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■期中進度報告

以人體動作分析與生理負荷分析對橢圓滑步機作人因分析

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計畫主持人：羅世忠
共同主持人：陳瓊玲、游家源
計畫參與人員：羅羽辰、杜育霖

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行政院國家科學委員會專題研究計畫成果報告

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Human factor engineering analysis of elliptical trainer by human motion analysis and physical load analysis

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Human factor engineering analysis of elliptical trainer by human motion analysis and physical load analysis

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The purpose of this study was to understand the factors affecting the musculoskeletal uncomfortableness with elliptical trainer. The evaluated parameters of elliptical trainer include the kinemaic data, center of mass （COM, joint angle and EMG (electromyography). Ten physically healthy male subjects volunteered for this investigation. In the result, there was significant difference in both up/down and anteral/posterial excursion of COM in low load and high loads compared between two types of elliptical trainer. The excursion ratio of COM, Machine A/Machine B, was 238%、211% and 199% in up/down direction and 156%、154% and 131% in anteral/posterial direction respectively. There were significant difference for knee and ankle angle except the hip joint angle between machine and machine B but there was no significant difference in joint angle among loading group. The home-used level of elliptical trainer showed fewer excursions than club-used level. The COM can be used for evaluation the fitness of exercise trainer.

INTRODUCTION

The exercise equipment used for strengthening muscle and shaping body is getting more prevalent due to the increased population and limited space in exercise. To meet this demand, manufacturers first introduced treadmills with impact absorbing suspension systems. Elliptical trainer is regarded as a good approach with full body motion like treadmill but reduced more impact force (Green, Crews et al. 2004; LANCE C. DALLECK 2004). However, unfitting exercise trainers and working over a long period of time cause musculoskeletal disorders. Little information is known for choosing the comfortable exerciser.

The purpose of this study was to understand the factors affecting the musculoskeletal uncomfortableness with elliptical trainer. The factor was set to three loads and two type of elliptical trainer. The evaluated parameters of elliptical trainer include the kinemaic data, center of mass （COM）joint angle EMG (electromyography) and oxygen consumptions.

METHOD

Subject and Experimental Protocol

Ten physically healthy male subjects volunteered for this investigation. They ranged from 23 to 28 years (26±2.6, mean ±SD) of age, from 58 to 81 kg (72.8±10.2, mean±SD) in body weight, and from 161 to 184 cm (172.6±6.1, mean±SD) in body height. None had ever suffered from upper extremity injuries or disorders. The Vicon Motion System (Vicon 460, Oxford, UK) with six 120 Hz cameras was used to measure relative joint positions.

A set of 42 reflective markers, PolygonRT-marker set (see figure 1), was placed on selected anatomic landmarks on the subject putting on a body. During the experiment, subjects were asked to completely perform two kind of elliptical trainer, Machine A (home-used), and Machine B (club-used)) with three loads, 70W, 220W and 330W (see Figure 2). Before the start of experiment, subjects were asked to keep their body in the "neutral anatomic position" with arms at their sides and palms facing forward as neutral reference position. They were instructed to perform randomly one of 6 combination of experiment. Five minutes was allowed for rest between sets, in order to avoid muscle fatigue.

Four 3.5cm × 5cm EMG electron were attached to 4 muscles of dominant lower extremity, rectus femoris, (biceps femoris, tibialis anterior and gastrocnemius. The cutoff frequency was range from 10 to 500Hz.

BIOPAC MP150 Module was used for measuring the oxygen consumption during 20 min experiment of elliptical trainer (figure 3.).

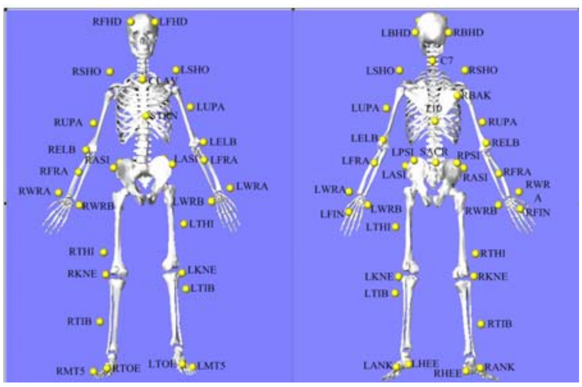


Figure 1 full body marker set

Figure 2. experimental setup for two elliptical machine

Figure 3 BIOPAC MP150 Module for oxygen consumption

Data Process

Laboratory-developed kinematics software were used to calculate the joint angles of lower extremity. Six CCD cameras were used to record 3-D position of the markers. Measurement of the lower-extremity kinematics was obtained by video recording of the markers. The joint center and angle is then calculated, using an Euler method. Center of mass (COM) was calculated with anthropometric data (Winter 1990). A generalized cross-validation spline smoothing (GCVSPL) routine at a cutoff frequency of 6 Hz was used for data smoothing (Woltring 1986).

Data Analysis

COM and kinematic data among two kind of machine and three level of loads were analyzed statistically by repeated two-way ANOVA with $p<0.05$ as statistical significance.

RESULTS

Center of mass

In the result, there was significant difference in both up/down and anteral/posterial excursion of COM in low load and high loads compared between two types of elliptical trainer (figure 4). The excursion ratio of COM, Machine A/Machine B, was 238%、211% and 199% in up/down direction and 156%、154% and 131% in anteral/posterial direction respectively (table 1).

