapt the variety of environment under the median intensity of stimulus of exercise, and this will lead to decay the performance of balance. To observe the characteristics of children at play or exercise, they are usually sprint and coursing each other or jumping suchlike a short period of time and high intensity movement. These types of less long period of time to raise fatigue situation in

middle/late children seem different from the study condition of Lepers et al. (1997). Adlerton and Moritz (1996) focused the fatigue movement of calf-muscle for body sway and showed that the body sway had no augment by the study condition. The researchers supposed there were the other physical mechanics to adjust the posture control to produce the compensation. However, there are two types of physical fatigue: the partial body fatigue and the whole body fatigue. Adlerton and Moritz's study to manipulate the condition of partial body fatigue were different from the middle/late children to perform whole body fatigue. It still be concerned that a short period of time and the whole body fatigue through instant and intense exercise to affect the posture control of middle/late children.

The studies about quiet stance characteristics as children development showed that spontaneous sway in children reaches adult levels around 9 years of age (Forssberg & Nasner, 1982; Shumway-Cook & Woollacott, 1985; Taguchi & Tada, 1982). Postural responses in children 4 to 6 years of age are in general slower and more variable than those found in the 15-month- to 3-year-olds, 7- to-10-year-olds, or adults, suggesting an apparent regression in the postural response organization. Woollacott, Debu, and Mowatt (1987) indicated that postural responses in children 7- to-10-year-olds are very similar to adult, but it is quite different in response to platform perturbations condition. Thus, the maturation of postural control will phase shift during the highly specific demands of the movement task transact with the environment in the development of postural control. Will it also appear under individual constraint of fatigue to affect the strategies of balance control?

In regard to passed balance control studies they were mainly focus on manipulated the task constraint or the environment constraint to approach the developmental effects. The purpose of this study was to investigate the age difference of the strategies of balance control in middle/late children under individual constraint of fatigue through instant and intense exercise for the whole body.

METHODS

Five volunteer boys for each age group (8-, 10-, and 12-year-old) served as participants in this study. Table 1 showed the participants' basic information. Every participant was asked to perform continuous counter movement jump on a Kistler Quattro Jump Platform monitoring the fatigue index until no more jump could be performed. Table 2 showed the situation of fatigue treatment through continuous counter movement jump. Before and after the fatigue treatment, the biomechanical characteristics were recorded by a Catsys 2000 Sway Force Plate system and a Biovision system with electrogoniometers and inclinometers during the one minute period in which each participant performed one foot standing balance movement with eyes open. Mixed-design two-way ANOVA and Duncan's test were adopted to analyze the statistical differences for developmental effects and before/after fatigue treatment with an alpha level of .05.

Table 1. The participants' basic information.

	8 years old		10 years old		12 years old	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	8.1	0.2	10.1	0.3	12.2	0.3
Height (cm)	126.2	2.2	136.8	1.7	151.1	4.0
Weight (Kg)	26.2	0.7	33.4	1.0	41.5	3.2

Table 2. The parameters of fatigue treatment through continuous counter movement jump.

	8 years old		10 years old		12 years old	
	Mean	SD	Mean	SD	Mean	SD
Times of jump (times)	26	4	29	6	32	10
Movement time (s)	33.6	7.0	32.9	7.2	35.2	8.6
Jump height for the first 5 times (cm)	25.5	1.4	28.2	2.0	36.1	4.9
Jump height for the last 5 times (cm)	15.5	2.0	16.9	2.6	21.3	3.2
Fatigue index (%)	60.5	6.1	59.6	6.8	59.3	7.4