There was significant difference right/left excursion of COM in high load and low load compared between the same machine (figure 4)

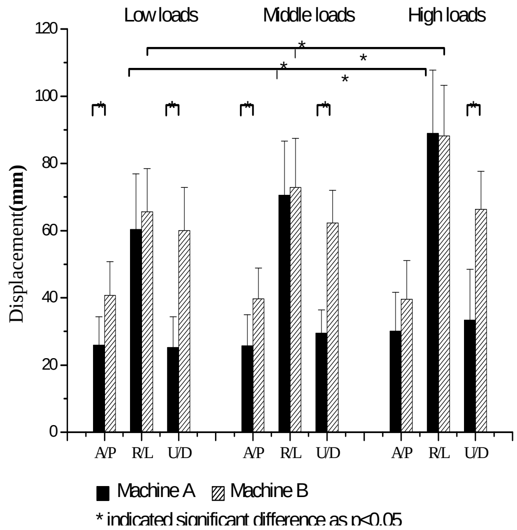


Figure 4: the displacement of COM in three directions, anterial/poster (A/P), right/left (R/L) and up/down (U/D) between two type of elliptical trainer, home-used Machine A and club-used Machine B, and three type of loads.

Table 1: Percentage of COM displacement ratio by Machine A/Machine B

	A/P%	R/L%	Up/Down%
Low	156%	108%	238%
Middle	154%	103%	211%
High	131%	99%	199%

Joint angle

Peak joint angles of lower extremity in sagittal plane for machine A were 52, 67 and 26 degrees respectively (table 2), and 53, 75 and 21 degrees for Machine B (table 3). There were significant difference for knee and ankle angle except the hip joint angle between machine A and machine B but there was no significant difference in joint angle among loading group.

Table 2: Peak joint angle (mean ± std) in sagittal plane

machine A Load	Hip	Knee*	Ankle*
Low	52±9	69±11	27±6
Middle	51±10	67±12	24±7
High	52±9	66±12	24±8
Machine B Load	Hip	Knee*	Ankle*
Low	54±8	74±8	21±7
Middle	53±8	75±10	22±5
High	52±8	74±6	19±3

Unit: degress

*: indicated significantly difference p<0.05 comparison between machine A and B

Table 3 Percentage of COM displacement ratio by Machine A/Machine B

	A/P%	R/L%	Up/Down%
Low	156%	108%	238%
Middle	154%	103%	211%
High	131%	99%	199%

*: indicated significantly difference p<0.05 comparison with low load

EMG

The muscle activation of lower extremity during elliptical trainer was about 35% MVC. There were significant difference between loads but there was significant difference between machine A and machine B (figure5).

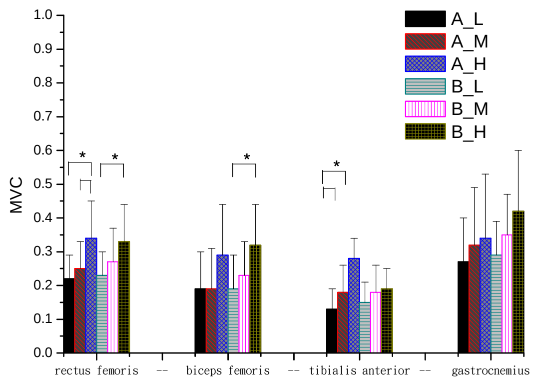
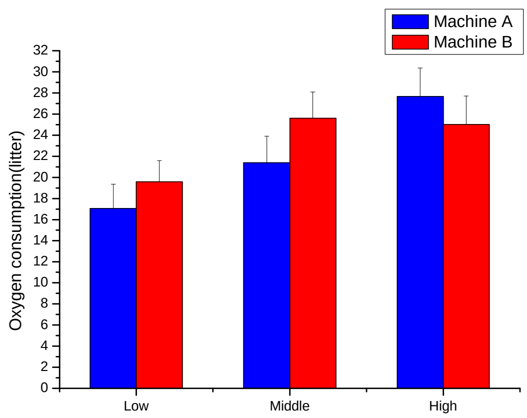


Figure 5 Peak MVC for 4 muscles during elliptical cycle.

Oxygen consumption

The oxygen consumption increased as the loads increased except the Machine B from middle to high load. There was significant difference between Machine A and Machine B



(figure 6).

Figure 6 Oxygen consumption in 20 min for two elliptical machines.

DISCUSSIONS

The trajectory of ankle joint was regarded to a key point in determination of good elliptical trainer. In this study, joint angle and trajectory of the ankle between both machines were analyzed and existed significant difference, but there is no explanation for feasible trajectory for elliptical trainer.

The COM is the crucial characteristics for human motion, especially in sports. Dierick noted the COM can be used as a important parameter for human motion on treadmill (Dierick, Penta et al. 2004). Elliptical trainer is the similar full body exerciser as treadmill. In this study, the excursion of COM between machine A and machine B was significantly different that also can be used to analyze the elliptical trainer.

The excursion of COM for normal people in level walking is round 2cm*4cm (upward and lateral) in frontal plane (Perry 1992). It increased up to 3.5cm up/down while the walking speed to 2.5m/s (Lee 1998). As the running up the excursion is up to 6cm (Lee 1998). In present study, the excursion of COM in machine A is the 2.5*6, 2.9*7 and 3.3*8.8 in low, middle and high load respectively. The excursion of COM was like walking. In machine B, the excursion of COM, 6*6.5, 6.2*7.2 and 6.6*8.8 was like running. That is to say, if the elliptical is used for running exercise it should choose the machine B. On the contrast, it should choose the machine A. In generally, the elliptical trainer for common people is for fitness. Therefore the machine B is suitable.

CONCLUSIONS

The home-used level of elliptical trainer showed fewer excursions than club-used level. The COM can be used for evaluation the fitness of exercise trainer.

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