RESULTS AND DISCUSSION

The results showed that the variability of angular velocity (VAV) for trunk inclination, the centre of pressure (COP) sway velocity, and the COP anteroposterior sway displacements significantly increased ($p < .05$) under the post-fatigue condition. For the balance control characteristics of lower extremity, there were no significant age differences for VAV at the hip, knee, and ankle joints under the pre-fatigue condition ($p > .05$). Nevertheless, under the post-fatigue condition, the VAV at the hip (Figure 1) in the sagittal plane for the 8-year-old children ($9.17 \pm 1.49 \text{ deg/s}$) was observed to be significantly greater than that for the 10-year-old children ($6.08 \pm 0.33 \text{ deg/s}$) ($p < .05$). It is further noted that under the same post-fatigue condition (Figure 2), the 10-year-old group exhibited a prominent increase in the activity at the ankle over the other 2 groups, as seen in the highest VAV at the ankle in the frontal plane ($14.57 \pm 4.70 \text{ deg/s}$) compared to that of the 8-year-old group ($9.38 \pm 2.12 \text{ deg/s}$) and the 12-year-old group ($9.60 \pm 1.54 \text{ deg/s}$) ($p < .05$).

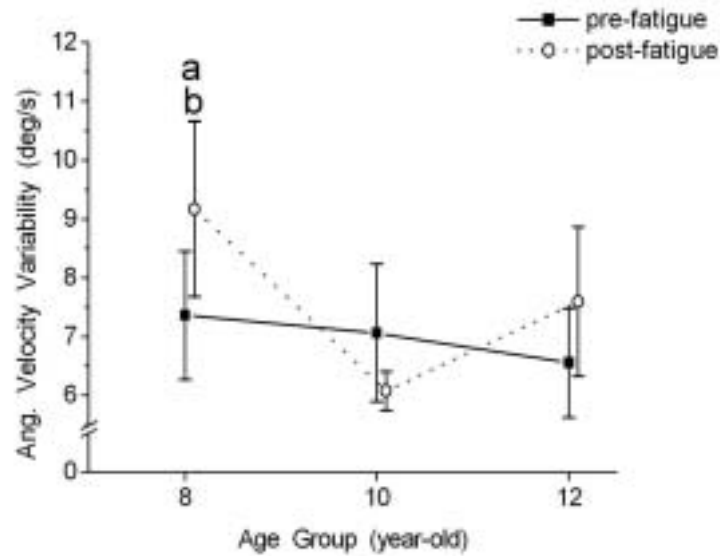


Figure 1: The variability of angular velocity at the hip joint in the sagittal plane. Significantly different from post-fatigue condition and the 10-year-old group, ^a $p < .05$. Significantly different from pre-fatigue condition and post-fatigue condition, ^b $p < .05$.

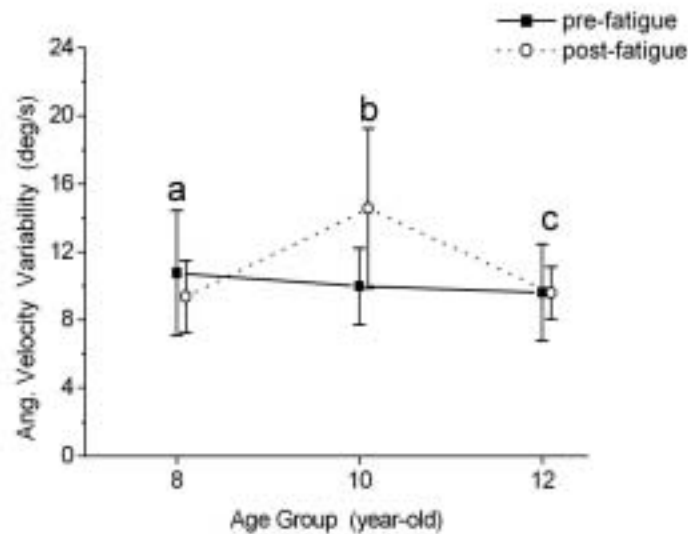


Figure 2: The variability of angular velocity at the ankle joint in the frontal plane. Significantly different from post-fatigue condition and the 10-year-old group, ^a $p < .05$. Significantly different from pre-fatigue condition and post-fatigue condition, ^b $p < .05$.

The findings indicated that middle/late children were affected by the fatigue constraint to exhibit an increase in body sway. With regard to the balance control characteristics at different joints, however, though under the pre-fatigue condition it seemed of no obvious difference among the three age groups, there did exist age differences in the balance control patterns under the fatigue constraint. This study demonstrated that fatigue, an individual constraint, could induce phase shift in the development of standing control.

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